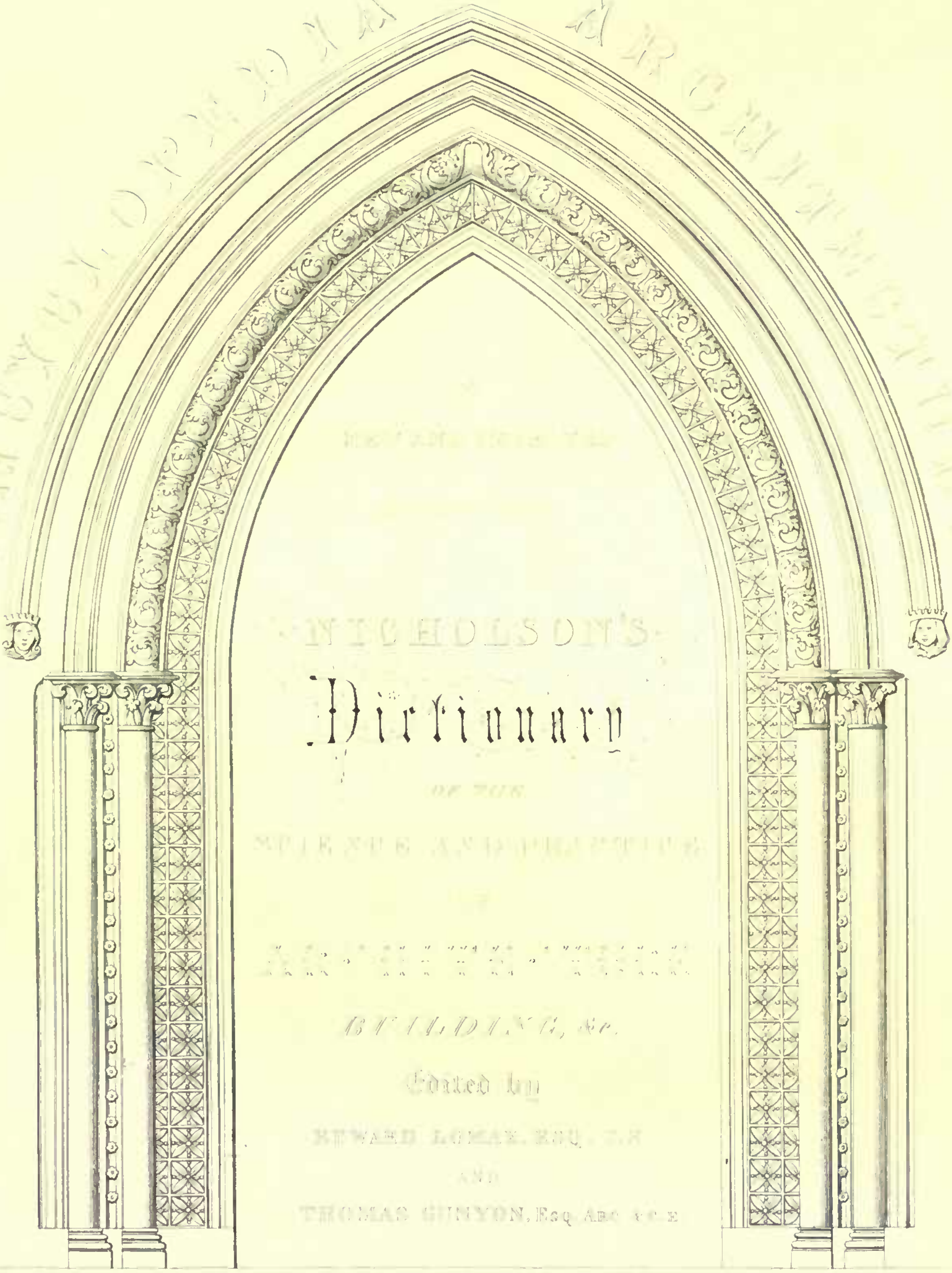
The New York Crystal Palace.



ENCYCLOPÆDIA OF ARCHITECTURE.

A

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NICHOLSON'S

Dictionary

OF THE

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OF

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BUILDING, &c.

Edited by

EDWARD LOMAX, ESQ. C.E.

AND

THOMAS GUNYON, Esq. Arc. & C.E.

DOORWAY WESTMINSTER ABBEY.

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ENCYCLOPEDIA OF ARCHITECTURE.

A
DICTIONARY
OF THE
SCIENCE AND PRACTICE
OF
Architecture, Building, Carpentry, Etc.,
FROM
THE EARLIEST AGES TO THE PRESENT TIME,
FORMING A COMPREHENSIVE WORK OF REFERENCE FOR THE USE OF ARCHITECTS, BUILDERS, CARPENTERS, MASONS, ENGINEERS, STUDENTS, PROFESSIONAL MEN, AND AMATEURS.

ENGINEERING SOCIETY
SCHOOL
OF
PRACTICAL SCIENCE,
TORONTO.

BY PETER NICHOLSON,
ARCHITECT AND BUILDER.

EDITED BY
EDWARD LOMAX AND THOMAS GUNYON,
ARCHITECTS AND CIVIL ENGINEERS.

ILLUSTRATED WITH TWO HUNDRED AND THIRTY ENGRAVINGS ON STEEL,
MOSTLY FROM WORKING DRAWINGS IN DETAIL.

IN TWO VOLUMES.
VOL. I.

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20/7/08

NEW YORK:
PUBLISHED BY MARTIN AND JOHNSON,
27 BEEKMAN STREET.

PREFACE TO THE AMERICAN EDITION.

It is the design of the present work to give an account, not only of ARCHITECTURE itself, but also of the various other ARTS and SCIENCES connected with it, and without which a comprehensive and complete knowledge of it cannot be attained.

An alphabetical arrangement was adopted by the author, MR. P. NICHOLSON, as considered the best adapted for the use of mechanics, as well as the most expeditious, a knowledge of the meaning of the terms of art, which are very numerous, being more easily acquired by this mode than by any other.

The RISE AND PROGRESS of every department are given as far as authentic information could be obtained. The greatest attention has been paid to the DEFINITIONS; and it is hoped that they will be found to be far more intelligible than those which have been hitherto given in Dictionaries, and in Treatises on Architecture. Geometry being the key to works of this description, such GEOMETRICAL PROBLEMS are introduced as will be found useful in delineating the various kinds of objects that may occur.

ORTHOGRAPHICAL AND PERSPECTIVE DRAWING being necessary, not only to the Architect, but also to the Builder and Workman, their principles are laid down, and their application is shown by means of numerous examples.

CARPENTRY AND JOINERY, also, are here treated in a manner far superior to that which characterizes any previous work upon those subjects.

In the other branches has been given, *not only what has fallen under the immediate observation of the author*, but also the *valuable information* which has resulted from the diligent inquiries he has made of the most skilful workmen. An account, also, of the PROPERTIES OF THE MATERIALS used in the execution of works, and of the RULES FOR JUDGING OF THEIR QUALITY, is given at large.

In preparing the present edition for the press, the Publishers have availed themselves of the valuable labours of MR. EDWARD LOMAX and MR. THOMAS GUNYON, practical Architects and Engineers.

The improvements are rather those of enlargement than of alteration, the greater part of the work being left in its original condition, more especially such parts as related to CARPENTRY, and subjects of a kindred nature, in which the Author is universally accredited as an authority of the highest standing.

Some parts of the original edition, however, had become obsolete and out of date, and such it was considered advisable to expunge, or modify in such a manner as might make them suitable to the more advanced knowledge of the present day. The articles on BRIDGES, STRENGTH OF MATERIALS, THE ORDERS, and such like, will afford a fair specimen of the treatment of such subjects as required modification or enlargement.

As an illustration of the new matter which has been added, may be particularly enumerated a series of papers treating of the HISTORY AND CHARACTERISTICS OF THE VARIOUS STYLES OF ARCHITECTURE, which, it is hoped, may prove an interesting and not unuseful feature in the present Dictionary. Besides these, many papers of an ARCHÆOLOGICAL and general, as well as of a practical character, have been added, and a very large number of Definitions introduced, which were not in the original work. Amongst the Archæological papers, those on CHURCH ARCHITECTURE and ECCLESIOLOGY in general, may, it is hoped, be referred to with satisfaction; whilst those of a practical character may be fairly represented by the articles on ROADS, SEWERS, CEMENT, &c.

The Plates contained in the original work have also been very carefully compared with the text. Several errors of importance have been corrected, besides a very large number of others of less importance, such as would, however, tend to perplex the student, and even render the information useless to those of more advanced knowledge, who have not the leisure to make the corrections for themselves.

In fine, the Publishers venture to hope, that, while the sterling matter of the original edition is preserved, some Additions and Improvements have been made which may be of service not only to the student and working man, but also to the mature and experienced practitioner; and they flatter themselves that nothing is wanting to render this work, as now presented to the public, containing all the improvements down to the present day, a COMPLETE ARCHITECTURAL DICTIONARY.

LIST OF PLATES.—VOL. I.

To the Binder.—The Plates may be bound up in a separate Volume, in the following order, for greater facility of reference. If, however, it be preferred, that they should be bound up with the text, their proper position is assigned to each in the following List.

LIST OF WORKS CONSULTED IN PREPARING THE PRESENT EDITION OF THE ARCHITECTURAL DICTIONARY.

Archæologia, 8vo., London.

Archæological Journal, 8vo., London, 1844.

Barr's Anglican Church Architecture, with some remarks on Ecclesiastical Furniture, 8vo., Oxford, 1846.

Barrington's Plain Hints for understanding the Genealogy and Armorial Bearings of Sovereigns of England, 8vo., London, 1843.

Barrington's Chronological Chart of British Architecture, fol., London, 1843.

Bartholomew's Specifications, 8vo., London, 1846.

Bentham's History of Gothic and Saxon Architecture, fol., London, 1798.

Bingham's (J.) Origines Ecclesiasticæ, or Antiquities of the Christian Church, and other Works, with additional annotations, revised and edited by Rev. R. Bingham, 8vo., London, 1821–9.

Bloxam's Glimpse of the Monumental Architecture and Sculpture from earliest period to 18th century, 12mo., London, 1834.

Bloxam's Principles of Gothic Ecclesiastical Architecture elucidated by question and answer, 12mo., London, 1843.

Do., do., 9th Edition, 12mo., London, 1849.

Brande, W. T.—Dictionary of Science, Literature, and Art, 8vo., London, 1842.

Brandon, T. A.—Parish Churches, 8vo., London, 1848.

Britton, J.—The Architectural Antiquities of Great Britain, 4to., London, 1801–7.

Britton, J.—Dictionary of the Architecture and Archæology of the Middle Ages, 4to., London, 1838.

Britton, J.—The History and Antiquities of the Cathedral Church of Salisbury, fol., London, 1814.

Britton, J.—Antiquities of Winchester Cathedral, fol., London, 1817.

Britton, J.—Antiquities of Cathedral Church of Norwich, fol., London, 1816.

Britton, J.—The History and Antiquities of the Cathedral Church of Salisbury, fol., London, 1821.

Brown.—Sacred Architecture, 4to., London.

Buck, G. W.—Practical Essay on Oblique Bridges, 4to., London, 1839.

Buckler, J. C.—Elevations, Sections, and Details of St. Peter's Church, Wilcote, Oxon., fol., Oxford, 1844.

Buckler, J. C.—Views of Cathedral Churches of England and Wales, 4to., London, 1822.

Carter, J.—Specimens of Gothic Architecture and Ancient Buildings in England, 12mo., London, 1824.

Chambers, Sir W.—A Treatise on the Decorative Part of Civil Architecture, edited by Jos. Gwilt, 8vo., London, 1825.

Chambers, Sir W.—Designs of Chinese Buildings, Furniture, &c., fol., London, 1757.

Coney, J.—Engravings of Ancient Cathedrals in France, Holland, and Italy, fol., London, 1839.

Cotman, J. S.—Architectural Antiquities of Normandy, fol., London, 1822.

Cotman, J. S.—Etchings Illustrative of Architectural Antiquities of Norfolk, fol., London, 1818.

Cranstoun, E.—Elevations, Sections, and Details of Chapel of St. Bartholomew, near Oxford, fol., Oxford, 1844.

Cresy, E.—Architecture of Middle Ages in Italy, Illustrated by Views, Plans, Elevations, Sections, and Details of Cathedral of Campo Santo at Pisa, by E. Cresy and G. L. Taylor, fol., London, 1829.

Cresy, E.—Illustrations of Stone Church, Kent, with Historical Account, fol., London, 1840.

LIST OF WORKS CONSULTED.

Dallaway, J.—Discourses upon English Architecture from Norman Era to Elizabeth.

Davies, E.—Celtic Researches on the Origin, Traditions, and Language of Ancient Britons, 8vo., London, 1804.

Denisis, J.—Architectura Sacra, 8vo., Exeter, 1818.

Denon, V.—Voyage dans la basse et la haute Egypte, fol., Paris, 1802.

Elmes, J.—A General and Bibliographical Dictionary of the Fine Arts, 8vo., London, 1826.

Fawcett, J.—Churches of York, by Mr. Monkhouse and Mr. E. Bedford; with Historical and Architectural Notes by F. Fawcett, 4to., York, 1843.

Fleury.—Ecclesiastical History from A.D. 400 to 429, translated, with Notes, by J. H. Newman, 8vo., Oxford, 1843.

Gray, H.—Tour to the Sepulchres of Etruria.

Grose, F.—Antiquities of England and Wales, fol., London, 1773–6.

Grose, F.—Antiquities of Ireland, 8vo., London, 1791–5.

Guilhabaud, J.—Monuments Anciens et Modernes, Vues générales et particulières, &c.

Gunn, W.—An Inquiry into the Origin and Influence of Gothic Architecture, 8vo., London, 1819.

Gwilt, Jos.—Encyclopedia of Architecture, Historical, Theoretical, and Practical, 8vo., London, 1842.

Gwilt, J.—Rudiments of Architecture, Practical and Theoretical, 4to., London, 1826.

Habershon, M.—The Ancient Half-timbered Houses of England, fol., London, 1836.

Hakewill, J.—An attempt to Determine the exact Character of Elizabethan Architecture, 8vo., London, 1835.

Halfpenny, W.—The Art of Sound Building, fol., London, 1725.

Halfpenny, W.—Practical Architecture. 12mo., London, 1736.

Hall, Sir J.—Essay on Origin and Principles of Gothic Architecture, 4to., London, 1813.

Hawkins, J. E.—History of Gothic Architecture, with an Investigation of its Principles, 8vo., London, 1813.

Hope, Thomas.—An Historical Essay on architecture, 8vo., London, 1835.

Hughes, T. S.—Travels in Sicily, Greece, and Albania, 8vo., London, 1830.

Hunt, T. F.—Examples of Tudor Architecture, 4to., London, 1830.

Inghirami, F.—Monumenti Etruschi o di Etrusco Nome, 4to., Fiesol, 1821–6.

Kendall.—Gothic Architecture, 8vo., London, 1842.

Knight H. G.—Ecclesiastical Architecture of Italy, fol., London, 1842.

Lloyd, H. E.—Architectural Beauties of Continental Europe, fol., London, 1831.

Mackenzie, C.—Crosby Place described, 8vo., London, 1842.

Mackenzie, F.—Specimens of Gothic Architecture, 4to., London.

Mant, R.—Church Architecture considered in relation to the Mind of the Church, 8vo., Belfast, 1843.

Moller, G.—Essay on Origin and Progress of Gothic Architecture, 8vo., London, 1824.

Murphy, J. C.—The Arabian Antiquities of Spain, fol., London, 1813.

Nash, J.—Mansions of England in the Olden Time, Series 1, 2, 3, fol., London, 1839–41.

Neale, J. P.—Views of Collegiate and Parochial Churches in Great Britain, 4to., London, 1824–5.

Parnell, Sir H.—A Treatise on Roads.

Petit, J. L.—Remarks on Church Architecture, 8vo., London, 1841.

The Practical Builder, 4to., London, 1838.

Pugin, A. W.—Apology for revival of Christian Architecture, 4to., London, 1843.

Pugin, A. W.—Contrasts, or Parallel between Edifices of Middle Ages and Present Day, 8vo., London, 1841.

Pugin, A. W.—Glossary of Ecclesiastical Ornament, 4to., London, 1844.

Pugin, A.—Gothic Ornaments selected from various Buildings in England and France, 4to., London, 1831.

Pugin, A.—Specimens of Gothic Architecture from Ancient Edifices in England, 4to., London, 1821.

Pugin, A. W.—The True Principles of Pointed, or Christian Architecture, 4to., London, 1841.

Rich.—Narrative of a Journey to Babylon in 1811—Memoir on Ruins—Remarks on Topography of Ancient Babylon by Major Rennell, &c., 8vo., London, 1839.

Richardson, C. J.—Architectural Remains of the Reigns of Elizabeth and James I., fol., London, 1838–40.

Rickman, T.—An attempt to discriminate the Styles of English Architecture from Conquest to Reformation, 8vo., London, 1820.

Rickman, T.—An Essay on Gothio Architecture, 8vo., London, 1825.

Shaw, H.—History and Antiquities of Chapel at Luton Park, fol., London, 1830.

Simpson, F.—Series of ancient Baptismal Fonts chronologically arranged, 4to.

Smirke, (Sir R.) Specimens of Continental Architecture, fol., London, 1806.

Smith.—Paronama of Science and Art, 8vo., London.

Stuart, J.—Antiquities of Athens, fol., London, 1830.

Stuart, R.—Dictionary of Architecture, 3 Vols., 8vo., London.

Stukeley, W.—Palægraphia Britannica, 4to., London, 1743–52.

Tappen, G.—Professional Observations on the Architecture of France and Italy, 8vo., London, 1806.

Tredgold.—Elementary Principles of Carpentry, 4to., London, 1840.

Vitruvius.—Civil Architecture, by Gwilt, 4to., London, 1626.

Walsh, R.—An Essay on Ancient Coins, Medals, and Gems illustrating Progress of Christianity in Early Ages. 2nd Edition, enlarged, 12mo., London, 1828.

Warton, J.—Essays on Gothic Architecture.

Weale.—Quarterly Papers on Architecture, 4to., London, 1843–4.

Weale.—Rudimentary Treatises, 12mo., London, 1851.

Whewell, W.—Architectural Notes on German Churches, 8vo., Cambridge, 1842.

Whittington, G. D.—Historical Survey of Ecclesiastical Architecture of France, 4to., London, 1809.

Wightwick.—Hints to young Architects, 8vo., London, 1846.

Wild, C.—Cathedrals—12 Specimens of Ecclesiastical Architecture of Middle Ages, fol., London.

Wild, C.—Twelve Examples of Ecclesiastical Architecture of France, fol.

Wilkinson, J. G.—The Manners and Customs of the Ancient Egyptians, 8vo., 1837.

Wilkins, H.—Suite de rues pittoresques des ruines de Pompeii, fol., Rome, 1819.

Willis, R.—Remarks on Architecture of Middle Ages, especially of Italy, 8vo., Cambridge, 1835.

Willis, B.—A Survey of the Cathedrals, 4to., London, 1727.

Wood, J.—Letters of an Architect from France, Italy, and Greece, 4to., London, 1828.

Wood, R.—Ruins of Palmyra, fol., London, 1753.

Wood, R.—Ruins of Balbec, fol., London, 1757.

A few Words to Church Builders, published by Cambridge Camden Society, with Appendix, containing List of Fonts, 8vo., Cambridge, 1841.

A few Words to Churchwardens on Churches and Church Ornaments, 8vo., Cambridge, 1841.

Church Enlargement and Church Arrangement, 8vo., Cambridge, 1843.

Ecclesiastic, 8vo., London, 1846.

Eccleologist, 8vo., Cambridge, 1841–4.

A Glossary of Terms used in Grecian, Roman, Italian, and Gothic Architecture, 8vo., London, 1836.

Gothic Architecture—A Chart of English, Ecclesiastical, or Gothic Architecture from Commencement in Saxon dynasty to Sixteenth century, fol.

A Guide to the Architectural Antiquities in Neighbourhood of Oxford, 8vo., Oxford, 1844–5.

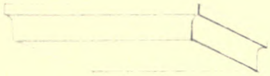
Instrumenta Ecclesiastica, a Series of Working Designs for Furniture, Fittings, and Decorations of Churches. Edited by Cambridge Camden Society, 4to., London, 1844.

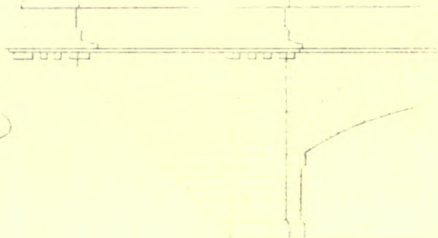
Prospects of all the Cathedrals and Collegiate Churches of England and Wales, 12mo.

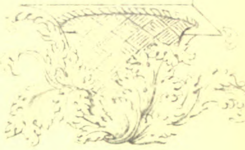
Quarterly Review, Vols. of 1845, 8vo., London, 1845.

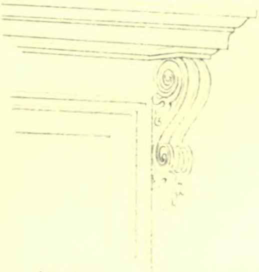
The Student's Guide to Measuring and Valuing Artificers' Work, 8vo., London, 1843.

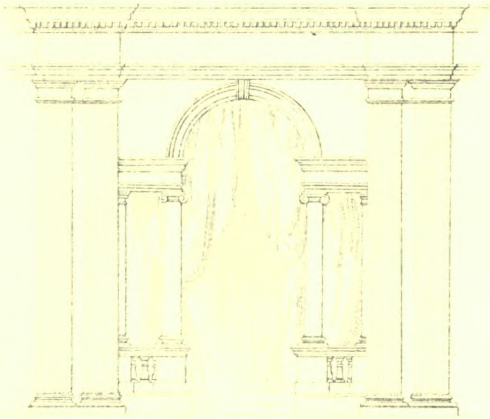
The Builder.

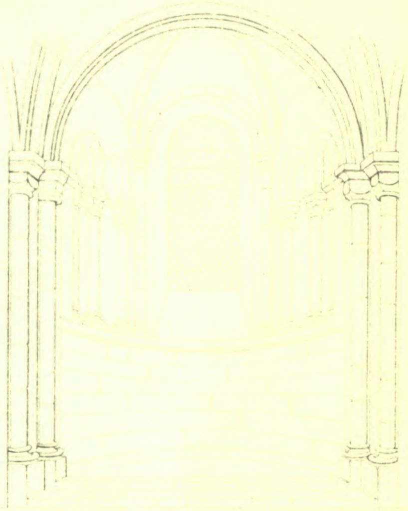


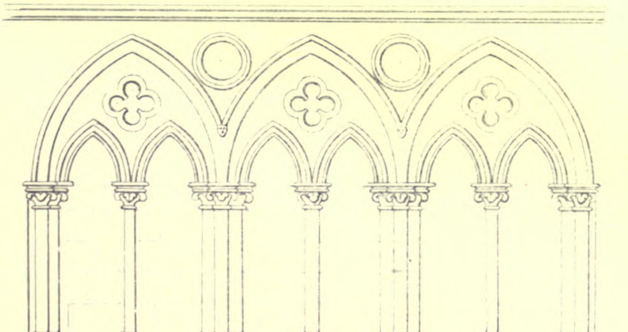




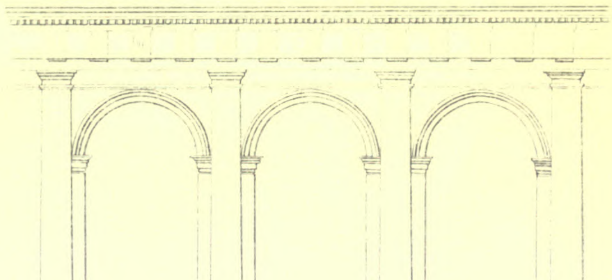








ARCADE.



ARCADE.

A. Gilbert Archt del.

ARCHITECTURAL DICTIONARY.

ABACI, according to Vitruvius, any flat tabulated surface.—The term is applied to the panels of walls formed in stucco, of which examples may be seen in various remains of antiquity; and to certain decorations of the walls above a part of the podium, or dado.—*Newton's Vitruvius, Chap.* III. and IV. *Book* 7.

ABACUS, (from Greek, *αβαξ*,) the uppermost member of the capital of a column, consisting of a flat, rectangular table contained between two horizontal planes. In all the existing Doric buildings, with perhaps one or two exceptions, it is in the form of a parallelopiped of equal rectangular sides. The same form is preserved in the other orders, but the thickness is considerably diminished. In the Corinthian and Composite, however, the sides are of a curvilinear form in plan. *See* Doric, Ionic, Corinthian, Tuscan, and Composite Orders.

ABBEY, a monastery, or religious house, governed by a superior under the title of Abbot. For a particular account of this species of building, and its distribution, see the article Monastery.

ABBREVIATION, a kind of shorthand, much used by surveyors in measuring work, and greatly facilitating the process. *See* Mensuration *of Artificers' Works.*

ABREUVOIR, or Abbevoir, (from the French,) in masonry the interstice, or joint, between two stones, to be filled up with mortar or cement. *See* Joints.

ABSTRACT, in artificers' works, is used in a general sense, to signify the collecting of sundry articles into one sum, when the same price is affixed to equal parts of each; or, to ascertain measure. *See* Mensuration *of Artificers' Works.*

ABUTMENT, or Butment, that which receives the end of, and gives support to anything having a tendency to spread or thrust outwards:—or it may be defined as the resisting surface of a body, on which another body presses in an oblique direction to the horizon, or in a different direction to the height or length of the body pressed upon; such are the abutments of arches and the joggles of truss-posts, which resist the pressure of the struts or braces. In bridge-building it is the extreme pillars only of one or a series of arches, and thus connects the bridge with the bank of a river, &c. Abutments should be made to resist a greater force than what is just sufficient to balance the abutting works, provided there be no rocks to rest upon. The foundation of an abutment, raised upon a sloping bank of rock, gravel, or good solid earth, will be a great saving of materials and labour; but if no such natural advantages occur, it will add greatly to the strength of the abutment to lay the stones with radiating or summering joints, according to the practice in laying the voussoirs, at least as high as the springing of the arch, and this disposition will present a greater resistance to the lateral thrust of the adjacent arch, than if the stones had been laid on level beds; and instead of the returning sides from the side of the aperture of the arch being vertical planes, they would be much stronger when reclining, and more particularly so if curved in a vertical direction. *See* Bridges and Wall.

Abutments, in carpentry and joinery, are the junctions, or meetings, of two pieces of timber, of which the fibres of the one run perpendicular to the joint, and those of the other parallel to it. M. Perronet, the celebrated French architect, formed the abutments of the timbers, in roofing, in the arches of circles, making the centre in the other extremity. With respect to the tranverse strain on the various pieces of a roof, the abutting joint is of little importance. For farther explanation, *see* Joggle.

ACADEMY, in antiquity, a public grove or villa, six stadia (half-a-mile) distant from Athens, which it is said took its name from one Academus, a citizen of Athens, to whom it originally belonged, and who appropriated it to gymnastic sports.

ACANTHUS, an ornament used in the enrichment of the Corinthian capital, and so called from its resemblance to the leaves of an acanthaceous plant. It is also commonly employed in sculptural and architectural enrichments generally; in the enrichment of modillions, of mouldings, and of vases, as well as of foliated capitals. In the ancient Roman models, this ornament is full and luxuriant; while in the Greek it is characterized by a graceful and restrained simplicity. *See* Orders.

ACCESSES, the passages of communication to the various apartments of a building. *See* Passages.

ACCIDENTAL POINT. *See* Vanishing Point.

ACCOMPANIMENT, an ornament added to some other ornament, for the greater beauty of the work.

ACRE, a quantity of land, containing four square roods, or 160 poles or perches. The acre is in length ten chains, and one in breadth; consequently contains ten square chains; and as the chain contains 22 yards in length, there will be 4840 square yards in the acre. The proportion between the English and Scottish acre, supposing the feet to be alike in both, is as 1089 to 1369, or nearly as four to five; the English chain being 66 feet, and the Scottish 74. The French acre, *arpent*, contains $1\frac{1}{4}$ English acre, or 54,450 square feet.

ACROLINTHON, or ACROLINTHOS, a colossal statue, placed in the temple of Mars, and situated in the middle of the citadel in the ancient town of Halicarnassus.

ACROPOLIS, (from *ακρος*, *height*, and *πολις*, *a city*,) the fortress or citadel of Athens, which derived its name from an eminence on which it stood. The summit is fortified by a wall built on its extreme edge, and encompassing the whole upper surface, which is nearly level. The natural strength of its situation is said to have induced the first inhabitants to settle there, and as their number increased they began to build on the adjacent ground, till the Acropolis, being surrounded on every side, became the fortress of a large and populous city. It was richly adorned by the Athenians, in the days of their prosperity, with temples, statues, paintings, and votive gifts to their divinities. Of this ancient place there are still many fine ruins, some of which are very entire. The remains of the famous Propylea, the little temple of Victory without wings, the Doric temple of Minerva, called the Parthenon, and Hecatompedon, erected in the time of Pericles, under the direction of Phidias, with the cell of Pandrossus, are still to be seen. Its walls have at different times been rudely repaired, or rebuilt, as little of the ancient masonry remains; but numerous fragments of columns, cornices, and sculptures, are seen in several parts, and exhibit a ruinous appearance.

ACROTERIA, a term applied to the little pedestals placed on the pediment or fastigium; one on the apex, and one on each lower extremity, serving to support statues. According to Vitruvius, those at the extremes ought to be half the height of the tympanum, and that in the middle an eighth part more. Acroteria likewise signify figures placed as ornaments or crownings on the tops of temples, or other buildings; they also denote the sharp pinnacles, or spiry battlements, which stand in ranges about flat buildings with rails and balusters, and which are sometimes called acroteral ornaments.

ACT, *Building*. *See* BUILDING ACT.

ACTUS, in building, a measure used by the Romans, and equal to 120 Roman feet. *See* FOOT.

ACUMINATED, ending in a point, or sharp-pointed.

ADIT, or ADITUS, (from *adire*, to go to,) in general, the approach or entrance to anything; in which sense we meet with adit of a house, of a circus, &c. Adits of a theatre, *aditus theatri*, in antiquity, were doors on the stairs, whereby persons entered from the outer porticus, and descended into the seats. The term is now generally applied to denote the opening by which a mine is entered, and which is usually made in the side of a hill.

ADJACENT, anything which lies immediately by the side of another.

ADYTUM, (from *a*, *δυω*,) the most retired place in the pagan temples, into which none but the priests were admitted, and in which the oracles were declared. The word originally signifies *inaccessible*, being compounded of *a*, *not*, and *δυω* or *δυνω*, *to enter*. The *sanctum sanctorum*, or holy of holies, of the temple of Solomon, was of the nature of the pagan *αδυτον*, or *adytum*, none but the high-priest being admitted into it, and that but once a year, on the great day of expiation.

ADZE, an edged tool, the iron part of which is called *the blade*, and is a small portion of a cylindric surface on both sides: it has a piece of wood, called *the handle*, fixed into a socket at one extremity of it, in a radial direction; and the other extremity, parallel to the axis of the cylinder, and consequently at right angles to the handle, is edged with steel, and ground sharp from the concave side. The adze is chiefly used for taking off thin chips of timber or boards, and for paring away certain irregularities which the axe cannot come at; and in most joinings of carpentry, particularly those which are notched upon each other, scarfings, thicknessing of flooring boards opposite to the joists, &c. *See* TOOLS.

ÆDES, in antiquity, a chapel, or inferior kind of temple, as the *agrarium*, or treasury, called *Ædes Saturni*.

ÆDICULA, otherwise called SACELLUM, generally signified a small temple, but had various significations; sometimes denoting the inner part of the temple, in which the altar and statue of the deity were placed; at other times, a niche in the wall, for receiving a statue.

ÆDICULUS, in Roman mythology, the deity who presided over the construction and conservation of buildings.

ÆOLUS, in mechanics, a small portable machine, for refreshing and changing the air in rooms that are too close.

AERIAL PERSPECTIVE, is that which represents bodies diminished and weakened in proportion to their distance from the eye. *Linear* perspective may be considered the material guide of the artist, originating in, and governed by, mathematical science; but *aërial* perspective is dependent for its application only on the capacity and perceptions of the artist.

ÆSTUARY, in the ancient bath, a secret passage from the stove into the chambers.

ÆTHERIUS, an architect, who lived in the beginning of the sixth century. He built the edifice named Chalcis, in the palace of Constantinople; and is supposed to have constructed the strong wall which extends from the sea to Selimbria, for preventing the incursions of the Bulgarians and Scythians.

AGGLUTINATE, to unite one part to another.

AGORA, the forum, or market-place, at Athens.

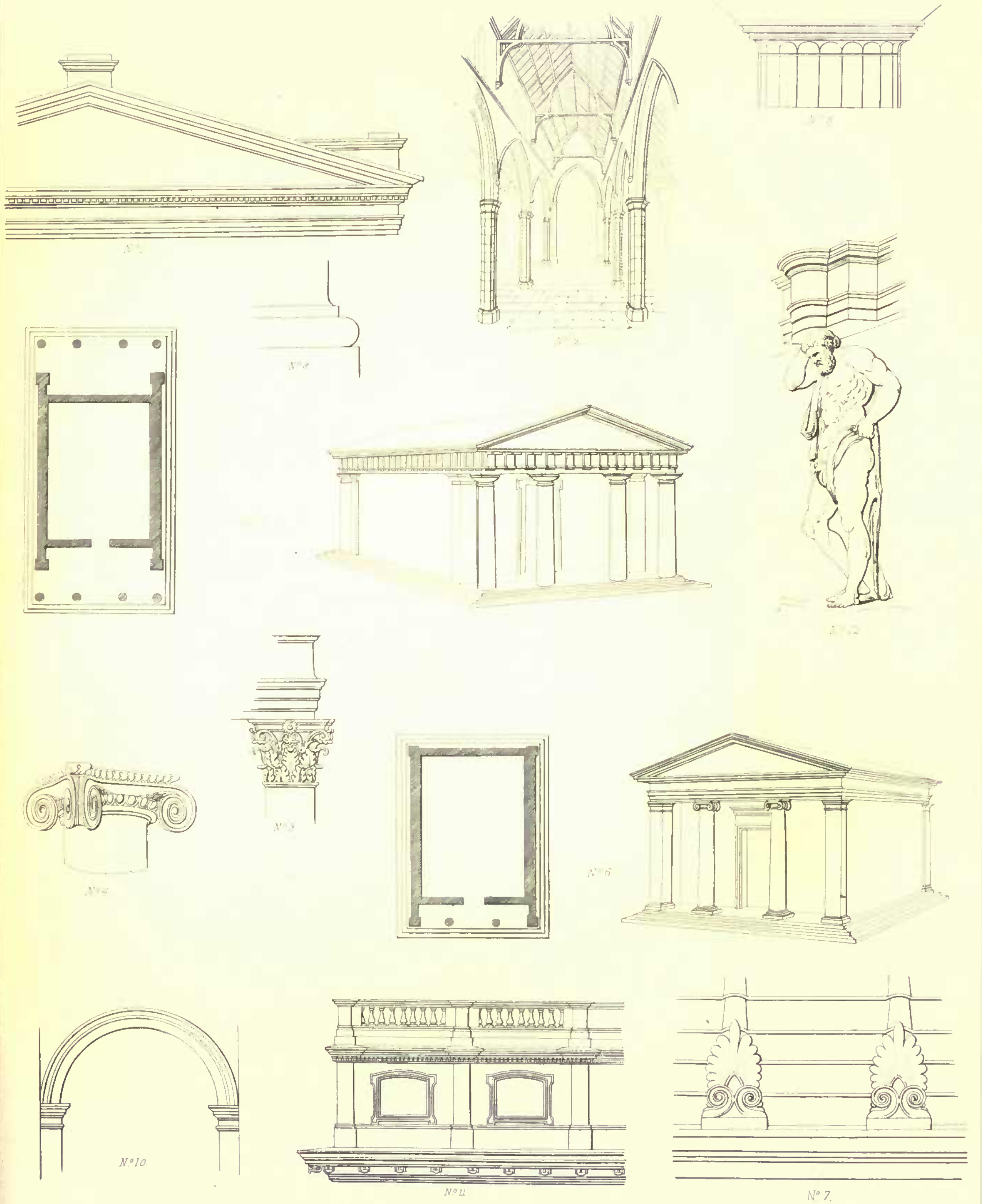
AGYCI, in antiquity, obelisks sacred to Apollo, and placed in the vestibule of houses.

AISLE, or AILE, (from the French *aîle*, a wing, or *allée*, a path.) When the breadth of a church is divided into three or five parts, by two or four rows of pillars parallel to the sides, the church is denominated a three or five aisled fabric. The middle and principal compartments is called the nave; the side divisions adjoining, the aisles; or, if the term be applied to all the compartments, as it lawfully may be, they are distinguished as the middle and side aisles.

In French, this term is applied to the outlying and returning ends of a building, called by us wings; such as the columned ends of the front of the General Post Office, London.

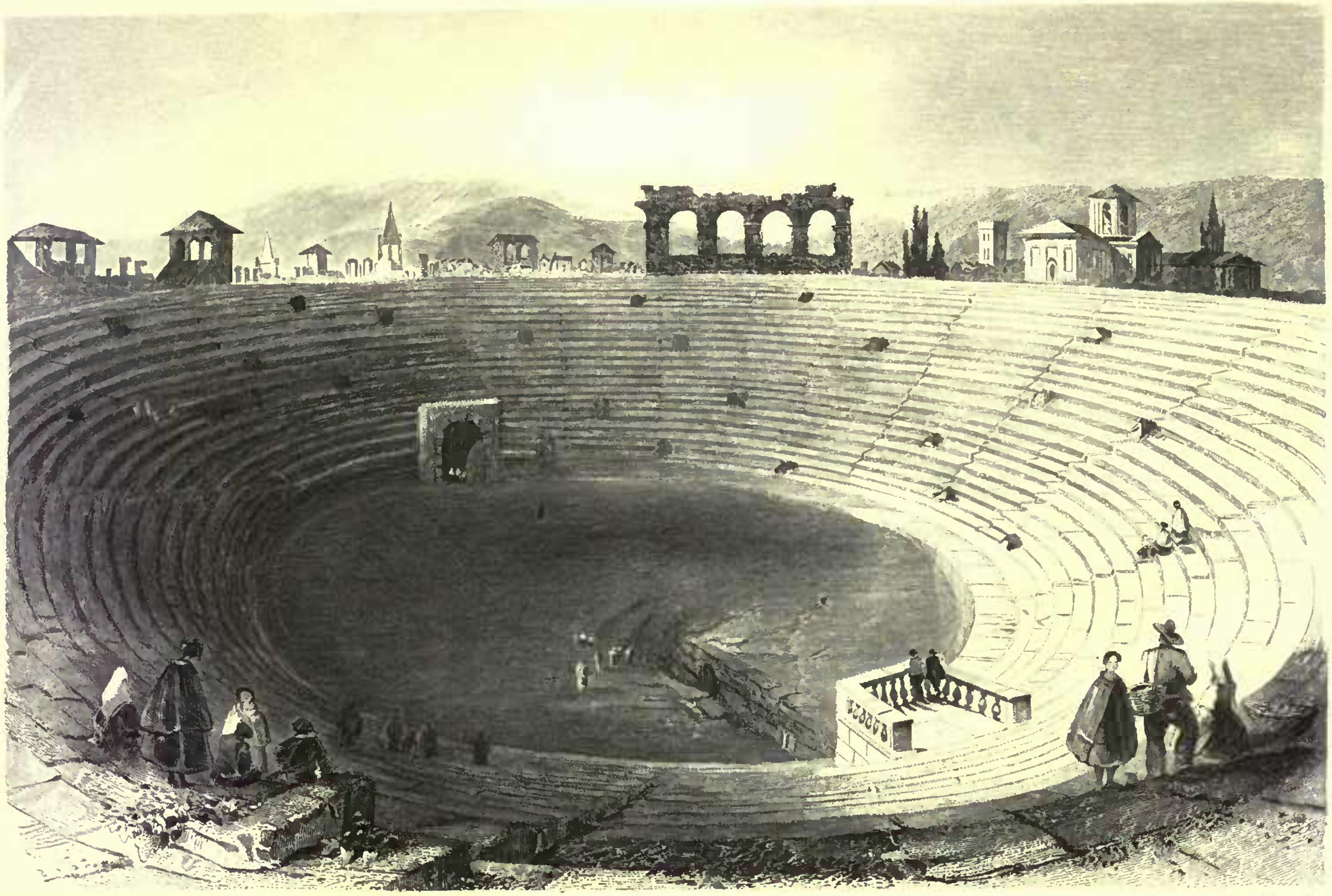
The ecclesiastical buildings in Great Britain are generally three-aisled; and no instance occurs of a five-aisled church, except a building at the west end of Durham cathedral; but on the continent there are several; the great church at Milan is one. Old St. Peter's, at Rome, was also a five-aisled fabric.

It is rather remarkable, that in Westminster abbey-church, and Redcliffe church, at Bristol, the aisles are continued on each side of the transept, and in Salisbury cathe-



A Gilbert

N° 1. Acroteria.
N° 2. Aisle.
N° 3. Amphiprostyle. Plan & Perspective view
N° 4. Angular Capital
N° 5. Annulets.
N° 6. Antæ Plan & Perspective view
N° 7. Ante fixæ
N° 8. Apophyge.
N° 9. Architrave.
N° 10. Archivolt.
N° 11. Attic.
N° 12. Atlantes.



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The Amphitheatre, Verona, Italy.

dral on one side only; but in no other church in this country.

Other particulars in connection with Aisle will be found under the articles Church, Transept, and Wing.

ALABASTER. *See* Gypsum.

ALÆ, two apartments on the right and left of the vestibulum, and separated from it either by columns or walls.

A-LA-GREC, or A-la-Grecque. *See* Frets.

ALBARIUM, *Opus*, in ancient buildings, the incrustation or covering of the roofs of houses with white plaster, made of mere lime. The workmen were called *albini* or *albarii*. This is otherwise called *opus album*, and differs from *tectorium*, which is a common name given to all roofing or ceiling, including even that formed of lime and sand, or of lime and marble; whereas albarium was restricted to that made of lime alone.

ALCOVE, in a sleeping room, is a recess made in the side for receiving the bed, either wholly or in part. Alcoves were formerly much in use in bedchambers, and were often raised upon two or three steps, with a rail at the foot of the bed; but now they are seldom employed except to obtain uniformity, or a communication to another apartment. The word is derived from the Spanish *alcoba*, and this again from the Arabic *al kubbeh*, the place for the bed.

There is little doubt but the alcoves were of Asiatic or African origin; for we frequently read of them in Arabian stories and descriptions of Asiatic palaces and gardens. They were introduced into Spain, from Arabia, by the Saracens; and by the Spaniards into France, Germany, and other nations. It is remarkable, that in the designs of Palladio and other contemporary Italian writers, there are no examples of alcoves; whence we may reasonably conclude that they had not become fashionable either in Rome or Venice. Swinburn mentions two, yet remaining, in the royal bedchamber of the Moorish palace of Alhambra, at Granada, which are probably the oldest in Europe. The word is also applied to a recess or arched seat in a garden.

ALESSI, a famous architect, born at Perugia, in 1500. He attained to such eminence in his profession, that he was applied to from France, Spain, and Germany, for plans of public buildings. His plan for the monastery of the church of the Escurial was preferred to those of the ablest architects of Europe. He died in 1572.

ALHAMBRA, an ancient palace of the Mohammedan kings of Granada, situated on a hill which runs out to the east of the town, and surrounded by strong walls flanked by square towers. These walls were built of a kind of cement formed of red clay and large pebbles, which, being exposed to the action of the weather, quickly acquired the solidity and hardness of stone.

The beauties of this magnificent specimen of Arabian taste and splendour, have been described at great length by Swinburn and other writers, who express the highest admiration of the exquisite taste displayed throughout the whole.

In visiting the Alhambra, the traveller ascends through a wood of lofty elms, whose interlaced branches shelter him from the sun's rays, to the Gates of Justice, and passes beneath its horse-shoe arch, so characteristic of its Arabian architecture, to the *Plaza de los Algibes*, or Square of Cisterns.

On the east side of this Plaza is the palace of Charles V., a beautiful specimen of the style of the fifth century, by Alonzo Berrequette. On the north is the Mesuar, or common bathing-court, 150 feet long and 56 wide, paved with white marble, and its walls covered with arabesques of the most admirable workmanship.

From the Mesuar the traveller passes to the Court of the Lions, which is also paved with white marble, and measures 100 feet by 60. In the centre is a large basin of alabaster supported by twelve lions, from which rises a smaller one. From this a large body of water spouts into the air, and, falling from one basin to the other, is sent forth through the mouth of the lions. A gallery, supported by light and elegant columns, surrounds the court; and at each end projects a sort of portico or gallery, supported by similar columns.

The Sala de Comares was undoubtedly the richest in the Alhambra. Its walls are ornamented with arabesques of the most exquisite workmanship; its ceiling of cedar-wood, inlaid with ivory, silver, and mother-of-pearl, while the softened light, admitted by windows sunk in the immense thickness of the wall, chastens the splendour of its richness, and enhances its surprising beauty and magnificence.

Lost in the contemplation of the charming objects which surround him on all sides, the traveller forgets the world and its dry realities, and seems transported into one of the palaces described in the "*Arabian Nights.*"

ALIPTERION, (*αλειφω, to anoint,*) the anointing-room in the bath.

ALMS-HOUSE, a small hospital, or edifice, endowed with a revenue for the maintenance of a certain number of poor, aged, or disabled people.

AMBO, or Ambon, in ancient churches, a kind of pulpit or desk, ascended by steps. The modern reading-desks have been gradually substituted for the ancient ambæ: there are, however, remains of them in some Roman churches still to be seen, as in that of St. John de Lateran, at Rome, where there are two movable ambæ.

AMPHIPROSTYLOS or Amphiprostyle, in ancient architecture, a temple with a portico in front, and another in the rear. The term is derived from *αμφ both*, *προ before*, and *ϛυλος column*, signifying columns on both fronts. *See* Temple.

AMPHITHEATRE, (from *αμφι, around;* and *θεατρον, theatre,*) in Roman antiquity, a large edifice, of an elliptic form, with a series of rising seats or benches disposed around a spacious area, called the *arena*, in which the combats of gladiators, wild beasts, and other sports, were exhibited. It consisted exteriorly of a wall pierced in its circumference by two or more ranges of arcades, and interiorly of vaulted passages radiating from the exterior arcades towards the arena, and several transverse vaulted corridors opening a free communication to the stairs at the ends of the passages, and to every other part of the building; the corridors and ranges of seats forming elliptical figures parallel to the boundary wall.

Sometimes, in the middle of the fabric, there was an intermediate corridor, which, like those on the ground-floor, surrounded the whole, and served as a common landing-place to all the staircases that led to the higher galleries; as in the amphitheatre at Nismes: and sometimes each staircase had its distinct landing, without any gallery of general communication: as in the amphitheatre at Verona.

The four passages in the direction of the greater and lesser axes were generally made wider than the rest, and, by intersecting arched passages, laid open to the adjoining passages on either side of them. The principal entrances, through which the emperor, the senate, and other distinguished persons passed, were placed in the direction of the lesser axes. The other two led directly to the arena by large arched gateways, which were appropriated to the beasts and gladiators. Through the other passages, the different orders of people passed to the staircases, which led to the respective seats. Every arcade around the exterior was numbered, as well as the divisions, or wedge-formed parts, called *cunei*, which separated the people into different orders.

The amphitheatre was regulated by certain laws, by which each person knew the entry through which he was to pass, to his appropriate seat. The door-ways, which opened from the stairs and passages, were denominated *vomitoria*. The benches, on which the people sat, were about two feet four inches broad, and one foot eight inches high. Before every range of vomitoria, a passage of communication, called a *precinctum*, was formed, about four feet eight inches broad, and bounded on the ascending side by a wall of about three feet four inches high. Surrounding the arena was a platform called the *podium*, which was of greater breadth than the precinctum, and which was defended on the front by strong netting, and rails of iron armed with spikes, and also with strong rollers of timber, which turned vertically, to prevent the hunted animals from leaping over. The emperor's pavilion, called the *suggestum*, was in the podium, at one extremity of the minor axis of the arena, highly decorated, and lined with silk. The seats of the most distinguished persons were also in the podium, and covered with cushions, while marble benches were in general covered with boards; but as the podium was not sufficiently large to contain all the people of high rank, other contiguous places were allotted for that purpose. Over the spectators, in time of rain or intense sunshine, a covering of woollen of different colours, called the *velum*, was occasionally stretched by means of pullies and cords, and drawn up or let down at pleasure.—On the sides of the passages, and under the stairs, on the ground-story, are many cells and rooms, which were probably prisons for criminals condemned to fight or to be devoured, and in which the beasts might be occasionally stabled. It was sometimes the practice to give novelty to the games, by erecting pieces of machinery on the arena, representing mountains, on which real trees were planted, and under them hidden caves were formed, from whence the animals rushed out to encounter the combatants, or to devour their victims.

Amphitheatres are undoubtedly of Roman invention, and were at first constructed of timber; and it was not till the reign of Augustus that one of stone was built by Statilius Taurus, but this does not appear to have been held in much estimation as it was very seldom resorted to. The Roman amphitheatre, called the *Coliseum*, or *Colosseum*, was begun by the emperor Vespasian, and finished by his son Titus, and is deservedly celebrated as a prodigy among the ancients. At the solemn games, when this edifice was dedicated, five thousand wild beasts, according to Eutropius, and nine thousand, according to Dio, were destroyed on its arena. When the hunting was concluded, the arena was suddenly filled with water, in which aquatic animals were made to contend, and then a sea-fight ensued. According to Tappen, the greater axis of the ellipsis of this stupendous edifice was 627 feet, and the lesser, 520. According to Desgodetz, the height of the exterior wall was 156 feet, the greater axis of the arena about 264 feet, and the lesser 165 feet; therefore the medium breadth of the circuit, for seats, galleries, and wall, was about 179 or 180 feet.—This edifice covered something more than five acres of ground.

The boundary wall was pierced by five ranges of apertures, of which the three lower were arcades, having eighty openings in each range, and the upper two rectangular windows. Its exterior side was decorated with orders, in four ranges, with continued entablatures; the three lower were colonnades, and the upper a pilastrade.

The lowest order was Doric, without mutules, triglyphs, and guttæ; but the shafts of the columns terminated with bases: the second was Ionic, with the Attic base; its volutes were slightly formed, and the dentil band uncut: the third and fourth orders were Corinthian, with unraffled leaves. The diameter of the columns, in the several ranges, was two feet eight inches and three quarters, as also the breadth of the pilasters; the columns of the lower range were twenty-six feet high, and each of the others twenty-four feet only. This makes the Doric columns higher than either the Ionic or Corinthian, and the altitude of the Ionic and Corinthian equal to each other, while all the columns have equal diameters, and are of the same breadth with the pilasters of the upper range. The sima of the cornice of the lower Corinthian was supported by modillions, without the intervention of the corona, and the column has a Tuscan base. The upper Corinthian had its cornice formed in front by three faces, and a cymatium like an architrave, and supported by cantalivers, projecting out of the frieze; or the entablature may be looked upon as an architrave cornice, reckoning the frieze and cantalivers a part of it. The whole edifice was crowned with a blocking course.

The first colonnade was raised on several steps, about three feet two inches above ground, and the bases of the columns stood on the uppermost step, which formed the pavement of the entrances. In the superior stories, the piers and columns were elevated on stylobatæ and podia, and the second and third ranges of arcades stood upon podia also. The boundary wall was diminished upwards in its thickness on both sides, but more particularly from the exterior side of it, in each succeeding story, and the columns of the two lower ranges projected three quarters of their diameter, while those of the third range did not project more than the half; and therefore the axes of the columns of each succeeding range upwards, were more recessed than those of the inferior range. This recession is more observable in the upper range of columns than in that immediately below; but still more in the pilasters of the third order. The diminution of the columns commences from the third part of their height. The straight soffits of the fillets and other horizontal projections rise more in the front than in the rear. The lower range of the rectangular windows had one window disposed in every alternate podium, below the upper order; and had the upper range of windows in the inter-pilasters above the imperforated podia. The cornice of the uppermost order was pierced with square mortises, through which the awning poles passed to a range of corbels below, something higher than the middle of the pilasters. Seventy-six of the lower range of arcades were about thirteen feet four inches broad, and the four placed upon the extremities of the axes, about fourteen feet six inches. The lowest range of arcades radiated vault-wise towards the arena, in a direction almost at right angles to the curve of the plan of the exterior wall, and intersecting two vaulted corridors, passed on to the staircases in the same direction. Two other corridors were placed between these stairs and the wall of the podium, and other stairs between the second and fourth corridors. The first staircases were entered by the second and third corridors, and those next to the arena by the third corridor only; this corridor was lighted from above, by vertical square holes, descending through the crown of the vault; and, it is probable, that the fourth corridor, adjoining the wall of the podium, was lighted in the same manner. The second story had three corridors, laid open to one another by radiating passages: the first two were placed over the first and second corridors on the ground-floor, and between the second and third were placed stairs, which ascended on the one hand to the second range of vomitoria, and on the other, to another high-groined corridor, forming a mezzanine, which was lighted from the floor of the gallery above, and from which the stairs ascended to the next story. The third story consisted of a double corridor, from which the stairs continued upwards to the fourth galleries, the interior wall of which was pierced with windows and doors, or vomitoria, that opened to the uppermost cunei of benches. On the inside of the exterior wall are vestiges of stairs which led to a fifth gallery; this again had four staircases, which led to a sixth gallery; and from thence the stairs continued to the top. The two upper floors were contained in the height of the pilastrade.

The stone employed in this edifice is the produce of the neighbourhood of Rome, and is called *Travertine-stone*, of which the exterior walls, the piers between the two outer corridors, the heads of the passages and corridors, and some bendstones, are constructed: all the rest is of brick. The exterior wall is cramped with ligatures of iron, without cement; some of the internal walls have remains of plaster ornaments, and others are lined with marble. The floors of the corridors are paved with flat bricks, and covered with a hard incrustation of stucco. This building is supposed to have contained 100,000 persons; but it will be found that by allowing two feet two inches from seat to seat, and one foot nine inches to the breadth of each person, not more than 80,000 could be accommodated, even supposing all the upper galleries to be filled.

"The proportions of this edifice," says Tappen, "were in such perfect harmony with each other, that there was nothing gigantic in its appearance, although the greatness of its dimensions never fails to impress every mind with ideas of its sublimity."

A structure of such dimensions, and of such contrivance and ingenuity as the Colosseum, eclipses the most magnificent works of the Egyptians and Greeks, and even those of modern times. The structures of Egypt, such as we may conjecture from what now remains, have little to recommend them, except their magnitude and the enormous stones employed in their construction. For beautiful simplicity, and chastity of parts, the Greeks excelled every other people; yet the Romans, though licentious in the detail and embellishments, showed much ingenuity, not only in the arrangement of their plans, but in the construction of the elevated parts, both with regard to the solidity of the work, and the end to be answered by the design. Our finest embellishments and best proportions are of Greek origin; but the Romans have set us the example in a beautiful diversification of plans.

The Amphitheatre at Verona consisted, formerly, of three stories of arcades, with pilasters against the piers of each story, bearing continued entablatures. The pilasters and arches are all rusticated and unwrought on the face. The orders which decorate the solid parts of the masonry are of no legitimate species, but more nearly allied to the Tuscan than any of the other three. The second pilastrade stands upon a plinth, and the third upon a triple plinth. The pilasters of the first and second ranges are very slender, particularly the second; those of the third range are double the breadth of those of the second range, contrary to the laws of strength.

The arches forming the heads of the first and second arcades are extradossed, and project out beyond the rustics, which form the horizontal courses above; the arches forming the heads of the third arcades are also extradossed, but each has another concentric extradossed arch, springing on each side from the pilaster, with its face in the same plane with the pilasters, and its inner diameter equal to the clear distance of the pilasters. The edifice is finished with a blocking course, resting upon the upper entablature: of the outer wall only a small part remains. From some mutilated courses of rustic work, and the lower part of two plain pilasters which remain, it has been supposed that the building had also a fourth story. The height of the three existing stories is about 90 English feet. This edifice was erected without cement; the stones being nicely joined with cramps of iron, covered with lead. The greater axis of the ellipsis of the plan, according to Desgodetz, is 433 feet 8 inches, and the lesser 333 feet 4 inches; the greater axis of the arena 237 feet, and that of the lesser 136 feet 8 inches; the breadth, for benches and wall, being 100 feet 4 inches; each range of arches were seventy-two in number, which opening into the first range of arcades, radiated towards the arena, in passages and staircases, crossing a corridor surrounding the whole; the passages, proceeding forward, crossed two other surrounding corridors, between which were other stairs.

The second story has one corridor above the exterior lower one. Above are forty-six tiers of seats, rising by equal degrees from the arena to the wall upwards. The interior of this edifice is entire, having been wholly reinstated by the inhabitants, from time to time, for the purpose of exhibiting plays, and other diversions.

The greatest diameter of the ellipsis of the Amphitheatre at Nismes is 430 feet, and the least 338 feet; the whole height 76 feet 6 inches.

The elevation consisted of two stories of open arcades and an attic. Each story had sixty arcades in its circumference, of which the four placed upon the extremities of the axes form the grand entrances, and are decorated with pediments. Against the solid parts of the masonry are Tuscan pilasters, resting on pedestals, and supporting an entablature which breaks over them. On the top are short, hollowed stone corbels, in which, it is supposed, poles were placed, for bearing an awning over the spectators. Many of the rows of seats are entire.

The remains of the Amphitheatre at Pola, in Istria, consist of an elliptic wall, pierced around its circumference with 72 arches; containing two stories on one side, and one on the other, being built on the side of a hill. Above the upper arcade is an attic, pierced by 72 square-headed windows, which surround the whole: through this are grooves for the poles that supported the velum. The greatest diameter of the ellipsis is 416, and the least 337 feet.

The Romans constructed Amphitheatres in England; one at Dorchester, and one at Ilchester.

AMPHITHURA, (from the Greek, *αμφιθυρα*, *both doors*,) in ecclesiastical antiquity, the veil or curtain which divided the chancel from the rest of the church; so called on account of its opening in the middle, after the manner of folding doors.

ANABATHRUM, (from *αναβαινω*, *I ascend*,) a kind of ladder, or steps, by which an eminence may be ascended. In this sense, we read of the anabathra of theatres, pulpits, &c.

ANAGLYPHICE, or ANAGLYPTICE, (from *ανα*, *γλυφω*, *to carve* or *engrave*,) a species of sculpture wherein the strokes of the figures are prominent or embossed: in opposition to the *Diaglyphice*, where the strokes are indented.

ANAMORPHOSIS, (*ανα μορφη*,) in Perspective and Painting, a monstrous projection, or a representation of some image, either on a plane or curved surface, deformed or distorted, but which, in a certain point of view, appears regular and in just proportion.

ANCHOR, an ornament in form of an anchor, or arrow's head, employed in the echinus, or ovolo, between the borders which surround the eggs. This anchor, with its concomitants, are generally carved on the ovolo of the Ionic capital;

and in the Grecian, Ionic, and Corinthian orders, upon all large mouldings of this form: they are not employed in the Grecian Doric, though they are used in the Trajan and Antonine columns of the Tuscan order, at Rome.

ANCONES, the trusses or consoles sometimes employed in the dressings of apertures, as an apparent support to the cornice, upon the flanks of the architrave. In many ancient doors, the ancones were narrower at the bottom than at the top, and, in some instances, were not in contact with the flanks of the architrave, but placed at a small distance from them; the ancones being further separated from each other. Vitruvius calls them *prothyrides*.

ANDREA DE PISA, a sculptor and architect, born at Pisa, in 1270. He built several castles, and the church of St. John, at Pistoia; but his skill in architecture was principally displayed at Florence, where he erected many mansions, enlarged and fortified the palace of the duke, and surrounded it with magnificent towers and gates. On account of these works, he obtained the right of citizenship. At the request of the duke of Athens, he made a model of a citadel, which he intended to erect for restraining the Florentines. On this account, they took the alarm, and expelled the duke; but Andrea passed the remainder of his days at Florence, cultivating the fine arts, such as painting, poetry, and music, besides those which were professedly his own. He died in 1345, aged 75.

ANDRON, or ANDRONA, (from *ανηρ, a man*,) in antiquity, an apartment in houses, assigned to the use of men. It was sometimes called *andronitis*, in opposition to *gynecæum*, the apartment appropriated to the use of women. The Greeks also gave their dining-rooms the title of andron, because the women were not admitted to feasts in company with the men. Androna, in ancient writers, denotes a public place where people met to converse on business, such as our exchanges; however, it is more particularly used to signify the space or alley between two houses; and in this sense it was used by the Greeks, for the passage between two apartments in a house. This word is sometimes written, *andra*, *andrion*, or *andronium*, and is of the same import as the Roman term *mesaulæ*.

ANGLE, *rectilinear*, (Lat. *angulus*, the elbow,) according to Euclid, "the inclination of two straight lines to one another, which meet, but are not in the same direction." This definition, if indeed it may be termed such, is so very indistinct, and even inaccurate, that it has been entirely discarded by modern mathematicians, who have individually given many suggestions for its improvement, but have not agreed so far as to adopt any as a standard definition. We give the following as one of the most correct:—"An angle is the ratio of the plane surface bounded by two infinite right lines which meet, to the plane surface on all sides indefinitely extended about the point where they meet." Thus the A B C is the ratio of the plane surface, bounded by the straight lines A B, B C infinitely extended to the unbounded plane of the paper about the point B. Objections, doubtless, may be urged against this, as against all other suggestions; but the subject is unquestionably a difficult one, as it necessarily involves the long-disputed question concerning infinite magnitudes. The following description, though not amounting in preciseness to a definition, affords a very intelligible notion of the idea intended to be conveyed by the term, viz: the opening made by two intersecting right lines.

Comparison of Angles. As every theory respecting the comparison of infinite spaces is attended with considerable difficulty, we shall leave the consideration of the more abstruse points of this subject to works of a different nature, and endeavour to explain, as clearly as possible, the method of comparing angles.

Let A B C, D E F, (see the plate) be two angles formed by the intersection of the straight lines A B, B C, D E, E F, at the points B E, respectively.

Apply the angle A B C to angle D E F in such a manner, that the points B E, and the lines B C, E F coincide, then the position of E D with respect to B A is determined. Such being the position of the two figures, if E D fall upon D A, the two openings coincide, or, in other words, the angle A B C is equal to the angle D E F. If, however, E D fall between B C and B A, the opening or angle D E F is less than the other A B C; if, on the other hand, E D fall without or beyond B A, the angle D E F is said to be greater than the angle A B C.

Again, supposing the angles to be applied as before, and E D to fall within A B; let E B remain fixed in that position, but let E F be turned about E D as an axis, until it fall on the opposite side of it; then, if E F coincide with B A, it is evident that the angle A B C is equal to twice the angle D E F. In the same manner may be explained the notion of one angle being three, four, or any number of times greater or less than another.

It may be necessary to observe, that the magnitude of the angle in no wise depends upon the length of the intersecting lines; for, if we suppose a part D *d* to be cut off from the side D E, upon applying the angle D E F to angle A B C, as above, we shall find that the line E *d* will still fall in the same position with respect to A B, as it did before D *d* was cut off; and will do so, however short E D may become, until the line, and therefore the angle, ceases to exist.

Again, let us suppose a line starting from a certain station A B, to revolve round one of its extremities A as a fixed point or axis, and to arrive at the situation A B_1; it will then, with its original position, describe an angle B A B_1. Let it now continue its revolution, until it has passed over another space equal to the preceding, and in so doing has reached the position A B_2; it will then be readily understood that the angle B A B_2 equals twice the angle B A B, and thus we might describe an angle any number of times greater than B A B.

Euclid's notion of an angle has been very much enlarged upon by later mathematicians, as we proceed to illustrate by reference to the last diagram. Let us conceive the line A B to continue its revolution to B_3, and thence to B_4; we say then that A B_4 forms with its first position the angle B A B_4, and thus far Euclid allows; but if the revolution be continued until A B arrives in the position A B_5, so as to form a straight line with its first position—which event takes place when it has performed half a revolution—Euclid no longer recognizes the opening so formed as an angle. Such, however, it is reckoned to be by the moderns, and that not without reason; for it will be readily acknowledged that the opening formed by the lines A B and A B_5, is greater than that formed by A B and A B_4, thus showing that such opening is liable to comparison in the same manner as any other angle. The same reasoning will apply to openings formed by a whole revolution or more; indeed, the moderns do not restrict the term to any number of revolutions however great.

A RIGHT ANGLE is that traced out by A B while performing a quarter revolution.

AN OBTUSE ANGLE is that which is greater than one right angle, and less than two.

AN ACUTE ANGLE is that which is less than one right angle. The angle formed when A B has completed one revolution and arrived at A B, is described as four right angles + angle B A B.

Measurement of Angles. Referring again to the last diagram, it will be seen that the point D in the line A B, during its revolution round its axis A, describes a circle. Now the circumference of any circle so described is supposed to be divided into 360 equal parts, called degrees, each of such degrees into 60 minutes, and each minute into 60 seconds. This division is made use of for the measurement of angles in the following manner:—As the angle traced out by a whole revolution passes over in its progress 360 of the larger divisions, it is styled the angle of 360 degrees; similarly, the right angle, which makes only a quarter revolution, is named the angle of 90 degrees; and so on for angles of any dimensions whatsoever.

The measure of the arc is sometimes used indiscriminately for that of the angle; but such measurement is, strictly speaking, incorrect. *See* ARC.

External ANGLE, in civil architecture, the same as *Saliant* ANGLE, which see.

Internal ANGLE, in civil architecture, the same as *Re-entering* ANGLE, which see.

Re-entering, or *Re-entrant* ANGLE OF A SOLID; an angle whose vertex recedes, or is turned inwards, from a right line extended between any two points in the legs; or it is a cavity or void, formed by two planes on the surface of the solid. Artificers call all such angles, made by walls or partitions, *Internal Angles.*

Saliant or *Sortant* ANGLE OF A SOLID, an angle, of which the vertex is prominent; or it is the solid matter contained between two planes inclined to each other in an angle less than two right angles; or, it is such, that if a point be taken in each plane, the straight line joining the two points, will pass through the solidity. Artificers call all such angles, made by walls or partitions, *External Angles.*

Solid ANGLE, the mutual inclination of more than two plane rectilineal angles meeting in a point, and not contained in the same plane.

ANGLE OF A WALL, the angle contained by the two vertical planes which form the angle of a building. It would be better denominated *the angle of a building*, a term sufficiently explanatory of itself; but as it is to be found in other dictionaries of this nature, it is here inserted. The angle of a wall is said to be "the point where the two sides meet;" but it should be *the line where the two sides meet*, which is commonly called by workmen the *arris;* still the arris is not the angle, but the line of concourse formed by the two sides, or planes, containing the angle.

ANGLE BAR, in joinery. When a projecting window stands on a polygonal plan, the upright bar at the meeting of any two planes of the sides of the window is called an *angle bar.* When there are mouldings on the other bars, the angle bars should be made to mitre with the horizontal bars on either side of them. The manner of finding the section of an angle bar, is shown under the term *Raking* MOULDINGS.

ANGLE BRACES; when a quadrangular frame has a timber opposite each angle, fixed to each of the two sides forming the angle, and thereby making the inside of the frame of an octagonal figure, the timbers so fixed, are called *angle-braces*, or *diagonal ties*, or *angle ties;* the angles of wall-plates are frequently braced in this manner. Also when a well-hole, of a circular section, is made through a roof or floor, for a sky-light, &c., the framing is first made quadrangularly; then braces are fixed opposite to each angle, and the aperture becomes an octagon; and lastly, pieces are again fixed in each angle of the octagon, meeting each other in the middle of its sides, so as to transform the section of the aperture into a circle, and thus the well-hole is shaped as required.

ANGLE BRACKET. *See* BRACKETING.

ANGLE RAFTER. *See Hipped* ROOF.

ANGLE RIB, a curved piece of timber, placed between those two parts of a coved or arched ceiling, or vault, which form an angle with each other, so as to range with the common ribs on each side, or return part. Examples will be seen under the articles DOME, GROIN, and *Hipped* ROOF.

ANGLE-STAFFS, or STAFF-BEADS, vertical beads, generally of wood, fixed to exterior angles, flush with the intended surface of the plaster, on both sides, for the purpose of fortifying the angles against accident: they serve also for floating the plaster. Their section is about three-fourths of a circle, with a projecting part from the other quarter, by which they are fastened to the wood bricks, plugging, or bond-timbers. The section of angle-staffs is sometimes that of a triple bead, the middle one being larger than that on either side of it, and flush with it and the plaster. Angle-beads of wood, around the intradosses of circular arches, are difficult to bend without cutting or steaming them; the former has a very unsightly appearance, and the latter is both inconvenient and troublesome: for this situation of angle-beads, no other material will finish better than the plaster itself; and it will be sufficiently strong, as at that height it is more out of the reach of accident. Whenever wooden and plaster beads are employed in the same margin, or angle, they should never join each other, but should always have an impost to intervene, as, otherwise the joint will show. In grand finishings no corner beads are employed; but the plaster is well gauged, and brought to an arris.

ANGLE TIES. *See* ANGLE BRACES.

ANGULAR, something relating to angle.

ANGULAR CAPITAL, is generally applied to the Scammozzian, or modern Ionic capital, which is formed alike on all the four faces, so as to return at the angles of the building, as in the Temple of Concord. It is also applied to those capitals of Grecian edifices which had two fronts alike on ea h angle of the building, in order to face the front and flank alike, and to correspond to the other capitals, upon the columns ranged in the flank, as well as in the front. *See* PLATE.

ANGULAR CHIMNEY, one which stands in the angle of an apartment, with the plane of its breast intersecting the adjacent walls. For the method of measuring angular chimneys, see CHIMNEY.

ANGULAR MODILLIONS, those which are placed at the return of a cornice, in the diagonal vertical plane, passing through the angle or mitre of the cornice.

As angular modillions are not to be traced among the ruins of Grecian edifices, it may be concluded, that they were seldom or never used by the Greeks; nor are they to be found among the ruined edifices of ancient Rome; it is however probable, that they may have been used in the decline of the empire, since they are to be seen in the remains of the palace of the emperor Diocletian, at Spalatro, in the vestibulum, and in the temples of Jupiter and Æsculapius. The ruined cities of Balbec and Palmyra exhibit many specimens, in the large porticos, and in the entablatures of doorways.

ANGULAR VAULT, a vault supported upon two circular walls; such as the temple of Bacchus, at Rome; the Temple church, London; the church of the Holy Sepulchre, at Cambridge, &c.

ANNULETS, (from the Latin, *annulus*, a ring,) the annular fillets between the hypotrachelion and echinus of the Doric capital. In the Roman Doric, they are generally three in number, and of equal size, with rectangular sections. One side of each annulet is a horizontal soffit, seen from below, the other is a vertical cylindrical surface, having the same axis with the column, the projection of each soffit being equal to the height of its respective vertical side. In the axisal section of the Grecian Doric, except in the case of the Doric portico at Athens, the number of annulets vary from three to five; the sinkings between each two follow the line of the echinus, and the outer sides of the fillets form a curve parallel to that of the sinkings; the upper side of each is perpendicular to the curve, and the lower side is concave towards the space between each two: the concavity begins in a direction perpendicular to the curve of the moulding; the flutings of the shaft of the column terminate under the lowest annulets. There are also other names by which an annulet is sometimes called, as *cincture*, *fillet*, and *list*, or *listella*, which are equally applicable to rectilineal members, and therefore should never be used but in a general description, where there is some common property to be explained, as they do not particularly imply circularity.

ANNULUS, a Cylindrical Ring, a solid formed by the resolution of a circle about a straight line without the circumference as an axis, and in the plane of the circle. For the method of measuring an annulus, see MENSURATION.

ANTÆ. When the two parallel side-walls or flanks of a temple. or other edifice, are protruded or lengthened out beyond the end of the building, and when each of the two projections is covered with a vertical body, projecting on each side of the thickness of the wall, having a base, a prismatic trunk, and a capital, similar to a pilaster; then these bodies, or terminations, are called *antæ*. The breadth of the antæ on the flanks of the temple was always less than in the front; and the two edges of the antæ which faced each other within, and on the sides of the pronaos, were equal to the diameter of the columns placed between them, while that of the opposite, or outsides of the flanks of the edifice, was much less. The capitals of the antæ never corresponded with those of the columns, though the mouldings were more or less enriched, as the order had more or fewer decorations. In the temple of Minerva Pollias, and the temple of Apollo Didymæus, in Ionia, the capitals of the antæ have a strong resemblance to those of the columns; they having also volutes, though not of the same proportion, nor depending in the same way; as these are hung to an upright, and those to a horizontal hem, connecting the two. Antæ differ from pilasters, not only in their capitals, but also in their situation. A portico is said to be "in antis" when columns are placed between the two antæ. *See* TEMPLE.

ANTECHAMBER, (from the Latin, *ante*, before, and *camera*, a chamber,) an outer chamber, before a principal one, where servants wait, and strangers are detained till the person to be spoken with is at leisure.

ANTEFIXÆ, blocks with vertical faces placed at regular intervals on the uppermost member of a cornice, for the purpose of hiding the ends of the covering or joint-tiles of the roof. The faces of antefixæ are usually carved with some ornamental device, as a flower, leaf, &c.

ANTEMURAL, (from *ante*, before, and *murus*, a wall,) an outer wall, environing the works and walls of a fortified place, in order to prevent the enemy from approaching too near. In some writings, it signifies the same as an outwork.

ANTEPAGMENTA, or ANTIPAGMENTS, (from Greek *αντι*, *πηγνυμι*, *to fix*,) in ancient architecture, the jambs of a door moulded like an architrave. The lintel returning at the ends, with similar mouldings, down upon the antipagmenta, was called the *supercilium*. Also carved ornaments of men, animals, &c., placed on the architrave.

ANTERIDES, in ancient architecture, the buttresses erected to strengthen a wall: they are called in Greek, *ερεισματα*, and answer to what our modern builders call *counter-forts*, and *archbutants*; by the Italians they are called *barbicane*, and *speroni*, or *spurs*. They are also sometimes called *antes*, sometimes *crismæ*.

ANTE-ROOM, a room through which a person must pass, in order to enter into another room. In many constructions of houses, there is a necessity for introducing ante-rooms, from the peculiar arrangement of the plan; and in many situations, besides being useful, they add both grandeur and elegance to the design.

ANTES. *See* ANTÆ.

ANTHEMIUS, a distinguished architect, a native of Tralles, in Asia Minor, and employed by the emperor Justinian in the construction of various edifices, particularly the church of St. Sophia, at Constantinople, which he designed, and also superintended 10,000 workmen in its execution. Anthemius was also a sculptor, a mathematician, and an experimental philosopher.

ANTICS, figures of men, beasts, &c., placed as ornaments to a building.

ANTICUM, the porch before a door; also, that part of the temple which is called the outer temple, and lies between the body of the temple, and the portico.

ANTIPORTICO, a word sometimes used to denote a vestibule, or porch, at the entrance of an edifice.

ANTIQUARIUM, among the ancients, an apartment in which their antique monuments were preserved.

ANTIQUE, in a general sense, denotes something ancient; but the term is chiefly employed by architects, sculptors, and painters, and applied to works, in their respective professions, executed by the Romans,or others anterior to their time; such as the Colosseum at Rome, the temple of Minerva at Athens, &c.

ANTIQUES, a mixed composition of the effigies of men, inferior animals, utensils, and implements of war, with foliage, flowers, and fanciful ornaments. The ornaments on the walls of the Vatican, at Rome, painted by Raphael, are of this kind, and were imitated from the grottos of the baths of Titus, of which there were ample remains in his time. This species of decoration is frequently called *arabesque*, or *grotesque*; the latter is the more correct appellation, as the former applies solely to Arabian ornaments, which consisted of foliages and fruit, without any animal representations.

ANTIS. *See* TEMPLES, ANTÆ.

ANTISTATES, one of the architects employed in raising the foundation of the temple of Jupiter Olympus, at Athens.

ANTONINE COLUMN, a pillar of the Tuscan order, erected in Rome, by order of the senate, to the memory of the emperor Antoninus. It is 175 feet in height, *viz*., 168 feet above ground, and 7 feet beneath the surface; and has a winding staircase, with 198 steps in the ascent, and 56 windows, or loop-holes. The sculpture, and other parts, are similar to those of Trajan's column, but the work is greatly inferior. *See* COLUMN.

APART, the distance between the nearest surfaces of any two bodies. This term is much used in building, particularly in the art of carpentry; as, joists are placed from eleven to twelve inches *apart*.

APARTMENT, any part of a house that is walled round, and that may be entered through doors; as kitchen, vestibule, saloon, dining-room, drawing-room, chamber, closet, library, passage, &c. All the apartments, on the same floor, taken collectively, when opening one into another, without an intermediate passage, are called a suite of apartments.

The word apartment may also denote a portion of a large house, wherein a person may lodge separately, having all the conveniences requisite to make a complete habitation.

A complete apartment is said to consist of a hall, a chamber, an ante-chamber, a closet, and a cabinet, or ward-robe.

When an apartment has one or more of its sides contiguous to one or more of the exterior walls, and has no other apartment above, it may be lighted either through apertures in the vertical sides of the exterior walls, or by a skylight, as may be found most eligible.

When an apartment is contiguous to one or more sides of the building, but has one or more apartments above, it becomes necessary to light it from apertures in the external walls. Dining-rooms, withdrawing-rooms, and bed-chambers, are more conveniently and agreeably lighted from the exterior walls, than from the roof.

When an apartment is surrounded on all sides by other apartments, but has no other above, it may be lighted by a skylight; or, if its height exceed the height of the adjoining apartments, it may be lighted from windows in the sides, above the roofs of the surrounding apartments. A saloon, a staircase, or a dome, is more elegantly lighted in this manner, than in any other.

When several contiguous apartments, above each other, are surrounded on the sides, they may either be lighted horizontally through the sides by borrowed lights, or vertically, through apertures in the several ceilings and the roof. Sometimes the situation of passages renders it necessary to light them in the latter method, by forming apertures through the several ceilings and the roof, over each other, with a sky-light at the top, and rails round the openings in the floor. Granaries and warehouses, consisting of several stories, and surrounded with buildings, cannot be lighted in any other way, than from skylights in the roof, and apertures through the several floors, vertically over each other. To save room, the space allotted for the passages, upon each floor, may be directed across the openings, and the openings may be ribbed or latticed with strong bars, for walking upon.

The method of proportioning and finding the number of apertures for lighting an apartment or room, will be seen under the article WINDOWS; and the proportion of chimneys to the cubature or sides of apartments, is shown under the article CHIMNEYS.

What relates to the ceilings of apartments, will be found under the articles, CEILINGS, COMPARTMENT CEILINGS, and VAULTS.

The proportions of apartments depend much on their use. The length of rooms may be extended from once to twice the breadth, and galleries even to three or four times. It is, however, to be observed in general, that the greater the cubature of the room, the greater also must be the ratio of the dimensions of the plan. Thus the dining-room, or withdrawing-room, in a very small house, may be square, but that in a large edifice may be a double square, or less, according as the disposition of the plan of the building may turn out; the length of the largest rooms should, however, never be less than once and one-third of their breadth. As to the height, it may be three-fourths of the breadth, when the ceiling is flat and equal to the breadth, or once and one-fourth of the breadth, when the ceiling is covered or arched, according to the rise of the arch. It may be thought, that there might be some ratio between the height and length, but this idea vanishes when it is considered, that the eye can only take in a certain portion of the length, and therefore the comparison must be made with the breadth.

If the apartment be a principal passage, its breadth may be one-third of the breadth of the principal room; and if it be a by-passage, or that of a very common house, its breadth may be one-fourth of the breadth of the principal room: the height is the height of a story; but the length is indefinite.

With respect to the staircase apartment, the area occupied by the floor depends on the height of the story, the rise and tread of the steps, the formation of the plan, the number of quarter or half paces, and the size of the passage, or lobby, at the beginning or landing; also whether the stair be made single or double; or whether it consist of one or two revolutions in the height of the story. The proportion of the dimensions of the plan of the staircase depends on the proportion of the individual dimensions of each apartment, the proportion of the area of the plans to one another, and their disposition. A principal staircase should never consist of two revolutions. The more of an oblong the plan of a staircase is, the less room will be required, provided the going of the steps be placed in the breadth, and that each flight on the opposite side consist of an equal number of steps, connected by windows, between the flights; since by such means the lobby and landing above are shortened, and also less room is occupied by the newal. What further relates to staircases, will be seen under the article STAIRS.

To preserve the best possible proportions in a floor of apartments, the principal rooms may have flat ceilings; the middle-sized ones may have their altitudes reduced by introducing cove and flat ceilings, cylindrical vaults, domes, groins, &c., as may be most suitable to their heights; and the smallest rooms may have mezzanines over them, wherever they are accessible to back stairs; but when the disparity is great between the height of the principal rooms, and those of the middle size, the whole of the rooms in the suite, except the principal ones, may have mezzanines above; the middle-sized rooms may have flat ceilings; and the smaller rooms arched ceilings. Mezzanine apartments are not only necessary on this account, but they may be employed with great advantage, since they afford servants' lodgings, baths, wardrobes, &c.

In buildings where beauty and magnificence are preferred to economy, the halls and galleries may be raised to the height of two stories. Saloons are most frequently raised the whole height of the building, and have galleries at the height of the stories, around their interior circumference, communicating with the various apartments. In general the area occupied by the saloon, may be half of that occupied by the dining-room, drawing-room, or principal-room.

The walls of apartments may be ornamented with columns, pilasters, entablatures, niches, recesses, panels, &c., as also with foliated and other enrichments.

When an apartment is adorned with an entire order, the entablature may occupy from one-sixth to one-seventh part of the height of the order, or of the room itself, when the ceiling is flat. If a cornice, frieze, and astragal are executed, instead of the full entablature, their height may be equal to one-tenth. If a cornice only is executed, its height may be one-twentieth or one-thirtieth part of the height of the room. In general, all interior proportions and decorations should be smaller and more delicate than those of the exterior: pilasters should not project more than one-eighth, or one-tenth of their breadth; and architraves round apertures should, in most cases, not exceed one-seventh of the openings. When the sides of rooms are straight, and are adorned with columns or pilasters ranged the whole length of each side, the columns or pilasters may be either single or coupled, as the piers of the windows may admit: if each extreme pier be equal to, or more than the half of each intermediate pier, the columns or pilasters may be placed single, or in couples, as the breadth of the intermediate piers may allow; but if each extreme pier, or one only of them. be less than the half of each intermediate pier, it will then be necessary to couple the pilasters. If one of the extreme piers is greater than the other, the former may be made equal by forming the end of the room cylindrical; if each extreme pier exceed the breadth of each intermediate pier considerably, then both ends may be formed into cylindrical surfaces, or otherwise columns may be introduced at each end, and the entablature continued over the columns; the recesses also may be adorned in a different manner, or one of the ends may be made cylindrical, and the other colonnaded.

Apartments of a quadrangular plan are either constructed so as to have the same symmetry on the opposite sides; or to have no corresponding symmetry whatever, on either pair of these sides. When bows are introduced into apartments, they are generally at the ends; but if upon one or both sides, they should be proportioned to the length. Sometimes, in very large apartments, with a fireplace at each end, two bows are introduced.

In the best houses, kitchens, halls, servants' rooms, and water-closets, are frequently wainscoted to the height of about four and a half feet, and coped with a neat moulding, which is generally a bead.

Halls, passages, staircases, and bedrooms, have frequently bases without dado, or surbases. Principal rooms have always complete pedestals. Apartments laid with stone-pavements, should have stone plinths, with wooden bases.

All further information respecting the finishing of apartments, will be found under the heads, CEILINGS, COMPARTMENT CEILINGS, VAULTS, DOORS, WINDOWS; and other particulars relating to distribution will be found in the article DESIGNING.

APERTURE, an opening through a body. An aperture in a wall has generally three straight sides, two of which are perpendicular to the horizon, and the third parallel to it, connecting the lower ends of the vertical ones. The stones forming the perpendicular sides are called *jambs*, the level side below is called the *sill*, and the upper part is called the *head*. The head of an aperture is either an arch, or a single stone, or beam.

Apertures are either made for entrance, light, or ornament. *See* DOOR, RECESS, and WINDOW.

A narrow aperture may be covered with a single stone, to such horizontal dimensions as may be found convenient to raise from the quarry.

When the aperture is wide, stones in separate pieces may be joggled together, in order to form a *straight arch*, as it is absurdly called by workmen; or the same kind of arch may be made with radiating joints concealed within the thickness of the wall, and vertical joints on the front, secured by strings or cramps of iron, if necessary; when an aperture is very wide, it becomes necessary to arch it over.

Too great a variety of apertures in the same front of a building destroys its uniformity.

The ancient Greeks and Romans made the sides of apertures frequently incline toward each other at the top.

Apertures are sometimes made quite circular or elliptical; but these forms are not in general use. In apertures of stone-work, if the jambs be of one entire piece, every alternate stone in the height of the aperture, next to the jambs, should be bond-stones; likewise, if the jambs consist of several stones in the height, every alternate jamb-stone should be a bond-stone. *See* STONE WALLS and WINDOWS, in MASONRY.

When the heads of apertures are arched, they require to be supported on *centres* while building; the method of constructing which is shown under the article CENTRE.

APEX, the highest point or summit of a structure.

APODYTERIUM, (αποδυμι, *to put off*,) an apartment at the entrance of the ancient baths, wherein the bathers undressed.

APOLLODORUS, a most distinguished architect, born at Damascus, who flourished in the reigns of the emperors Trajan and Adrian, about the beginning of the second century. Under the former, he built the stone bridge over the Danube, which was esteemed one of the most considerable undertakings of that prince: he also raised several edifices round the forum Trajanum, at Rome, among which were the sculptured column of Trajan, still existing, and a triumphal arch.

Historians relate, that as Apollodorus was once conversing with Trajan about some architectural designs, Adrian interfered, and gave his opinion, which was treated by the artist with contempt: "Go," said he, "and paint gourds, (an amusement which he knew Adrian to be fond of,) for you are very ignorant of the subject on which we are conversing." This affront was not easily to be forgiven or forgotten; accordingly, when Adrian had succeeded to the empire, he sent to Apollodorus the plan of a temple he purposed erecting in honour of Venus, and desired to have his opinion, which, however, he did not intend to follow, being only desirous to show that he could do without his services. Apollodorus wrote his opinion freely, and pointed out such essential faults in the design, that the emperor could neither deny nor remedy them. But instead of acknowledging the merit and genius of the artist, Adrian threw himself into a violent passion, and banished him; and some time afterwards, under pretext of some supposed crimes, ordered him to be put to death.

APOMECOMETRY, (from απο, *from*, μηκος, *distance*, μετρεω, *to measure*,) the art of measuring things at a distance.

APOPHYGE, (αποφυγειν,) a concave quadrantal moulding, joining two vertical members of different horizontal projections, and forming an exterior angle with that which has the greatest projection, and a tangent with the other. The apophyge is used in the Ionic and Corinthian orders, for joining the bottom of the shaft to the base, as well as to connect the top of the shaft to the fillet under the astragal. The word is originally Greek, and signifies *flight;* and the French call it by a term which implies *escape*. English architects and builders also call it the *scape* or *spring* of the column. *See* COLUMN.

APOTHECA, (from αποτιθημι, *to lay aside*,) among the ancients, a store-room.

APOTHESIS. *See* APOPHYGE.

APPEARANCE, in perspective, the projection of a figure, body, &c., being the same as the representation of an original object. *See* PERSPECTIVE.

APPLICATE, in geometry, a right line drawn within a curve, and bisected by the diameter of the curve, otherwise called an *ordinate*.

APPLICATION, in mensuration, the art of applying one thing to another by approaching or bringing them together; thus any number of magnitudes of the same kind may be compared together by the successive application of a small magnitude of the same kind to each of them.

APPLICATION, in geometry, the act or supposition of placing one figure upon another, to find whether they be equal or unequal, which seems to be the primary mode by which the mind first acquires both the idea and proof of equality. In this way the first principles of geometry are demonstrated. Thus, if two triangles have two sides of the one equal to two sides of the other, and the angle included be also equal, then the two triangles are themselves equal in every respect:

conceive the one triangle to be so placed upon the other, with the two corresponding equal sides upon each other, the angles included by these sides being equal, the other sides will also coincide, and the two figures will agree in all respects. The same may be observed of other figures.

APRON, in plumbing, the same as FLASHING, which see.

APRON, a platform, or flooring of plank, raised at the entrance of a dock, against which the gates shut.

APRON-PIECE, or PITCHING-PIECE, a horizontal piece of timber in a wooden double-flighted stair, for supporting the carriage pieces or rough strings, and joistings in the half spaces or landings. The apron-pieces ought to be firmly wedged into the wall. *See* STAIRS.

APRON-LINING, the facing over the apron-piece.

APSIS, (from Greek *αψις*, *an arch*,) a term generally applied to any projecting portion of a building, having a semicircular or polygonal plan, and vaulted roof. In ecclesiastical structures, it signifies that part where the altar is situate, and which is reserved exclusively for the clergy. It differs from chancel in having the form above described. *See* CHANCEL.

APSIS GRADATA, a term peculiarly used for the bishop's seat or throne, in ancient churches, as it was raised on steps, above the ordinary stalls. It was also denominated *exedra*, and in later times, *tribune*.

APTERAL, a building without columns on its flanks or sides.

APYROI, (from *α*, *πυρ*, *fire*.) a name given by the ancients to altars, on which sacrifice was offered without fire. In this sense the word is in contradistinction to *empyroi*.

AQUEDUCT, or AQUÆDUCT, (from Latin *aqua*, water, and *duco*, to lead,) a construction upon or through uneven ground, for the purpose of forming a level canal for conducting water from one place to another. Aqueducts were formed either by erecting one or several rows of arcades across a valley, and making these arcades support one or more level canals, upon one or each of the ranges, or by piercing through mountains which would have interrupted the watercourse. They were built of stone or brick, and covered with a vaulted roof, or with flat stones, to shelter the water from the sun and rain. Some aqueducts were paved; but others conveyed the water through a natural channel of clay, to reservoirs or castella of lead or stone, whence it was brought to the houses by leaden pipes.

Aqueducts had also ponds disposed at certain distances, where the sediment of the water might be deposited. When the water was conveyed under ground, there were openings at about every 240 feet. Some of the Roman aqueducts brought water from the distance of sixty miles, through rocks and mountains, and over valleys, in places more than 109 feet high. The inclination of the aqueduct, according to Pliny, was one inch, and, according to Vitruvius, half a foot in the hundred. The proportions adopted by the moderns is nearly the same as that mentioned by Pliny. The principal aqueducts now remaining are—*Aquæ Virginia*, repaired by Pope Paul IV.; *Aquæ Felice*, constructed by Pope Sextus V.; the *Aquæ Paulina*, repaired by Pope Paul V. in the year 1611; and that built by Louis XIV. near Maintenon, to convey water from the river Bure to Versailles. This latter is perhaps the largest aqueduct in the world, it being 7,000 fathoms long, is elevated 2,560 fathoms, and contains 242 arcades.

ARABESQUE, or MORESQUE, an Eastern style of ornament, consisting of a fantastic mixture of foliage, flowers, fruits, &c., made use of both in painting and sculpture. Sometimes animal representations are introduced, but such are not strictly allowable.

ARABO-TEDESCO a style of architecture, exhibiting a mixture of the Moorish, or low Grecian, with the German Gothic. Of this style is the Baptistry at Pisa, erected by Dioti Salvi, in 1152. It is a circular building, with an arcade in the second order, composed of pillars with Corinthian capitals and plain round arches; between each arch rises a Gothic pinnacle, and above it is finished by sharp pediments, which are enriched with foliage terminating in a trefoil.

ARÆOPAGUS. *See* AREOPAGUS.

ARÆOSTYLE, or ARÆOSTYLOS. *See* INTERCOLUMNIATION and COLONNADE.

ARÆOSYSTYLE. *See* COLONNADE.

ARBOR, the principal part of a machine, which serves to sustain the rest. Also the axle or spindle on which a machine turns.

ARC (from the Latin *arcus*, a bow) in geometry, a part of any curve line which does not consist of contrary curvatures, for then two or more arcs would be formed, though in contrary directions.

ARC OF A CIRCLE, any part of the circumference less than the whole.

The line joining the extremities of an arc is called its chord.

Arcs are named after the angles which they subtend or are opposite to, and are measured by such angles and the radii of the circles to which they belong;—in other words, arc varies as angle $\times$ radius.

ARCS, *concentric*, are those that have a common centre.

ARCS, *equal*, such as subtend equal angles in equal circles.

ARCS, *similar*, such as subtend equal angles, whether in equal or unequal circles.

ARCADE, a range of apertures with arched heads, supported upon square pillars, or other columns. Arcades are sometimes employed to form porticos instead of colonnades; and though they are not so beautiful, they are stronger, more solid, and less expensive. In such buildings, the utmost care should be taken that the piers be sufficiently strong to resist the pressure of the arches, particularly the piers at the extremities, for they alone support the whole.

The lateral pressure upon the extreme piers in the range, will be equal to that on the piers of a single arch, and all the intermediate piers will be without such lateral pressure; for the lateral pressures of any two adjoining arches upon the intermediate piers are equal, and being opposite they destroy each other's effect: but the extreme pier having only one adjoining arch, must be sufficiently strong to withstand the horizontal thrust of that arch. The greater the weight or vertical pressure put upon the extreme piers, the more will these piers be able to counteract the thrust of the adjoining arch; consequently, if each extreme pier have to support a wall, the higher the wall, the less dimensions the pier requires. It is upon this principle, that the slender pillars, dividing the nave on either side from the aisle, in churches of the Saxon and pointed styles of architecture, are capable of withstanding the horizontal thrust of the groins; for if the insisting wall were taken away, the pillars of most of these buildings would not be able to withstand the thrust of the arches for one minute.

Arcades were employed in triumphal arches, theatres, amphitheatres, and aqueducts of the Romans, and frequently in their temples: towards the decline of the empire, the intercolumns were formed into arcades; but what relates to their history will be found under the article ARCH.

Arcades may be used with propriety in the gates of cities, palaces, gardens, and parks: they are much employed in the piazzas or squares of Italian cities, and, in general, are of great use in affording both shade and shelter in hot and rainy climates; but they are nevertheless a great nuisance to the inhabitants, as they very much darken their apartments.

Lofty arcades may be employed, with great propriety, in the courts of palaces and noblemen's houses. There are various methods of decorating the piers of arcades, as with rustics, columns, pilasters, caryatides, persians, or terms surmounted with appropriate entablatures. Sometimes the piers are so broad as to admit of niches between columns or pilasters. The arch is either surrounded with rustic work, or with an archivolt, sometimes interrupted at the summit by a key-stone in the form of console, or mask, or some other appropriate ornament in sculpture. The archivolt rises sometimes from a plat-band, or impost, placed on the top of the piers, and at others from an entablature, supported by columns on each side of the arch. In some instances, the arches of arcades are supported entirely by single or coupled columns, without the entablature, as in the temple of Faunus, at Rome. This form is far from being agreeable to the eye, and it wants stability, as the columns would be incapable of resisting the lateral pressure of the arches, were they not tied together by a circular wall. In large arches, the key-stone should never be omitted, and should be carried to the soffit of the architrave, where it will be useful for supporting the middle of the entablature, which would otherwise have too great a bearing.

When columns are detached, as in the triumphal arches at Rome, it is necessary to break the entablature, and make its projection in the intercolumns the same as if pilasters had been used instead of columns, or so much as is just sufficient to relieve it from the naked appearance of the wall; this is unavoidable in all intercolumns of great width; but should be practised as little as possible, as it destroys the genuine use of the entablature. Arcades should never be much more, nor much less, than double their breadth: the breadth of the pier should seldom exceed two-thirds, nor be less than one-third of that of the arcade; and the angular pier should have an addition of a third or a half, as the nature of the design may require. The impost should not be more than one-seventh, nor less than a ninth; and the archivolt not more than one-eighth, nor less than a tenth of the breadth of the arch. The breadth of the bottom of the key-stone should be equal to that of the archivolt, and its length not less than one and a half of its bottom breadth, nor more than double. In porticos, the thickness of the piers depends on the width of the portico and the superincumbent building; but with respect to the beauty of the edifice, it should not be less than one-quarter, nor more than a third of the breadth of the arcade. When the arcades form blank recesses, the backs of which are pierced with doors, windows, or niches, the recesses should be at least so deep as to keep the most prominent part of the dressings entirely within their surface.

In the upper stories of the theatres and amphitheatres of the Romans, the arcades stood upon the podiums or inter-pedestals of the columns, perhaps as much for the purpose of proportioning the apertures, as to form a proper parapet for leaning over.

In Gothic Architecture—arcades, whether detached or engaged, are of very frequent occurrence; more especially in the Transition and early English styles. Engaged arcades are very common indeed, and may be found frequently running round the interior walls of a building, as at Westminster Abbey, the Chapter-House, Canterbury, and in innumerable other instances; in the conventual buildings at Canterbury is a very fine specimen of a detached arcade. The engaged form came into very extensive use with the intersection of the semicircular arch, and was employed in almost every situation both on the interior and exterior of buildings, as well as in the decoration of their furniture, such as fonts, &c. The arcade indeed was a very prominent, if not the principal feature in all Gothic architecture, and is that which adds so greatly to the solemn grandeur of our noble cathedrals.

This term is also applied to any arched covered way, more particularly to the close passages recently introduced, such as the Burlington and Lowther arcades, which are used as promenades, as well as for purposes of trade.

ARC-BOUTANTS, (from the French, *arc*, an arch, and *bouter*, to abut.) *See* Buttress.

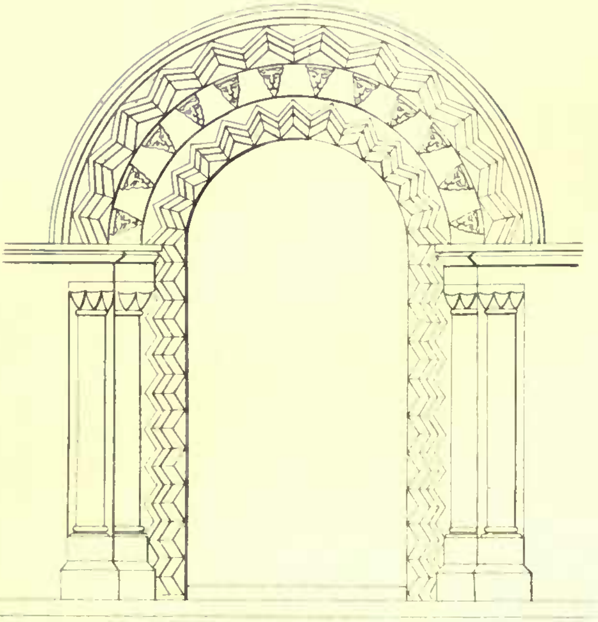
ARCH. A structure composed of separate inelastic bodies, arranged in such a manner that their lower surface shall form the arc of a curve, being supported at its two extremities.

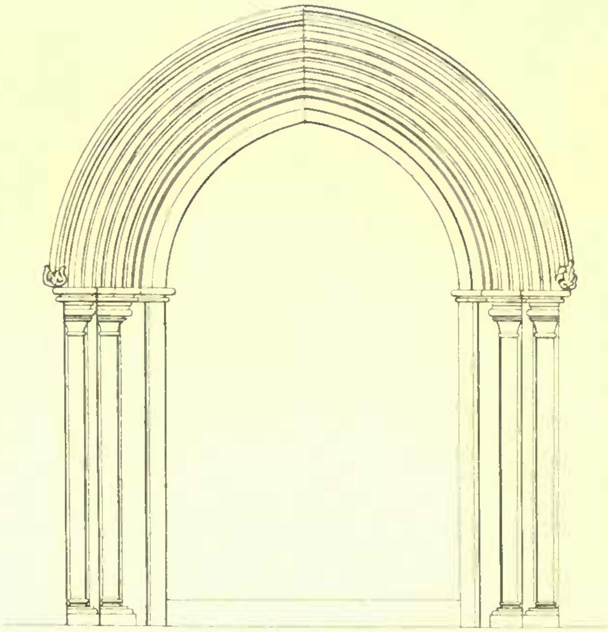
History. The invention of the arch has been assigned by different writers respectively to Babylonians, Egyptians, Greeks, Romans, and Etrurians.

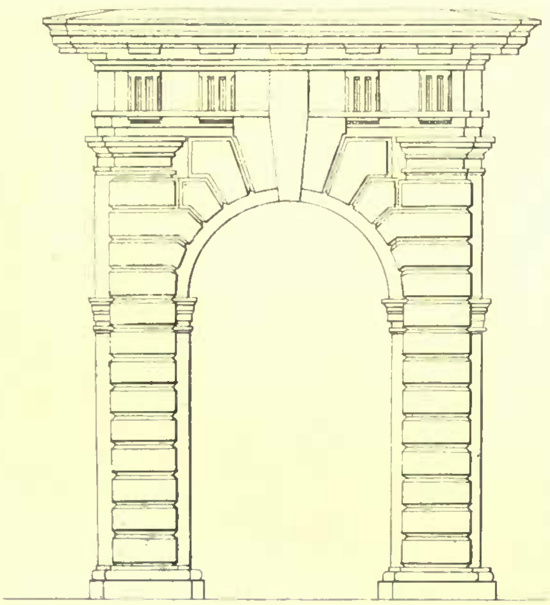
The claim made for the Babylonians rests principally on a passage found in Strabo, wherein he states, that the Hanging-Gardens were formed by means of arches: a passage of Herodotus is also quoted, as favouring the supposition. This historian, speaking of the great gates in the city-wall, relates, that Nitocris was buried in a chamber above one of them, and it is urged by the supporters of this opinion, that so heavy a superstructure could not have been supported over an aperture of such dimensions by mere beams, or indeed by any other contrivance than that of the arch. On the other side it is argued, that Nitocris would have made use of the arch in the erection of her bridge, had the principles of its construction been understood, instead of the awkward application of horizontal timber beams; and with respect to the gateways, it is stated, that Herodotus, in this instance, speaks of jambs and lintels, and makes not the slightest mention of an arch. Besides, it is argued, if the arch was used to any extent, we should certainly find some vestiges of it in the ruins of that city, whereas the concurrent testimony of all travellers goes to prove that none such exist, while lintelling has been found in several instances, where the arch might have been applied with advantage.

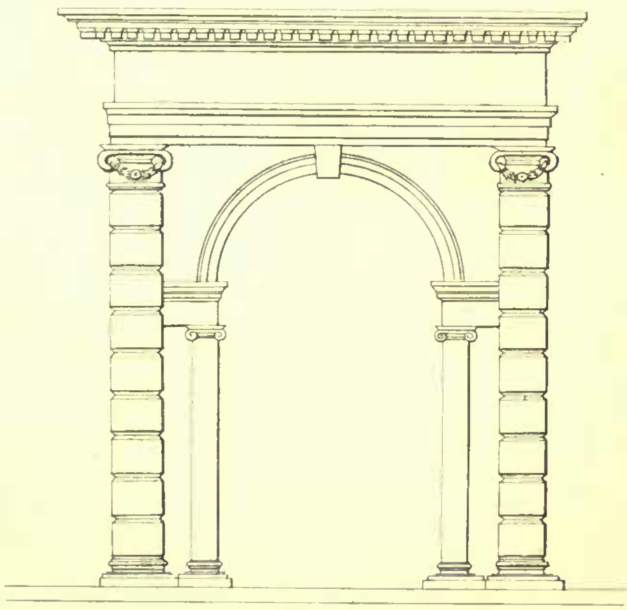
In favour of the Egyptian title to this distinction, we are referred to specimens of arched work still to be found in the remains of Egyptian temples. The first specimen produced is from Abydos, where the roof is certainly of an arched form, but on inspection proves to be constructed of three horizontal stones; the centre one, which is the largest, overlapping the two side-ones. The under surface of these stones is cut out in such a manner as to form a semicircular arch. The other specimens adduced, are without doubt true arches, and if their antiquity be allowed, the question is at once set at rest. These arches are found at Thebes, and are formed of four courses of bricks arranged in a semicircle. If the fact of their antiquity, however, be admitted, it is difficult to understand why the arch should not have been more generally employed.

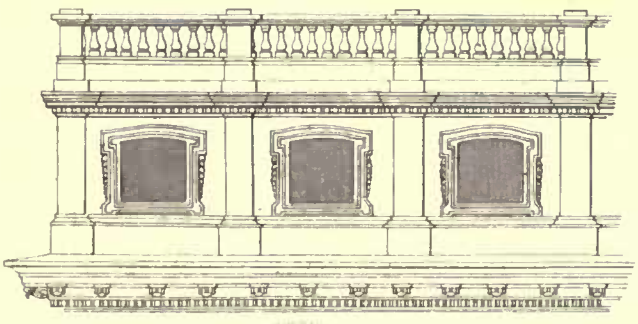
The same reasoning may be applied in the case of the Greeks, for, although it is said that true arches are found in their works, yet it seems probable that they were not in use previous to the second or third century before the Christian era, as, if so, we should naturally expect to find them employed in many cases where they would have proved











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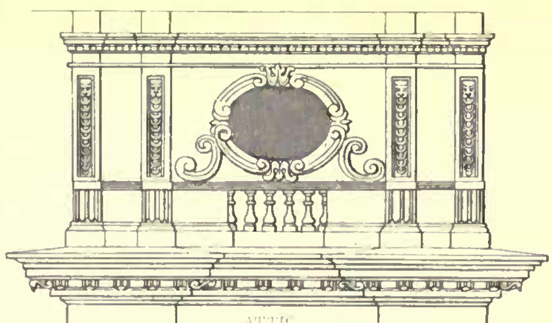

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most useful. The general arrangement of their buildings would scarcely have been such as it is, if they had been acquainted with the principles of the art.

The first example of any arched construction to be found among the Romans, is that of the cloaca maxima, or public sewer, said to have been built by Tarquin. The identity of the existing remains with the original structure has been doubted, but in fact this is of no great importance, as there is no scarcity of examples of this kind, although of somewhat later date than the reign of Tarquin. There are some who assign the merit of the introduction of the arch among the Romans to the Etrusci, and who are not entirely without reasons for this assumption. They say that Tarquin brought this knowledge with him from Etruria, his native country, and that Etrurians were employed by him in the construction of the sewer; others, however, refer the actual construction to Greeks. It is possible indeed that the Etrurians may have introduced this form of building, as it is well known that that people had arrived at some excellence in the arts at an early period, and also were in close communication with the Romans; be this, however, as it may, there can be no doubt that we are principally indebted to the latter people for the full development of the power and utility of the arch; whoever it may have been who first became acquainted with the principles, whether Egyptians, Greeks, Romans, or Etrurians, there never was any doubt as to the people who carried its knowledge into execution. As far as the Greeks or their predecessors are concerned, we might have remained in utter ignorance as to the utility of this style of building. It is to the Romans we owe our practical knowledge on the subject; they it was who made a worthy application of their knowledge, and put their theories into extensive execution; and although they employed this form to a greater extent than perhaps good taste might sanction; yet this we judge to be the natural procedure of any people upon first becoming acquainted with a principle of so peculiar a character and such unlimited usefulness.

Although the Romans employed arches in the construction of their edifices, to a very great extent, yet they always confined them to one form, namely the semicircular. It is to the architects of the middle ages we are indebted for the great variety of figure employed in this kind of construction; among others we may especially notice the pointed arch,—but for further information on this subject, we beg to refer the reader to that particular style of architecture.

Of the forms, &c. of arches. Arches are named according to the curve assumed by them, as circular, elliptical, cycloidal, parabolical, hyperbolical, catenarian, &c.: circular arches are again subdivided according to the quantity of the circumference described by them, such as semicircular, segmental or surbased, containing less than the semicircumference, surmounted, horse-shoe or Moorish, containing more than the semicircumference. Arches are also denominated according to the method adopted in describing the curve, as two, three, or four-centred arches; also by the nature of the angle formed at the apex, thus, pointed arches are distinguished by the appellation of lancet, equilateral, and depressed. Further, there are arches of equilibration and of discharge; askew and reversed arches.

The separate masses or stones, of which the arch is composed, are called *voussoirs* or *arch stones*, the central or uppermost of which is called the key-stone, the lowermost, or those nearest the supports, *springers*. The highest point in an arch is termed the *vertex*, or *crown*, the lowest line the *springing line*, and the spaces between the crown and springing line on either side, the *haunches*, or *flanks*. The under or concave surface is denominated the *intrados*, the upper or convex the *extrados*. The supports of an arch are called *piers*, *abutments*, *springing walls* or *reins*. Piers are distinguished from abutments, the former term being applied to a support to resist a vertical pressure, the latter an horizontal thrust. The upper parts of the supports on which the arch rests, or from which it is said to *spring*, are named *imposts*. The *span* of an arch is the width between the points, where the intrados meets the imposts on either side, which in the case of circular arches coincides with the chord of the arc: the *rise* is the height of the highest point in the intrados above the *springing* or *spanning-line*.

Arches which have the curves of both intrados and extrados concentric or parallel, are said to be *extradossed;* and such as rise from supports at unequal heights, are called *rampant arches*. There are other kinds of arches, but these are more applicable to VAULTING, under which head they will be treated of.

In order to avoid farther extending this article, we must refer the reader for the THEORY of the ARCH, to STONE BRIDGE.

ARCH, TRIUMPHAL; an edifice erected by the Romans in various situations, but more especially at the entrances of their cities, in honour of victorious generals, and in later times of the emperors. These structures were originally built of brick, but afterwards of stone, or marble; their form was that of a parallelopipedon, having one, and often three, arched apertures in the longer side, decorated with columns, sculpture, and other embellishments; the whole being surmounted with a heavy attic. When three arches were employed, they were situate so as to have one large one in the centre with a smaller one on each side of it.

Under the emperors, triumphal arches became very numerous, and were made of costly materials richly ornamented. The oldest of such structures remaining in Rome is that of Titus, enriched with sculptures representing the triumph of that emperor. Two other arches erected in honour of Trajan are still in existence, the one at Ancona, the other at Benevento; the former is of white marble of chaste ornamentation, consisting in part of bronze statues; the latter has several fine relievos, and is in a state of good preservation. The above are single-arched; several, however, were constructed of three arches, amongst the most remarkable of which are those of Constantine and Septimius Severus; that of Constantine has been cleared of the soil which had accumulated to some height round its base, and is perhaps the most beautiful and complete of any at Rome, but manifests some discrepancies of parts, as it was built partially of old materials from an earlier monument of Trajan; that of Severus is a noble structure, but is much more dilapidated; it is sixty-one feet in height, seventy-one in length, and twenty-two in depth, the central archway is twenty-two feet wide, and thirty-six high, the side ones ten feet wide, and twenty-two feet high.

But few structures of this kind have been erected by the moderns; amongst them, however, we may notice one triple arch of Bonaparte on the Place du Carrousel, and a much finer one at Milan.

ARCHEION, the treasury, and most secret and retired place in Grecian temples, where not only the richest treasures appertaining to the deities were deposited, but also other valuable articles, which they were desirous of keeping secure. The practice of the Romans was very similar to that of the Greeks, but they confined the deposition of their public treasure to the temple of Saturn.

ARCHITECT, (Greek *αρχος τεκτων*, *the chief fabricator.*) In considering the correct application of this word, we shall not confine ourselves to any one period of time, as the word has been variously applied under different circumstances. We find the word ἀρχιτέκτων employed by Herodotus, and also by Homer, in their respective works, who seem to have given to it a very extensive signification. In one and the same passage, (iii. 60,) Herodotus uses the term in two different senses, for he speaks of the "architect" of a tunnel for supplying water, as well as of the "architect" of the great temple of Samos. Homer uses the same term to signify a carpenter, a house-builder, and also a ship-builder. It seems probable, then, that in these early ages, the word "architect" was not restricted to any one signification, but was applied as circumstances required. In succeeding ages, however, when the more perfect civilization of mankind required structures not only more numerous and more elegant, but also in greater variety, and suited to multifarious uses, it was found inconvenient, if not utterly impracticable, for any single individual to qualify himself to superintend the construction of so great a variety of buildings. Thus resulted a division of labour: the duties of the "architect" were alleviated by allotting to several the task originally undertaken by one. Thus arose the distinct duties of architect and engineer, which are again subject to several subdivisions, distinct departments of one grand and comprehensive whole.

ARCHITECTOGRAPHIA, the description of ancient buildings, as temples, theatres, amphitheatres, triumphal arches, baths, pyramids, tombs, mausoleums, aqueducts, &c.

ARCHITECTURE, the art of building. Did we apply to this word the signification derivable from the original Greek, we should have before us a very extensive field for investigation. Custom, however, has limited the application of the term to the science of erecting artificial structures.

The origin of this department of science is involved in impenetrable obscurity. It is reasonable to expect that man, a being of acute feelings, should soon have sought out some method of protecting himself against the inconveniences to which his physical conformation rendered him obnoxious. Exposed to the vicissitudes of the weather and the variations of temperature, he must, at a very early period, have discovered some means of shelter and security; the method, however, which he adopted for effecting this object is left entirely to conjecture. Various speculative opinions have been hazarded on the subject, remarkable for the most part not more for the inventive imaginations of their authors, than for the crudeness and absurdity of the speculations themselves. Vitruvius, the first writer on the subject, has given a very elaborate, if not very correct account of the contrivances of our primeval ancestors in the way of house-building; this account, strange to say, has been transmitted as an authority from time to time almost down to our own age, gathering in its progress additional strength from the names of those who have given credence to its manifold absurdities.

In considering the subject, we must not forget that mankind originally inhabited a warm climate, where the inclemency of the weather was comparatively but little felt, and where consequently there was no need of such defences as in a colder region. The chief inconvenience arose probably from the extreme heat, a natural retreat from which was found in the shelter afforded by the luxuriant foliage of the trees. We might reasonably suppose that, as there was no necessity for a very substantial edifice, tents formed of the skins of beasts offered in sacrifice, or of other convenient substance, would have formed the primitive dwellings of mankind; this, however, there is some reason to suppose, was not the case, as we read that Jabal was the father of such as dwelt in tents, whereas Cain had built a city sometime before Jabal's birth. What this city was, we have no means of judging; of its materials and its form we are alike ignorant. The next mention made of a city in the sacred writings is that of Babylon, which was built by Nimrod; here it was that the famous tower of Babel was commenced, in the building of which, it is stated, burnt bricks and slime (bitumen) were made use of. The same Nimrod is related to have built Nineveh and three other cities. Whether the above were the first cities that were built after the flood is left doubtful, for we find no mention in the sacred history of any Egyptian cities, yet doubtless such must have existed at a very early period; we cannot, therefore, say for certain whether the sons of Cush or Mizraim took the precedence in such works; nor can we tell whether the buildings seen by Herodotus and other pagan historians were in any part the same as those whose erection is mentioned by Moses. These, as well as all other subjects connected with the early ages of mankind, must ever remain matters of mere conjecture; yet with respect to the latter question, it does appear somewhat worthy of attention, that Herodotus relates having visited, situate in the midst of Babylon, a tower of vast dimensions and unusual height; the coincidence of the two accounts is, to say the least, remarkable. If we allow the towers spoken of by the two historians to be identical, and also that the separation of mankind did not take place, at least to any extent, before the confusion of languages, we shall have no difficulty in accounting for the remarkable affinity of the Persian, Hindoo, and Egyptian architecture, especially with reference to the pyramidal form of their structures: we shall also be enabled to form some notion of the progress of mankind in this art, as well as of the nature and method of building at the period.

We have hitherto been considering the first rise and progress of architecture in the earliest ages of the world; we must bear in mind, however, that some people in later ages have, by some means or other, lost all traces of the civilization of their ancestors. This fact may appear strange, but it is not our part to account for it in this place; the fact is before us, startling perhaps, but undeniable notwithstanding. We intend here briefly to consider, how those people, after having lost all their previous knowledge of architectural science, set about to regain it. And here we might introduce the theory of Vitruvius, but not, as he does, in the shape of a general fixed rule; for although it may be true, even in the majority of cases, that the first rude attempts in the erection of dwellings have been, as he states, of a conical form, yet this was by no means universally the case. The fact is, the method of building so much depended upon the character of the people, the nature of the locality inhabited by them, as well as that of its productions, upon the materials and resources for building, and lastly, upon the examples which nature more prominently set before them; that it is utterly impossible to lay down any rule as that by which mankind have been universally governed in the erection of their first structures.

Although Architecture had its rise doubtless in the construction of buildings for the purposes of shelter and defence, yet it is no less certain that it is indebted for its rapid advancement, and its ultimate perfection, to the religious feelings of mankind. It is in the temples we look for beauty of design, for appropriateness of embellishment, for grandeur, ideality, and magnificence. Had it not been for religion, architecture would never have risen to that eminence which it so early attained in the sacred edifices of the ancients; and which have attracted such universal admiration. It is to temples, then, we must look for the progress of a people in this great art; by them must we compare nations as to their advancement in skill, taste, and science, as well as in the general progress of civilization.

Having thus far considered the origin of Architecture as a science, we shall now give a very concise sketch of its progress in different countries.

Our very first steps in entering upon the history of Architecture are greatly impeded for want of trustworthy information on the subject. We are left in the dark as to what style may justly claim precedence in point of time. Following the account of the creation and civilization of mankind, as given by Moses, we should naturally enough look towards the East for the first origin of this, as of all other arts, and this supposition is confirmed as well by the concurrent testimony of history, as by the investigation of the remains of Eastern edifices. But although we may, without hesitation, yield the priority to the ancient Eastern edifices as a whole, we still meet with difficulties in assigning its proper position to each separate style. We should prefer to place the Babylonish or Persian architecture first on the list, as well for the reason previously assigned, as that, as far as we are enabled to judge from the specimens that remain to us in the ruins of Babylon, the buildings of this style appear to be of ruder construction than those either of India or Egypt. For this latter cause, we should give to Egypt the next place, as we find the sculptures of India of more rounded form, and more elaborate workmanship than the Egyptian.

In endeavouring to give to each style its relative chronological position, we do not mean to deny that they were equally indebted to each other for various improvements at different periods. We would especially instance the case of Persepolis, the principal specimen of Persian architecture remaining to us: here we find truly a great advance upon the architecture of Babylon, and we can have no doubt respecting the introduction of some peculiarities of the Egyptian style. Whatever doubts, however, there may remain concerning the relations of the above styles, separately, in respect of age, there can be none as to their general resemblance and affinity, or as to their position, taken as a whole, in the chronology of Architecture.

Next in the order of age comes Grecian Architecture. Here again Vitruvius has given us some very fanciful suggestions respecting the prototype of the entire edifice, as well as the origin of its varied details; nothing, however, can be more absurd than his notions respecting the latter; and as to the former, he gives the Greeks credit for inventive genius, which certainly cannot lawfully be claimed for them. We may, with equally the same justice, yield to them their boasted title of *αυτοχθενες*, as their claims to originality in their style of building. Obscure as are the traditions respecting the colonization of Greece, we have ample evidence to show that it was indebted to Egypt, Phœnicia, and other parts of the East, for the majority of its inhabitants; add to this the similarity existing between the earlier styles of Grecian architecture, and those of Egypt and Persepolis, and there can, we think, remain no hesitation in assigning to the latter the origin of Grecian art. While, however, we refuse the claims of Greece to originality, we cannot forget how much we are indebted to her for the introduction of so many and valuable improvements. In her hands this department of art arrived at its greatest excellence, insomuch as to form a new era which for purity and chaste grandeur has never been surpassed.

The great distinction between the last mentioned and the Roman style is in the employment of the arch. The use of the arch gave the Romans great advantage over all previous nations, and permitted of great variety in the construction of their buildings. This people aimed rather at utility than ornament; and although many of their buildings are well worthy of admiration on account of their appropriateness to the purposes for which they were intended, and even of some degree of beauty, yet they may not be compared with the purity and grandeur of Grecian taste. The Greeks were lovers of art for its own sake, the Romans for the sake of the benefits it afforded them. We must not, however, consider the Romans as devoid of taste or original conception, for they may claim the Corinthian order almost entirely as their own, and this says not a little for their appreciation of the beautiful. They had this advantage also over the Greeks, that whereas the latter were confined to one plan, the parallelogrammic, which gave their structures a monotonous appearance, they, on the contrary, could vary the form in any way they deemed suitable; and this introduced the practice of grouping, or composition, as it is called. The introduction of another practice we owe to the Romans, namely, that of internal decoration. Thus, while the Greeks may claim the palm for purity of taste, the Romans take precedence in utility and variety of construction.

Having thus considered the history of our subject from its earliest commencement to the perfect development of the great principles of construction, we deem it advisable to postpone the consideration of the later styles to their respective heads. We have now arrived at the grand model of all future eras, and to which all modern styles owe their origin. The Romans, owing to their wide-spread dominion, have introduced their knowledge of the arts throughout almost the entire world, and so their architecture has been the grand prototype of all succeeding ages. For although the variation of different styles from each other, and also from their common pattern, be considerable, yet there can be no doubt as to the source from whence they all had their origin. It is true that, at first sight, the elaborate edifices of the style known under the name of Perpendicular, seem to have but little affinity to the heavy Norman structure; and yet when the intermediate links are added to the chain by which they are connected, few persons will be found to question their immediate relation; and certainly the step between the Norman and late Roman requires but little explanation. Considering, therefore, the Roman as the foundation upon which medieval, as well as modern architecture was erected, we leave each style to be considered under its separate title.

It is our intention to enter into a more minute investigation of this subject under the following heads:—Babylonian Architecture, Byzantine, Celtic, Chinese, Egyptian, English, Etruscan, Gothic, Greek, Hindoo, Italian, Mexican, Moorish, Norman, Pelasgian, Persian, Pointed, and Roman.

ARCHITRAVE, (from *αρχος*, *chief*, and *trabs*, *a beam*,) that division of the entablature which rests upon the columns, and which may perhaps represent the linteling beam placed over the columns, and over the intercolumns, for supporting the cross beams, in the roof of the primitive wooden structure.

In the remains of ancient Grecian structures, the architrave is of very great height, being nearly equal to the superior diameter of the column, and in some instances even more, as in the Doric temples of Theseus at Athens, Corinth, near the ancient city of that name, Pæstum in Italy, and in the Ionic temple on the river Ilissus at Athens; but there are few or no instances where it is so high as to be equal to the inferior diameter. Examples in which the lowest architraves are to be found are the portico of Philip, king of Macedon, and the Doric portico at Athens; the altitude of the former being only thirty-eight minutes, and that of the latter forty-five minutes, or two-thirds of the bottom diameter. In the remains of Roman buildings, the architraves are low, being in most cases between two-thirds and three-fourths of a diameter. The lowest architrave in these remains is that of the theatre of Marcellus at Rome, which is only half a diameter. This proportion has been generally followed in the Doric order by the modern restorers of ancient architecture. What relates particularly to the forms and parts of the architrave of each particular order will be seen under the heads of TUSCAN, DORIC, IONIC, CORINTHIAN, and ROMAN ORDERS.

The soffits of the architraves of Grecian buildings are always found to exceed the upper diameter of the columns; but in the Roman they are equal.

In the Saxon and early Norman styles of architecture, arches rise from the capitals of the pillars, instead of being linteled by the architrave as in the Egyptian, Grecian, and Roman buildings: this is one of the most striking differences between ancient architecture and the styles afterwards practised in the middle ages.

ARCHITRAVE OF A DOOR, a collection of members surrounding the aperture, of a section similar to the architraves of the Ionic, Corinthian, and Roman orders. The head or lintel is called the *traverse*, and the sides the *jambs*. Vitruvius calls the jambs *antepagmenta*, and the head or traverse *supercilium*. In the remains of the edifices at Balbec and Palmyra, and in the palace of Diocletian at Spalatro, the architrave jambs are often flanked with consoles, which gives an apparent support to the cornice, and the cornice frequently rests upon the traverse, without the intervention of the frieze; but the flank pilasters under the consoles are scarcely to be met with among ancient ruins, though practised by the modern Italians, and represented in their works. This is however an improvement, as it diminishes the apparent weight of the top, by spreading out the lower part. The proportion of the architrave to the aperture, in ancient edifices, varies greatly: the usual proportions given by the moderns is from one-seventh, to one-sixth part of the opening. When the architrave jambs are flanked with pilasters and consoles, the breadth may be one-seventh of that of the aperture, and the breadth of the pilasters two-thirds of that of the architrave; but when it is unaccompanied with these ornaments, it ought not to be less than a sixth part of the breadth of the aperture.

In the ruins of Roman and Grecian buildings the architrave rests upon the floor, and has no flanking consoles; but in the ruins of Balbec they are supported by plinths.

When there is too much surface of naked wall on each side of the architrave jambs, the sides of the architrave may be flanked with pilasters and consoles, in order to reduce the naked, and proportion it to the dressings of the front. The dressing of an aperture may be heightened by adding a cornice, or a cornice and frieze, as the space above will admit; and if the space above requires further diminution, the altitude of the dressing may be still further increased, by surmounting the cornice with a pediment. When the material of the architrave is stone, the jambs are either built in heights corresponding to the courses of the naked of the wall, or if stones can be procured, each jamb is made of one entire piece, or sometimes in two or three, according to the difficulty of raising them from the quarry.

When they are coursed with the work, every alternate stone should be a bond-stone, and, if the jambs are in one height, or not coursed, every alternate stone in the altitude of the naked, adjoining each architrave jamb, should be a bond-stone: the fewer pieces the architrave jamb consists of, the more beautiful will the work appear, therefore one is preferable to several.

In the arched apertures of ancient buildings, the jambs are seldom or never moulded as an architrave, but the arch is frequently ornamented with members of an architrave section; these members are called the archivolt, which always rests upon imposts. The imposts project in most cases from the naked of the wall, and in a few cases form the capital of pilasters upon the jambs.

ARCHITRAVE, in joinery, is one constructed of wood. Architraves may be wrought out of a solid piece of wood; this, however, would be attended with a waste of both stuff and time. The best method is to glue it up in two or more longitudinal pieces, as may be judged proper from the combination of its parts. For a full description of this method, see JOINERY.

ARCHITRAVE CORNICE, is an entablature which consists of an architrave crowned with a cornice, without the intervention of the frieze. There are few ancient examples where an architrave cornice is supported by columns or pilasters: the only ones which we can recollect are, that on the inside of the portico of the Pantheon, and the entablature of the third order of the Colosseum at Rome (if it may be so called) and that supported by the caryatides of the temple of Pandrosus at Athens: the imposts of the arch of Septimius Severus are also formed like an architrave cornice. The remains of antiquity exhibit many instances where the dressings of rectangular apertures are finished with architrave cornices, as in the temples of Erechtheus at Athens, Vesta at Rome, and in other ruins exhibited in Adam's *Spalatra*, and in Wood's *Balbec and Palmyra*.

ARCHITRAVE JAMBS. *See* ARCHITRAVE OF A DOOR.

ARCHIVAULT. *See* ARCHIVOLT.

ARCHIVE, an apartment wherein the records or charters of a state or community are preserved, in order to be consulted occasionally.

The word comes from the Greek *αρχαιον*, which signifies that part of their temples in which the public treasury was deposited. Colleges and monasteries had all their archives; but that of the Romans was restricted to the temple of Saturn in particular.

ARCHIVOLT, a collection of members on the face of an arch, adjacent to, and concentric with the intrados, supported upon the imposts. The word is derived from the French *archivolte*, which signifies the same thing as *arcus volutus*.

The archivolts in Roman and Grecian edifices are formed upon the face of the arch with their section perpendicular to the curve of the intrados and the wall, and similar in figure to that wrought on the face of an architrave; the intrados being, in most cases, the surface of a cylinder, and, in some few cases, that of a cone. In the latter ages of the Roman empire, arches with archivolts were substituted instead of the horizontal entablature, by supporting the arches upon the capitals of columns as imposts. This innovation gave birth to that style of building most commonly known by the name of Gothic, and forms one of the most characteristic features of this style of building. The archivolts of Saxon edifices were at first very similar to those of the Romans, but in process of time, the pillars became clustered with small columns, and each shaft of the clustered pillar had its separate capital; therefore, in order to make the bottom extremities of the arch bear equally on the tops of the pillars, it became necessary to form the archivolt in deep recession from the soffit, rather in a conical than a cylindrical surface. The archivolt was separated into several similar divisions, each one consisting of a collection of mouldings, with deep sinkings between.

ARCS DOUBLEUX, the soffits of arches.

AREA, in architecture, is the surface of the ground of a court, or the bottom of the part of an excavation sunk below the general surface of the ground, before the basement story of a building, and level with its floor.

Area, in geometry, is the quantity of surface on a body, or the superficial extent of any figure.

ARENA, the plain space in the middle of the Roman amphitheatre, where the gladiators fought: the same term was also used by the Romans to denote the amphitheatre itself. This term is further applied to the body of a temple, including the whole space between the antæ and extreme wall.

ARENATUM, a word used by Vitruvius to signify a kind of plaster: mortar made up of lime and sand.

AREOPAGUS, a place near Athens, where the Athenians held their court of justice.

ARONADE, *Embattled*, a conjunction of several lines, forming indentations like the boundary of an embattled wall, except that the middle of every raised part is terminated by the convex arch of a circle, which arch does not extend to the length of that part.

ARRIS, the intersection, or line, on which two surfaces of a body forming an exterior angle meet each other. This term is much used by all workmen concerned in building, as the arris of a stone, of a piece of wood, or of any other material. Though the edge of a body conveys the same meaning in general language as arris, yet, in building, the word *edge* is restrained to those two surfaces of a rectangular parallelopipedal body, on which the length and thickness may be measured, as in boards, planks, doors, shutters, and other framed joinery.

Arris Fillet, a slight piece of timber of a triangular section, used in raising the slates against chimney shafts, or against a wall that cuts obliquely across the roof, and in forming gutters at the upper ends and sides of those kinds of skylights that have their plane coinciding with that of the roof.

When the arris fillet is used in raising the slates at the eaves of a building, it is then called the eaves-board, eaves-lath, or eaves-catch.

Arris Gutter. *See* Guttering.

ARSENAL, a public store-house for depositing arms or warlike ammunition.

ASAROTUM, a kind of painted pavement, used by the Romans before the invention of Mosaic work. The most celebrated was that painted by Sesus at Pergamus, which exhibited the appearance of crumbs, as if the floor had not been swept after dinner.

ASHLAR, among builders, signifies common or free-stones, as they come from the quarry, of various sizes.

Ashlar, the facing of squared stones on the front of a building. When the work is smoothed or rubbed, so as to take out the marks of the tools by which the stones were cut, it is called *plane ashlar. Tooled ashlar* is understood to be that, the surface of which is wrought in a regular manner like parallel flutes, and placed perpendicularly in the building; but when the surfaces of the stones are cut with a broad tool, without care or regularity, the work is said to be *random-tooled:* when wrought with a narrow tool, it is said to be *chiselled*, or *boasted:* and when the surfaces of the stones are cut with very narrow tools, the ashlar is said to be *pointed.* When the stones project from the joints, the ashlar is said to be *rusticated:* in this kind, the faces may either have a smooth or broken surface. Neither pointed, chiselled, nor random-tooled ashlar are employed in good work: in some parts of the country, herring-bone ashlar, and herring-bone random-tooled ashlar are used.

ASHLARING, is the act of setting an ashlar facing.

ASHLERING, in carpentry, is the fixing of short upright quarterings between the rafters and the floor in garrets, in order to make more convenient rooms by cutting off the acute angles at the bottom. The triangular spaces on the sides are either left unoccupied, or formed into cupboards or closets.

ASIMINTHOS, a large vessel used by the Greeks for bathing in.

ASPHALTUM, a kind of bituminous substance, found sometimes in a solid, sometimes in a soft or liquid state, in various parts of the world. A species of it discovered in Neufchatel, has been used with great success, as a cement for walls and pavements; it is very durable in air, and impenetrable by water. Of late years, various combinations of Asphaltum with other materials have been employed under the name of Asphalte, or Asphaltic Cement, for covering roofs, floors, &c., and for other useful purposes. The best of these "Asphaltes" is that known as "*Claridge's Asphalte of Seyssel*," which has a deserved reputation as an excellent pavement, and valuable material for the different purposes above named.

ASSEMBLAGE, the joining or uniting of several things together, or the things themselves so united. Carpenters and joiners have various kinds of assemblages, as by mortise and tenon, dove-tailing, &c.

Assemblage of the Orders, the placing of the columns upon one another in the several ranges, so that their axis shall be in the same straight line.

ASSERS, in ancient carpentry, were the laths which supported the tiles of the roof: from the projecting ends of these the denticulated cornice is supposed to have originated: they were not disposed horizontally, but according to the inclination of the roof; and hence Vitruvius forbids the use of dentils in pediments.

Assers were also the ribs of brackets of an arched ceiling.

ASTRAGAL, (from *αςραγαλος*, the *heel-bone*,) a moulding of a semicircular section, projecting from a vertical diameter. It is remarkable that Vitruvius does not mention any astragal between the shaft and the hypotrachelion of the Doric and Tuscan columns, as is to be found in the Doric of the theatre of Marcellus, at Rome; so that it is probable, the hypotrachelion might be formed without any mouldings whatever, by making it recede in a small degree within the shaft, or by fluting it, as in the column of Trajan. This doctrine is also very conformable to all the Grecian examples of the Doric order; for the hypotrachelion is separated from the shaft by one, two, or three annular channels, without any projecting moulding, and the flutes are continued upwards through the hypotrachelion, to meet the under side of the annulets. In the Ionic order of the temple of Erechtheus, at Athens, the hypotrachelion is however separated from the shaft by an astragal; and in the temple of Minerva Polias, at the same place, they are separated by a plain fillet.

In all the other numerous Grecian examples of this order there is no hypotrachelion: the astragal is placed immediately below the echinus. The same is to be found in the few remaining Roman examples of this order. In the Corinthian and Composite orders, the astragal is never omitted between the under row of leaves and the shaft, except in the Corinthian of the monument of Lysicrates, at Athens, which is one of the oldest examples of this order; where, instead of the astragal, there is an annular groove, from which, and from the beauty and delicacy of this example, it seems probable that the astragal might be originally formed of a metal ring.

The astragal is a moulding of very frequent application, not only at the upper ends of the shafts of columns, but also in their bases and entablatures. It is the simplest of all mouldings, and the only one which can stand alone by itself, and project from a plane surface without the aid of a fillet or straight part.

The Greeks and Romans frequently cut their astragals into beads, formed alternately of oblate and prolate spheroids, or, instead of prolate spheroids, figures consisting of double cones, with cylindrical parts between, are introduced: this practice is followed by the moderns with various innovations.

In the Egyptian architecture, we meet frequently with clusters of astragals, circumscribing the shafts of the columns; in various places dividing them into several compartments, of which some of them are frequently receded vertically with astragals. The capitals often join upon the tops of the shafts, without any horizontal moulding between them.

The astragal and torus are exactly similar figures: the only distinction is, that when they are compared with the other, in the same piece of work, the torus is large, and the astragal small, perhaps not exceeding one-third part of the diameter of the torus; but in most cases any proportion less, so that it may be sufficiently distinct.

ASULÆ, marble chips.

ASYMPTOTE, a straight line, which continually approaches to a curve without meeting it.

ATHENEUM, or Athenæum, the name applied in ancient times to public buildings erected for rehearsals and lectures. In modern times, the title of Athenæum has been frequently given to establishments connected with literature and art, public reading-rooms, &c.; a celebrated club-house in London is called the Athenæum.

ATLANTES, Atlantides, or Atlas, the name given by the Greeks to the figures or statues of men used to support entablatures with mutules instead of pilasters or columns. They were also called Zelamones and Persians.

In the architecture of the modern Italians, the Atlantes are often found supporting the entablature over an entrance to a palace or garden. At Milan there is a colossal example of the former; and the rustic gate to the Farnese Gardens at Rome is a specimen of the latter.

ATRIUM, a court or hall in the interior of the Roman noblemen's houses, of an oblong plan. Three sides of the atrium were supported on columns, the materials of which, in later times, were marble. The side opposite to the gate was called *tablinum*, and the other two sides *alæ*. The tablinum was filled with books, and the records of what any one had done in his magistracy. It was in the atrium where the nuptial couch was erected, where anciently the family used to sup, where the mistress and maid-servants wrought at spinning and weaving, and where the clients used to wait on their patrons. The atrium was adorned with pictures, with statues of their ancestors, and with plate; and was usually the most splendid and important part of a Roman house.

In later times, the atrium seems to have been divided into different parts, separated from one another by hangings, into which persons were admitted, according to their different degrees of favour. The atrium was frequently in ancient times confounded with *vestibulum*, which was only a recess on the exterior side of the building, and what is now called by the Italians *loggia*.

Even Vitruvius, in chap. iii., book vi., confounds it with *cavædium*, which was an enclosure still further within the interior. This author assigns three different proportions to the length and breadth of the atrium: the first is 5 to 3, the second 3 to 2, and the third is the ratio which the diagonal of a square has to its side. Their height to the under side of the ceiling is equal to their length, wanting a fourth part. The difference between the atrium of a city and country residence was this, that in the former it was placed near the entrance, and in the latter, the peristylium was placed between the atrium and the gate.

The Greeks had no atrium in their houses. In some temples an atrium was to be found.

Atrium, in ecclesiastical antiquity, a large open court before a church, making part of what was called the *narthex*, or *ante-temple*; it was surrounded with a cloister or portico. In this apartment the penitents stood to beg the prayers of the faithful, as they went into the church; and here those remained who were not suffered to go further into the church.

ATTIC, is a part of a building standing on the cornice, similar in form to that of a pedestal, and is either broken or continued. It is so named from its being supposed to have been first used in Attica. The use of an attic is to conceal the roof, and give greater dignity to the design. The Romans employed attics in their edifices, as may be seen in the remains of the triumphal arches, and in the forum of Nerva. In the arch of Constantine, pedestals are raised over the columns as high as the base of the attic, and these pedestals are again surmounted with insulated statues. In the ruins of Athens there are no attics to be found; except one over a Corinthian colonnade at Thessalonica, with breaks forming dwarf pilasters over the columns, and with statues placed in front of the pilasters, as in the arch of Constantine. The attic carried round the two courts of the great temple of Balbec, is also broken into dwarf pilasters over the columns and pilasters of the order; and the dwarf pilasters have blocking courses over them, on which statues are supposed to have been placed. Attics are very disproportional in the ruins of these ancient edifices, some of them being nearly one half of the height of the order. The moderns make their height equal to that of the entablature: as to the proportion of the height of the members, it may be the same as that for pedestals.

The pilasters employed in attics are sometimes plain, and at other times panelled; they have no diminution, nor any regular base and capital. Attics are much used by the moderns, particularly by Italian architects; and when applied to modern houses, they have frequently windows in the podium or dado.

Amongst the best examples of the use of the attic in modern public buildings, may be adduced Somerset House, in the view towards the street.

Attic Base, is that which consists of an upper and lower torus, a scotia, and fillets between them. It is described by Vitruvius as follows:—"The bases are fixed in their places, and so proportioned, that, including their plinth, they have in height half the thickness of the column; and in projection what the Greeks call *εκφοραν*, *ekphoran*, a quarter: so that the breadth and length will be once and a half the thickness of the column. Their height, if they are to be attic, must be so divided, that the upper part is one-third of the thickness of the column, and the remainder is left for the plinth. The plinth being excluded, the remaining part is divided into four equal parts, and the upper torus has one-fourth: the remaining three are equally halved: one-half makes the lower torus, and the other the scotia, which the Greeks call *τροχιλον*, *trochilon*, with its squares."

In many examples, both Grecian and Roman, the fillet over the trochilus projects as far as the most prominent part of the upper torus, and leaves a deep recess between the upper surface of the fillet and lower side of the torus. This base seems to be as much a favourite of the moderns as it was of the ancients.

Attic Door. *See* Door.

Attic Order, a term improperly used to denote the pilasters which are frequently employed in the decoration of an attic.

Attic Story, a term frequently applied to an upper story of a house.

ATTITUDE, in painting and sculpture, the posture or action in which a figure or statue is placed.

ATTRIBUTES, in painting and sculpture, are symbols given to figures.

AUDITORY, in ancient churches, the *nave*, where the people stood to be instructed in the gospel.

AUGER, a carpenter's and joiner's tool, for boring large holes with, and formed of a wooden handle, and iron spindle, terminated at the bottom with steel. The modern augers are pointed and sharpened like a centre-bit, the extremity of one of the edges being made to cut the wood clean at the circumference, and the other to cut and take away the core, the whole length of the radius.

AULA, a court or hall in the ancient Roman houses.

AXE, a tool with a long wooden handle, and a cutting edge in a plane passing longitudinally through the handle. Its use is for hewing timber, by cutting it vertically: the adze being employed in forming horizontal surfaces. The axe differs from the hatchet in being much larger, and by its being used with both hands; while the hatchet is used with one hand only. Axes are also used by stone-cutters and bricklayers, the particular forms of which depend upon the quality of the materials. *See* Tools.

AXIS, of a rotative figure, is the straight line passing through the centres of the circular sections at right angles to them. In a sphere, any right line passing through its centre may be the axis.

B.

BABEL, a city and tower built by Noah's posterity in the plain of Shinar. Its precise situation is not ascertained. It was however within the province of Shinar, and, probably, the ancient Babylon was but an enlargement of it. Its situation is supposed to have been on the north-west of Bagdad, on an extensive plain, between the Euphrates and the Tigris; as an extensive, insulated, shapeless heap of ruins is there to be seen, called the tower of Nimrod.

In sacred Scripture we are informed, that the materials of which this tower was constructed were burnt brick, and slime for mortar. The slime was of a pitchy substance, similar probably to bitumen. *See* Architecture.

BABYLONIAN ARCHITECTURE. In commencing this article, we must premise that we cannot pretend to any detailed description, as the materials for such an undertaking are almost entirely wanting. An account of this style of architecture must needs be very imperfect, when the very situation of the ancient Babylon remains uncertain. This once vast city, the metropolis of one of the great empires of the world, is now but one mass of undistinguishable ruins.

Owing to the interest belonging to so ancient and powerful an empire, much pains have been taken in the examination of the remains of the city, but so great is the confusion, that it has hitherto baffled the exertions of travellers to determine with certainty the situation and extent of any of the buildings mentioned by ancient authors: among the more successful of our modern travellers, we may especially mention the names of Rich and Ker Porter; and among the ancients, those of Herodotus, Strabo, and Diodorus. We shall proceed to give an account of the city as described by the latter class of writers.

Herodotus in his usual circumstantial manner, gives us a very exact and lengthened description. According to his account, the city was of a quadrangular form, four hundred and eighty stadia in circuit, divided into two districts by the river Euphrates: it was defended on all four sides by a deep trench and wall, of which the following is the method of construction. In the first place, the earth was excavated to form the trench, and, as it was dug up, was carried in masses of convenient size for bricks to the furnace, and there burnt; when this process was complete, the bricks were employed in lining the sides of the ditch, and erecting the superincumbent wall: the work was cemented together by bitumen, and bonded at every thirtieth course by layers of reeds. The wall on each side was a hundred and twenty stadia in length, fifty royal cubits in thickness, and two hundred in height; on the top, and on each side of it, was erected a row of houses of one story in height, facing each other, and leaving a space or roadway between them, wide enough to allow four horses to be driven along it abreast. Where the outer walls met the river, a return wall was carried along each opposite bank to fortify the city against attacks from this quarter, and behind this again another, but of smaller dimensions. In the four walls surrounding the city, were a hundred apertures or entrances closed by means of brazen gates, from each of which was continued a street to the corresponding ones on the opposite side, intersecting the roads which led from the transverse walls at right angles. Where the streets met the return wall along the banks, an opening was made down to the river, provided with brazen gates. The city was filled with houses of three and four stories in height; and among the most remarkable buildings, were the temple of Belus and the palace, one in each of the principal divisions on either side of the Euphrates. The former is a very remarkable building on account of its supposed connection with the tower of Babel mentioned in the Mosaical account of the colonization of the earth. Herodotus gives the following description:—The tower was of a square plan, surrounded by a wall of similar form, having each of its sides two stadia in length; the sides of the structure itself were only half this length, or one stadium. Our author does not give the height, but he states that the tower consisted of eight tiers, which gave to it the appearance of being composed of eight towers, placed one above the other; but this in reality was not the case; such resemblance being occasioned by an inclined platform winding round outside the building, and thereby making eight revolutions: this platform formed the only means of ascent. About halfway up the incline, was a resting-place, and at the highest extremity a large temple dedicated to the god Bel, or perhaps Baal: there was another chapel in this building, containing an image of the god, of which we have no particular description.

Our historian further relates, that Nitocris having temporarily diverted the waters of the Euphrates by a course outside the city, embanked a part of the river, and made a descent into it from each of the gates in the return wall. This embankment was constructed of baked bricks in the same manner as the walls; a different material, however, was used by this queen in the construction of a stone bridge, or perhaps we should more correctly say piers of a bridge, as the roadway was formed of horizontal timbers, laid, as seems probable, from pier to pier. The beams were taken up at night, thus forming a kind of draw-bridge. In the piers, hewn stones were employed, which were securely connected together with iron and lead. Another remarkable work of this reign, was the erection of a building over the principal gates, to be used as a place of sepulture.

Thus far Herodotus; later authors differ from him in several particulars, still however preserving the same general account. Diodorus considerably diminishes the size of the outer wall, both in length and height, but the difference in the latter is easily accounted for, as he relates their condition as they appeared after the time of Darius Hystaspes, who reduced the height to fifty cubits. Strabo also gives the circuit of the wall at three hundred and eighty-five stadia. Diodorus further makes mention of two palaces, one on each side of the river, and connected by means of a bridge above and a tunnel below; he gives the circuit of the new palace as sixty stadia, that of the old thirty stadia; the new palace was surrounded by circular walls, enriched with decorations of sculptured animals, painted in colours on the bricks, and afterwards burnt in. The connecting tunnel our author states to have been vaulted, being twelve feet in height, and fifteen broad. This palace also contained the hanging gardens said to have been built by Nebuchadnezzar for his wife the Median Amytis. The gardens, occupying a space of ground four hundred feet square, consisted of terraces built one above the other until they reached a height equal to that of the outer walls of the city; the terraces being supported on piers and arches, as stated by Strabo, over which were laid large flat stones, sixteen feet long by four in breadth, and above those a layer of reeds mixed with bitumen, covered with two courses of bricks in cement. The extreme covering consisted of thick sheets of lead, on which was placed the mould for the garden. The spaces between the terraces were formed into magnificent apartments, and on the highest terrace was a pump, by means of which a supply of water was raised from the Euphrates to irrigate the gardens. The ascent to the top was by steps ten feet in width. Strabo gives us one additional particular respecting the tower belonging to the temple of Belus, namely, the height, which he states to be one furlong; according to Wesseling's reading, however, this particular is given by Herodotus.

Such is the description afforded by the ancients; let us now turn to the investigations on this subject by modern travellers, and in doing so we shall take the liberty of laying before our readers the account given by Mr. Rich, who has examined the ruins of this city with perhaps greater care than any other person. We must premise, that the site of the ancient city is a matter of dispute, but is allowed to be situate somewhere in the neighbourhood of Hillah and Mohawill. This position has been determined upon on account of the mounds and heaps of ruins which are found dispersed about this quarter, on or near the banks of the Euphrates.

"The ruins of the eastern quarter," says Mr. Rich, "commence about two miles above Hillah, and consist of two large masses or mounds connected with and lying north and south of each other, and several smaller ones which cross the plain at different entervals. These ruins are terminated on the north by the remains of a very extensive building called the Mujelibé, from the south-east angle of which proceeds a narrow ridge or mound of earth wearing the appearance of having been a boundary wall. This ridge forms a kind of circular enclosure, and joins the south-east point of the most southerly of the two grand masses. The river-bank, on the south-west of the tomb of Amram, is skirted by a ruin extending nearly eight hundred yards; it is for three hundred yards forty feet perpendicular; a little above this is a piece of ground formerly the bed of a river; here earthen vases with bones were found. From the east angle of the ruin on the river bank, commences another mound similar to that first mentioned, but broader and flatter; this mound is the most southerly of all the ruins.

"On taking a view of the ruins from south to north, the first object that attracts attention is the low mound connected with the ruin on the south-west of the tomb of Amram: on it are two small walls close together, and only a few feet in height and breadth. This ruin, which is called Jumjuma, and formed part of a Mohammedan oratory, gives its name to a village a little to the left of it. To this succeeds the first grand mass of ruins, which is 1100 yards in length, and 800 in its greatest breadth; its figure nearly resembles that of a quadrant; its height is irregular; but the most elevated part may be about fifty or sixty feet above the level of the plain, and it has been dug into for the purpose of procuring bricks. Just below the highest part of it is a small dome in an oblong enclosure distinguished by the name of Amran Ibn Ali. On the north is a valley of 550 yards in length, the area of which is covered with tussocks of rank grass, and crossed by a line of ruins of very little elevation. To this succeeds the second grand mass of ruins, the shape of which is nearly a square of 700 yards length and breadth, and its south-west angle is connected with the north-west angle of the mounds of Amran by a ridge of considerable height, and nearly 100 yards in breadth.

"Not more than 200 yards from the northern extremity of this mound is a ravine, hollowed out by those who dig for bricks, in length 100 yards, and 10 feet wide by 40 or 50 deep. On one side of it a few yards of wall remain standing, the face of which is very clean and perfect, and appears to have been the front of some building. Under the foundations, at the southern end, an opening is made, which discovers a subterranean passage, floored and walled with large bricks laid in bitumen, and covered over with pieces of sandstone a yard thick and several yards long; the weight above has been so great as to have given a considerable degree of obliquity to the side-walls of the passage; the opening is nearly seven feet in height, and its course is to the south. The superstructure over the passage is cemented with bitumen, other parts of the ravine with mortar, and the bricks have all writing upon them." The souterrain widens considerably as you proceed farther. This passage seems to form part of the *kasr*, or palace, and may have been perhaps the tunnel alluded to by ancient authors. The principal portion of this ruin, to which alone the term *kasr* is applied at present by the natives, is situate a little to the west of the ravine, and presents a remarkably fresh appearance, insomuch so, that Mr. Rich was not willing, until after a very close inspection, to allow its claims to being considered an original Babylonian remain. "It consists," says he, "of several walls and piers, which face the cardinal points, eight feet in thickness; in some places ornamented with niches, and in others strengthened by pilasters and buttresses, built of fine burnt brick still perfectly clean and sharp, laid in lime cement, of such tenacity that it is almost impossible to extract a brick whole. The tops of these walls are broken, and may have been much higher; on the outside they have in some places been cleared nearly to the foundations; but the internal spaces formed by them are yet filled with rubbish, in some parts almost to the summit. One part of the wall has been split into three parts, and overthrown as if by an earthquake; some detached walls of the same kind, standing at different distances, show what remains to have been only a small part of the original fabric; indeed, it appears that the passage in the ravine, together with a wall which crosses its upper end, were connected with it.

"A mile to the north of the *kasr*, or palace, five miles from Hillah, and 950 yards from the river-bank, is a ruin called the *Mujelibè*, meaning *the overturned;* its shape is oblong, and its height, as well as the measurements of its sides, irregular. The sides face the cardinal points; the northern is 200, the southern 219, the eastern 182, and the western 186 yards in length; and the elevation of the south-east, or highest angle, is 141 feet. The western face, which is the least elevated, is the most interesting, on account of the appearance of building it presents. Near the summit of it appears a low wall, with interruptions, built of unburnt bricks mixed up with chopped straw, or reeds, and cemented with clay-mortar of great thickness, having between every layer a layer of reeds; and on the north side are also some vestiges of a similar construction. The south-west angle is crowned by something like a turret, or lantern: the other angles are in a less perfect state, but may originally have been ornamented in a similar manner. The western face is lowest and easiest of ascent; the northern the most difficult. All are worn into furrows by the weather; and in some places, where several streams of rain-water have united together, these furrows are of great depth, and penetrate a considerable way into the mound. The summit is covered with heaps of rubbish, in digging into some of which, layers of broken burnt brick, cemented with mortar, were discovered, and whole bricks with inscriptions are sometimes found. The whole is covered with innumerable fragments of pottery, brick, bitumen, pebbles, vitrified brick, or scoria, and even shells, bits of glass and mother-of-pearl. In the northern face of the Mujelibè, near the summit, is a niche, or recess, high enough for a man to stand upright in, at the back of which is a low aperture leading to a small cavity; whence a passage branches off to the right, sloping upwards in a westerly direction till it loses itself in the rubbish." Receiving intimation that human remains had been discovered near this spot, our traveller commenced a strict investigation, and after excavating to some depth through a hollow pier, formed of fine bricks laid in bitumen, and in size sixty feet square, he met with several antiques, amongst which were a number of earthen vessels, some thin and highly glazed. Prosecuting his labours still further, another passage was laid open; this cavity was narrow, about ten feet high, composed of both burnt and unburnt bricks, the latter with a layer of reeds between every course, except the two lowest, where they were laid in bitumen. In this passage Mr. Rich discovered a wooden coffin containing human remains, which presented the appearance of being of great antiquity. To the north and west of this mass of ruins, and at about 70 yards distant from it, runs a low mound, which may have formed an enclosure round the whole.

The only ruin of any consequence to be found on the western side of the Euphrates is that which is termed by the Arabs the *Birs Nemroud*, and by the Jews *Nebuchadnezzar's Prison;* it is situate about six miles to the south-west of Hillah, and is perhaps the most remarkable of all the ruins. Mr. Rich gives us the following description:—"The Birs Nemroud is a mound of an oblong form, the total circumference of which is 762 yards. At the eastern side it is cloven by a deep furrow, and is not more than fifty or sixty feet high; but at the western side it rises in a conical figure to the elevation of 198 feet, and on its summit is a solid pile of brick, thirty-seven feet high by twenty-eight in breadth, diminishing in thickness to the top, which is broken and irregular, and rent by a large fissure extending through a third of its height. It is perforated by small square holes disposed in rhomboids. The fine burnt bricks of which it is built have inscriptions on them; and so excellent is the cement, which appears to be lime-mortar, that it is nearly impossible to extract one whole. The other parts of the summit of this hill are occupied by immense fragments of brickwork of no determinate figure, tumbled together and converted into solid vitrified masses, the layers of brick being perfectly discernible. These ruins stand on a prodigious mound, the whole of which is itself a ruin, channelled by the weather, and strewed with fragments of black stone, sandstone, and marble. In the eastern part, layers of unburnt brick, but no reeds, are to be seen. In the north side may be seen traces of building exactly similar to the brick pile. At the foot of the mound a step may be traced scarcely elevated above the plain, exceeding in extent, by several feet each way, the true or measured base; and there is a quadrangular enclosure round the whole, as at the Mujelibè, but much more perfect, and of greater dimensions. At a trifling distance, and parallel with its eastern face, is a mound not inferior to that of the kasr in elevation, but much longer than broad; on the top of it are two *koubbès*, or oratories: round the Birs are traces of ruins to a considerable extent."

Having thus given a description of the ruins as they now exist, it remains to determine the identity between them, and the buildings mentioned by ancient authors. On this subject great differences of opinion exist; the chief difficulty arising from the almost entire absence of any vestiges of building on the western side of the Euphrates: this it has been attempted to obviate in various ways. Major Rennell, the author of a "Geography of Herodotus," is of opinion that the river has left its original bed, and formed a new channel for itself, which, he says, is a common occurrence in alluvial tracts of land, such as that upon which Babylon was situate; he supposes the ancient course of the river to have been between the Kasr and Mujelibè. In favour of this supposition, he quotes the words of Mr. Rich, where he says that the valley on the north of the Amran Ibn Ali is covered with tussocks of rank grass;—this, Major Rennell conjectures to have been the bed of the river. In opposition to this opinion, Mr. Rich states, that there are no sufficient grounds for supposing the river to have taken this course, but rather that the buildings seem entirely to preclude such idea; besides, he adds, every occasion was made use of to prevent the alteration in the course of the Euphrates in this neighbourhood; the possibility of such an occurrence was obviated by the artificial canals and cuts which were so numerous in this part of the country. He further accounts for the existence of the tussocks of rank grass, by the circumstance of the river occasionally overflowing its banks, and on its subsidence, leaving some portion of its waters in the hollows; this appears, we must confess, in some degree to invalidate his former argument; it does seem, however, somewhat premature to suggest any material alteration in the course of the Euphrates, if difficulties can be accounted for by any other method; if any alteration is allowed to have taken place, it seems more reasonable to suppose the original course to have been through the ravine to the west of the ruins, especially as a number of bones have been found at this spot. The difficulty respecting the position of the river, however, is principally owing to Major Rennell's considerably contracting the dimensions of the city: he considers the statements of ancient authors respecting its magnitude as merely fabulous; but seemingly without any other reason than their improbability, or rather inaptitude, to our present notions of a city. If, however, present experience were to be universally applied, we should, with equal justice, deny the existence of many erections of which we have ocular demonstration, for instance, of the Pyramids and Sphinxes of Egypt. It is true that the circuit of Babylon, as given by ancient authors, is immense, but it is not entirely unaccounted for; for Quintus Curtius tells us, that nearly one-half of the city was occupied in gardens and other cultivated lands, and not, as modern cities, composed almost entirely of houses. Internal evidence also respecting the truth of his statement, is furnished by Herodotus, when he relates that, at the capture of Babylon by Cyrus, the inhabitants of the interior parts were not aware of what was taking place until some time after the circumstances occurred. If we allow the account of the ancients to be correct in this respect—and indeed we see little reason to the contrary—our difficulty in determining the localities of the ancient city will be considerably diminished; as we shall then be able to discover at least some remains on both sides the Euphrates, though not so great a number on the western side as we may have been led to expect.

Another mistake which, in our opinion, Major Rennell has been led to make, is the determining, at the very commencement of his inquiry, the site of the temple of Belus. Whether the position he has assigned it be the correct one, is another question; all that we suggest at present is, that such allocation is, in this case, premature; it at once puts a limit to free inquiry, as it determines what must be the relative position of every other edifice. Mr. Rich, on the other hand, commencing the subject entirely afresh, and taking a more comprehensive view of the matter, arrives at a different conclusion; he gives it as his opinion that the Birs Nemroud has the better claims to be considered as the ancient tower. In favour of this opinion it may be observed, that it would at once obviate the difficulty we have in reconciling the statement of the ancients, respecting the location of the palace and temple of Belus on opposite sides of the river, with the discoveries of the moderns. But, it may be objected, Herodotus states that these edifices were in the centre of either division of the city: now the word used by that author is ἐν μέσῳ, which, we think, may be translated literally enough by *in the midst*, or even by the preposition *within*, and certainly more correctly so than by *in the centre*. Should, however, any objection be made to this translation, we would argue that in so large a space, our author may be allowed a little latitude in cursorily describing the position of principal buildings in the plan of so vast a city. Moreover, we have further evidence in favour of this assumption, in the remarkable similarity of the remains to the descriptions we have of the old edifice. Before proceeding further, we may as well get rid of one objection which may be urged in opposition to the statements we are about to make: the plan of the remains is an oblong, and not a square, as stated by Herodotus; now, we must remind our readers that, although the more common reading states the building to have been of a square plan, yet that this reading has been with good reason objected to, and has been altered by Wesseling in his edition; we do not think, therefore, that this objection ought to have much weight. To return:—The ruins present the appearance of a building of 762 yards periphery, surrounded by an outer wall; the present height of the building is 235 feet, in which space Mr. Rich discovered traces of three different stages, similar to those described by Herodotus; and Mr. Buckingham, a later traveller, in the same space, thinks four stages clearly discernible. Now, if we add the same height for other four stages to complete the number of eight as given by Herodotus, we shall find the total height of the building equal to 470 feet, or about a stadium, the height given by the ancients. This we think amounts to almost conclusive evidence for the supposition of Mr. Rich; further, however, the appearance of the kasr answers very well to the description of the ancient palace, and one part is especially to be noted for its resemblance to the hanging-gardens: the hollow shaft mentioned amongst the discoveries of Mr. Rich, is very similar to the hollow piers supporting the terraces as described by Strabo. The author, from whose narrative we have so copiously extracted, supposes the whole of that mass of ruins on the eastern bank of the river, enclosed by circular walls, to have formed a part of the ancient palace, for, says he, it is manifest that the palace was not merely a single edifice, but consisted of a number of buildings, surrounded probably by an outer wall; and this supposition appears very probable, especially as it related that the hanging-gardens were within its precincts. Major Rennell, however, while he assigns the kasr especially to the palace, and the Mujelibè to the temple of Belus, considers the circular rampart which encloses them as an erection of modern date. In opposition to this notion, Mr. Rich suggests that we have no accounts of any later erection on this spot, whereas Diodorus expressly states that the palace was surrounded by circular walls. Besides this, he brings forward what he considers a convincing proof of its antiquity, which is this—that wherever bricks engraved with the arrow-headed characters are here found, they are all placed with the engraved sides *downwards*. This circumstance he considers sufficient evidence of the walls having been erected at a very early period; for during his extensive researches, he observed that in the old buildings the bricks were invariably laid in this particular position; in later erections, where the old materials had been made use of, this peculiarity had not been attended to.

The question respecting the identification of the remains with the ancient buildings, has elicited considerable information on the subject, and has been very ably treated by many learned men. A variety of opinions has arisen in consequence of the difficulties with which the subject is attended, none of which, however, have been broached without good reason: we are inclined to give the preference to Mr. Rich's suggestions, but at the same time we must confess that the other views taken of this case are worthy of most careful consideration.

We have extended the present article to so great a length, on account of the interest which must necessarily appertain to a style of building of such early date. Much as the originality of the various modes of architecture has been discussed, and although many weighty reasons have been alleged in proof of the superior antiquity of some few of the other styles, of, for instance, the Cyclopean, the Egyptian, and the Indian; yet it seems to us that the Babylonian has a greater claim to originality than any other. As far as we can discover from historical records, it is very evident that the first great empire established in the world was that of Babylon. The account given in the sacred history, and which is confirmed, as far as may be, by all other historical records, tells us that the first great kingdom was founded, and the first city built, by Nimrod, a name which has been preserved by tradition even up to the present time, and is still held in especial reverence; thus proving, at least, the existence of such a person, and his pre-eminent usefulness to the city and people of Babylon. It may be said, we are well aware, that this is mere tradition; yet we cannot allow that tradition, even when it appears in its most absurd colouring, is entirely to be despised: we cannot account for the promulgation of any legend that has absolutely no origin, such an idea is indeed absurd; every traditional story must have some real, tangible source, and reality cannot but be truth; such stories may have been embellished, or, if you please, disfigured by fiction, but they must have their foundation at least in fact.

Many persons, we know, are very unwilling to assign much credit to the Mosaical narrative; but we think we are fully entitled to claim for it equal authority with that of most of the other historians who make any reference to the occurrences of so early a date, especially as its author is allowed to be the earliest historian, and for this reason must have lived closer to, and have been, we should suppose, more competent to relate the occurrences of, the times to which he refers. Claiming so much authority, then, for our author, we would beg our readers to allow a fair modicum of credit for his sketch of the early history of Babylon; we say sketch, for it has no higher pretensions, nor could we naturally expect any detailed history from an historian living eight hundred years posterior to the period whose history he is relating. We may here apply a very sensible remark made by Rollin in speaking of the history of this empire: "where," he says, "certainty is not to be had, I suppose a reasonable person will be satisfied with probability." It is true that Moses does not expressly state that Babylon was the first city, but we have every reason short of certainty to believe that he intended to imply as much. In giving the genealogy of Noah's descendants, he stops at the name of Nimrod, to tell us that "he began to be a mighty one in the earth;" which expression, if it does not indeed say in so many words that he was the first one who obtained superiority, may, at least, when taken in connection with all other attendant circumstances, imply quite as much; and it is further told us, that "the beginning of his kingdom was Babel." Further on in the narrative, we are told where and what this Babel was, as well as when its erection took place, namely, in the time of Peleg, the fifth from Noah, probably at some particular period of his life; perhaps shortly after his birth—for, "in his days was the earth divided:" the causes of this division, and the particulars of the building of Babel, are related as follows: "The whole earth was of one language, and of one speech; and it came to pass, as they journeyed from the east, that they found a plain in the land of Shinar; and they dwelt there. And they said, Go to, let us build us a city, and a tower whose top may reach unto heaven; and let us make us a name, lest we be scattered abroad upon the face of the whole earth. And the Lord came down to see the city and the tower which the children of men builded. And the Lord said, Behold, the people is one, and they have all one language; and this they begin to do: and now nothing will be restrained from them, which they have imagined to do. Go to, let us go down, and there confound their language, that they may not understand one another's speech. So the Lord scattered them abroad from thence upon the face of all the earth: and they left off to build the city; therefore is the name of it called Babel." To any one reading this account, there can, we think, be little doubt, that it was the writer's intention to signify, that Babel was the first permanent erection of any significance, that it was the joint erection of all men then in existence, and also that it was the origin of the city afterwards known by the name of Babylon.

It now rests with us to shew the identity of the existing remains, and of the city erected by Nimrod, and in this case again we must rest content with probability. Now it seems universally allowed that some part of the mounds are identical with the ruins described by Herodotus; how large a portion this may be we do not pretend to assert, but we have already stated that Mr. Rich includes a large proportion of the existing remains. We have only in continuation to give our reasons for considering the buildings described by Herodotus as identical with those referred to by Moses. In the first place, then, the former writer seems to speak of Babylon as a very ancient city in his time, and mentions it as a remarkable occurrence that the tower of Belus was then standing; he speaks of a long line of kings, and relates that Semiramis made some improvements in the city, thus implying that the city had been erected some considerable period before her reign. This queen is supposed to have lived from twelve hundred to two thousand years before our era, thus bringing the erection of the city close upon that of Babel, as recorded in the Scriptures. Another proof of identity is seen in the nature of the materials used in the buildings, and in the manner of their erection, and in these matters the two accounts perfectly coincide. Moses, in that part of his narrative already quoted, says,—"And they said one to another, Go to, let us make brick, and burn them thoroughly; and they had brick for stone, and slime (bitumen) had they for mortar." The account of Herodotus, although of a more detailed description, agrees in every particular with that just given;—we need not refer to it here, as it has already been given in full. Again, is there not every reason to believe that the tower of Babel and that of Belus are one and the same edifice? Herodotus evidently looks upon the tower as of very remote origin, as the oldest building in Babylon; indeed, it seems to be a building remarkable on many accounts, standing out distinct from all surrounding edifices, as well by its great height, as by its unusual construction; it is apparently looked upon by all those who have seen it with a kind of awe, as though its erection, and every other thing connected with it, was entirely beyond their comprehension.

Taking all these circumstances into consideration, we venture to assert there will be considered sufficient evidence to satisfy any reasonable person of at least the probable identity between the buildings referred to in the Mosaical narrative, and the ruins now in existence, as described by recent travellers.

The remains of this great city do not afford us an opportunity of stating, with any preciseness, the style, so to speak, adopted in its architecture. The buildings generally are rude, and show but little evidence of constructive science; they are of gigantic proportions, and very massive, on which quality they rely chiefly for their strength; their construction is indicative of greater antiquity than that of the Indian or Egyptian styles, for, whereas, in the latter, we find detached columns, in the Babylonian we see no traces of them; indeed, the construction is altogether much heavier and of more barbarous appearance. The edifices were almost universally composed of bricks, of which there were various qualities, some dried in the sun, others baked in a kiln; there was also a finer sort, the clay of which, previous to being burned, was mixed up with chopped straw or reeds, and these last seem to have been used for facing walls built of the commoner sort of brick; there is one peculiarity about them, however, which may not be overlooked, and this is the indentation on their surface of certain marks arranged in parallel lines, termed arrow or nail-headed characters. These marks are supposed to represent letters, or words; but, although much learned labour has been given to the task, their signification has not been discovered, nor, indeed, the method of deciphering them determined upon: similar inscriptions have been found at Persepolis and Susa, also on some rocks near Argish, in Armenia, and sometimes, but very rarely, in Egypt. To return:—The bricks were cemented together with hot bitumen, but were sometimes laid in clay, and at others in lime-mortar, and bonded together by straw, or reeds. The walls, as we have previously mentioned, were of great thickness, strengthened at intervals by pilasters, or buttresses, which were sometimes adorned with niches. Columns were not made use of, the nearest approach to the idea being found in the large hollow piers which supported the hanging-gardens. The principle of the arch does not seem to have been understood, although some authors have stated a contrary opinion; no examples of its application have been found, and the fact of inconveniently large masses of sandstone having been made use of in places where the arch would have been most applicable, as in the case of the passage described by Mr. Rich, is, we think, a conclusive argument that the principle was not known. (For further information on this subject we refer to the article on ARCH.) The working of metals seems to have been in extensive practice, as Herodotus tells us that all the gates were made of brass.

Although externally their buildings were of this rude description, the Babylonians evinced some taste in the interior decorations. Among other modes of ornamentation, they made use of coloured bricks. These bricks were painted while in a moist state, and the colours afterwards burnt in; the subjects represented were usually animals, standing out in relief from the general surface, and richly painted in their natural colours. Statues likewise formed a very usual mode of decoration

We have now only to notice that peculiar building, the Birs Nemroud, of which we have elsewhere given a description; it will, therefore, be unnecessary to enter into detail here; we would only beg of our readers to notice its peculiar form, that of a pyramid, and remark, that if this tower be allowed to be the first erection of importance, it will very readily account for the circumstance of that form being so universal in other styles of very early date. This kind of erection is found, not only in Egyptian and Indian architecture, but also in other styles, whose connection with the Babylonian is not so easily accounted for; and Humboldt, in speaking of a pyramidal mass of ancient Mexico, says,—"It is impossible to read the descriptions which Herodotus and Diodorus Siculus have left us of the temple of Jupiter Belus, without being struck with the resemblance of that Babylonian monument to the teocallis of Anahuac." It is true that the pyramidal is that form which would most naturally suggest itself to men unacquainted with the contrivances of art, but we venture to think, that the suggestion we have above thrown out, is not entirely unworthy of the attention and consideration of the curious.

Having at length arrived at the conclusion of this article, we would apologize for having extended it to a length which some may be inclined to think unreasonable; when, however, the interest attaching to such ancient remains, and the comparatively slight attention the subject has hitherto obtained, are considered, we feel confident of receiving the pardon of our readers.

BACK, the side opposite to the face, or breast. In a recess, upon a quadrangular plan, the face is that surface from which the recess is made: therefore the back is the surface which has the two adjacent planes, called the sides, elbows, or gables. When a piece of timber is fixed in a level or inclined position, the upper side is called the back, and the lower, the breast: thus the upper side of the hand-rail of a stair is called the back. The same is to be understood with regard to the curved ribs of ceilings, and the rafters of a roof: their upper edges are always called the backs.

BACK OF A CHIMNEY. *See* CHIMNEY.

BACK OF A HAND-RAIL, is the upper side of it. Its formation is shown under the articles STAIRS and HAND-RAILING.

BACK OF A HIP-RAFTER. *See* HIP-ROOF.

BACK LINING OF A SASH-FRAME. *See* SASH-FRAME.

BACK OF A RAFTER, is the upper side of it, in the sloping plane of the one side of a roof. The manner of forming the back is shown under RAFTER. *See* also ROOF, in CARPENTRY.

BACK-SHUTTERS, or BACK-FLAPS, are additional breadths hinged to the front shutters, necessary in closing the aperture completely, when the window is required to be shut. When the aperture is open, or when light is required, the back-shutters are concealed in the boxing by the front-shutters. Back-shutters are generally made thinner than front-shutters, and framed with bead and butt.

BACK OF A STONE, the side opposite to the face, which is generally rough.

BACK OF A WINDOW, in joinery, is the board, or wainscoting, between the sash-frame and the floor, joining upon the two elbows, and forming a part of the finish of the room in which it is placed. It is in general parallel to the face of the wall, or to the glass, or sash-frame, and, when framed, it has commonly a single panel with mouldings on the framing, corresponding to the doors, shutters, elbows, soffits, &c., in the same apartment in which it is placed. The framing of the back and the skirting are generally in the same plane, or flush, and the upper edge of the skirting is wrought with a bead, which conceals the joint between the lower edge of the rail, and the upper edge of the skirting below it. The top edge of the upper rail is generally capped with a slip of timber, level on the top, beaded on the front edge, and tongued into the sash-frame. The capping bead is returned upon the two elbows, and has the most prominent part of the convexity flush with the framing of the elbows, as well as that of the back. Framed backs and elbows for good houses are generally finished at one and one-eighth inch thick.

BACKING OF A RAFTER, or RIB, the formation of an upper or outer surface, so as to range with the edges of the ribs or rafters, on either side of it. *See* also RANGING, or EDGING.

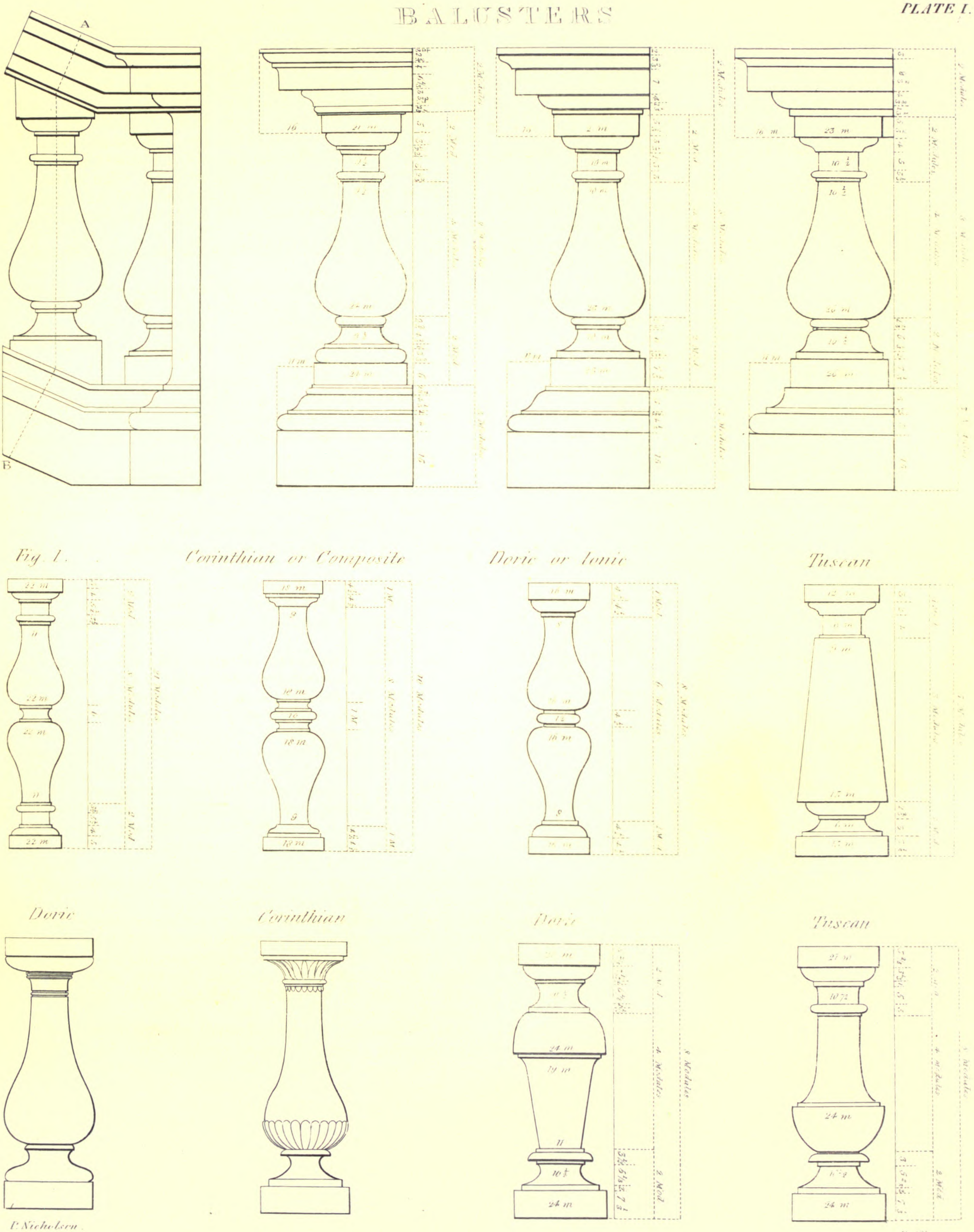
The formation of the inner edges of the ribs for lath-and-plaster ceiling, is sometimes improperly called backing.

BACKING OF A WALL, is the building which forms the inner face of the wall, or, the act of building the inner face. This term is opposed to facing, which is the outside of the wall. In stone walls the backing is generally rubble, though the facing be ashlar.

BADIGEON, a mixture of plaster and free-stone, well sifted, and ground together: it is used by statuaries to fill up the small holes, and repair the defects in stones of which their work is made. The term is also used by joiners, for a composition of saw-dust and strong glue, with which the chasms of their work are filled. Joiners likewise use for this purpose, a mixture of whiting and glue. When this is used, the filling-in should remain till quite hard, otherwise,

PLATE I.

BALUSTERS



P. Nicholson.

R. Thew.

when it is plained or smoothed off, it will shrink below the surface.

BAGNIO, a *bath.* The word is applied by us to houses which have conveniences for bathing, sweating, and otherwise cleansing the body. Bagnio, in Turkey, is a general name for the prisons where their slaves are kept. So called from the baths they contain.

BAGUETTE, a small astragal moulding, sometimes carved and enriched with pearls, ribbands, laurels, &c. When the baguette is enriched, it is called *chaplet*, and when unornamented, *bead.*

BALBEC, or Baalbec, a famous city of Syria, celebrated by the Greeks and Latins under the name of Heliopolis, the city of the sun, or Baal. It was surrounded with walls, which were flanked with towers at regular intervals. The principal remains consist of the great temple, a smaller one, called by Mr. Wood the most entire temple, a circular temple of a singular construction, and a Doric column standing alone. The longitudinal direction of the great and most entire temples is east and west. Before the entry to the great temple are two courts and a portico, which face eastwards. After passing the portico, we come to an hexagonal court, surrounded with columns and apartments; we thence enter a quadrangular court, the area of which is also surrounded with columns: on the north or south side of this court are seven apartments, or exhedræ; five are rectangular on the plan, one stands in the middle, having a semicircular exhedra on each side of it. These were probably lodging rooms for the priests. At the other extremity of this court, upon the south, are columns of a colossal magnitude, being the remains of the peristyle of the temple. The shafts are twenty-one feet eight inches in circumference; and the entire height of the columns fifty-eight feet.

The columns are all joined with iron cramps, and without cement, which is nowhere used in these edifices, but the surfaces are so close that there is hardly room for the blade of a knife to be inserted between them. The stones which compose the sloping wall are of enormous size. On the west the second course is of stones from twenty-eight to thirty-five feet long, and nine feet in height: and at the north angle, over this course, are three stones, which occupy one hundred and seventy-five feet seven inches. The shafts of the columns of the great temple consist each of three pieces which are joined with iron pins about one foot long, and one foot diameter. Most of the bases had two sockets, one circular, and the other square. Greek and Roman authors are entirely silent as to these astonishing ruins.—(*Ruins of Balbec, by Wood and Dawkins.*)

BALCONY, (from the French *balcon,*) an open gallery projecting from the front of a building, surrounded with a rail or balustrade, of various devices, and supported by cantalivers, brackets, or columns. It is made of wood, stone, sometimes of cast-iron, and sometimes also of bar-iron fashioned into crail-work, of various fanciful figures.

Balconies are generally made on a level with the sills of the windows of the first floor; sometimes every window in the range has a separate balcony, each of which is convex to the street. When there is but one, it is generally placed in the middle of the length of the front, or extends the whole length of the front. Sometimes a portico or porch is surmounted with a balcony; in this case the balustrade may be of stone, as well as of iron, or wood. When balconies are used, the windows are generally brought down to the floor, without adding any additional breadth to the aperture. *See* Balustrade.

BALDACHIN, (from the Italian *baldacchino,*) a piece of architecture in the form of a canopy, supported with columns, and serving as a covering to an altar. The baldachin supplanted the ciboreum, which was of the same nature; but whereas the former was a canopy, the latter was in form similar to the monoptral temple described by Vitruvius.

The baldachin in St. Peter's at Rome is of bronze, and was made by Bernini. The dais, or covering, is supported on four large twisted columns of the Composite order, on pedestals of black marble. Above the columns are four figures of angels; at the top of the covering there is a cross, and below the entablature the fringe of the banner-like cloth of the portable baldachin has been imitated. The height is 125 feet 3 inches from the floor of the church to the summit of the cross, and the whole work is in the highest degree elegant and graceful.

BALECTION MOULDINGS. *See* Belection Mouldings.

BALKS, large pieces of timber brought from abroad in floats: their scantling being from five to twelve inches square. Balks, in some parts of England, are used for the summer-beams of a building, also for the poles or rafters laid over out-houses, or barns.

BALLOON, (from the French *ballon,*) a crowning of a globular form, used by way of an acroter to a pediment, pillar, or the like. That on the top of St. Peter's at Rome is of brass, about eight feet diameter, and placed at the height of sixty-seven fathoms.

BALL-FLOWER, an ornament resembling a ball placed in a circular flower, the three petals forming a cup round it; much used as an enrichment to mouldings, and otherwise in the decorated style of Gothic architecture.

BALLIUM, the space immediately within the outer walls of an ancient castle.

BALTHEI, bands, or girdles. This word is used by Vitruvius for some part of the Ionic volute. The balthei are supposed to be the mouldings which encompass the bolsters of the volutes.

BALUSTER, sometimes corruptly called Banister, a small kind of column or pillar belonging to a Balustrade, (which *see.*) The various forms of Balusters given in the accompanying plate, are selected chiefly from Sir William Chambers, who has appropriated some of them to the orders of architecture, as their names express. The two last, denominated *Corinthian* and *Doric*, were designed by Mr. Nicholson, and their curve is found by an algebraic equation as in Oval. Their general form is graceful, and their elegance may be preserved in any proportion; thus, suppose it were wished to have a very slender baluster made from the very stout one, here called Doric; divide the length of the baluster required into ten equal parts, and the given baluster into the same number; draw lines on both, as ordinates; place the ordinates of the given baluster upon the respective lines of the one required, and through the extremities draw a curve, which will complete the baluster sought for.

Balusters of the Ionic Capital, the two lateral parts contained between each front and rear volute, called by Vitruvius, *pulvinata.*

BALUSTRADE, a range of small columns called balusters supporting a cornice, used as a parapet, or as a screen, to conceal the whole or a part of the roof. It is also sometimes used as a decoration for terminating the building. Balustrades are employed in parapets, on the margins of stairs, before windows, to enclose terraces, or balconies, by way of security, or sometimes to separate one place from another. In the theatres and amphitheatres of the Romans, the pedestals of the upper orders were always continued through the arcades, to serve as a parapet for the spectators to lean over; the lowermost seats next to the arena in the amphitheatres, and those next to the orchestra in the theatres, were guarded by a parapet, or podium. The walls of ancient buildings generally terminated with the cornice itself, but often with a blocking course, or attic. In the monument of Lysicrates at Athens, the top is finished with finials composed of honeysuckles, solid behind, and open between each pair of finials; each plant or finial is bordered with a curved bead, and the bottom of each interval with an inverted curve. Perhaps terminations of this nature might have been employed in many other Grecian buildings, as some coins seem to indicate; but this is the only example of the kind. The temples in Greece are mostly finished with the cornice itself; which was also the case with many of the Roman temples: and as there were no remains of balustrades in ancient buildings, their antiquity may be doubted: they are, however, represented in the works of the earliest Italian writers, who, perhaps, may have seen them in the ruins of Roman edifices.

When a balustrade finishes a building, and crowns an order, its height should be proportioned to the architecture it accompanies, making it never more than four-fifths, nor less than two-thirds, of the height of the order, not reckoning the plinth on which it is raised; as the balustrade itself should be completely seen at a proper point of view. Balustrades designed for use should always be of the height of the parapet walls, as they answer the same purpose, being nothing else than an ornamented parapet; this height should not exceed three feet and a half, nor be less than three feet. In the balusters, the plinth of the base, the most prominent part of the swell, and the abacus of their capital, are generally in the same straight line: their distance should not exceed half the breadth of the abacus, or plinths, nor be less than one-third of this measure. On stairs, or inclined planes, the same proportions are to be observed as on horizontal ones. It was formerly customary to make the mouldings of the balusters follow the inclination of the plane; but this is difficult to execute, and, when done, not very pleasant to the eye; though in ornamental iron work, where it is confined to a general surface passing perpendicularly by the ends of the steps, it has a very handsome appearance. The breadth of pedestals, when placed over an order, is regulated by the top of the shaft, the die being always equal thereto. When balustrades are placed upon the entablature of an order, over the intercolumns, or interpilasters, and the base and cornice of the balustrade continued, so as to break out and form pedestals over the columns, or pilasters, the breadth of the die of the pedestals should be equal to the breadth of the top of the shafts; and when there is no order, the breadth of the die never more than its height, and very seldom narrower: the dies of the pilasters may be flanked with half dies, particularly when the range of balusters is long.

BAND, a narrow flat surface, having its face in a vertical plane, as the band of the Doric architrave, and the dentil band, which is the square out of which the dentils are cut. The word facia, or plat band, is generally applied to broad members, as the facia of an architrave; and band, to narrow ones wider than fillets. Band is also the cincture around the shaft of a rusticated column.

Banded Column, is that which is encircled with bands, or annular rustics.

BANDELET, or Band, any flat moulding, or fillet. *See* Band.

BANKER, the stone-bench on which masons cut and square their work.

BANQUETING-ROOM, an apartment for entertainment, used among the Romans in the latter ages of the empire. In ancient times they supped in the atrium of their houses, but in after-times, magnificent saloons, or banqueting-rooms, were built for the more commodious entertainment of their guests. Lucullus, we are informed by Plutarch, had several very grand banqueting-rooms, and the Emperor Claudius had a very elegant one, named Mercury; but everything of this kind was outdone by the lustre of the still more celebrated banqueting house of Nero, called *domus aurea*, the house of gold, which, by the circular motion of its ceilings and partitions, imitated the revolution of the heavenly bodies, and represented the different seasons of the year, which changed at every service, and showered down flowers, essences, and perfumes on the guests.

BAPTISTERY, (from *βαπτιζο, to wash*,) a building, or apartment, designed for the administration of baptism.

In ancient times, baptism was performed by immersion, and the place for the purpose was a pond or stream; but about the middle of the third century, distinct or insulated houses were erected for the purpose. In 496, they were attached to the exterior sides of the church; and in the sixth century, they were brought within the church; but though there might have been two or more churches in one city, yet, in general, there was only one baptistery; and when it became fashionable to dedicate the churches, that to which the baptistery belonged was dedicated to St. John the Baptist. The baptismal churches in Italy were usually built near rivers and waters. In later times, the bishop of baptismal churches granted licenses to other churches to erect baptisteries, taking care at the same time to maintain his own jurisdiction over the people.

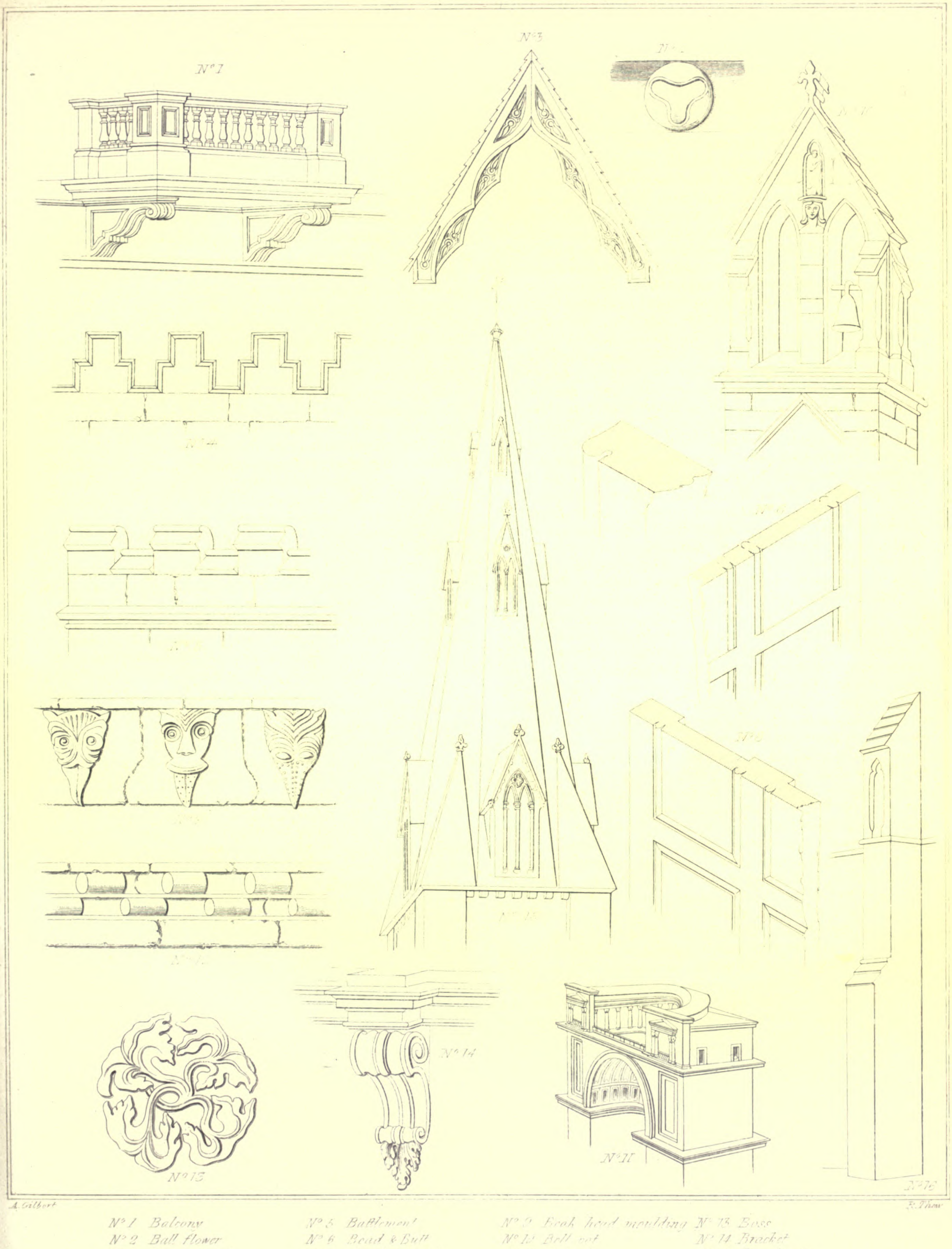
The baptistery was an octagon building, covered with a cupola roof, adjacent to the church, but not forming a part of it.

In the interior was a hall, sufficient to contain a great number of people, on the sides of which was a number of apartments; sometimes, instead of these apartments, rooms were added on the outside, in the manner of cloisters: in the middle of the hall was an octagon bath, which, strictly speaking, was the baptistery, and from which the whole building derived its appellation.

The most celebrated baptisteries are those of Rome, Florence, and Pisa; the most ancient is that of S. Giovanni in Fonte at Rome, said to have been erected by Constantine the Great. The plan of this building is octangular; the roof is supported by eight large polygonal pillars of porphyry under the cupola; in the centre of the floor is the bath, lined with marble, with three steps for descending into it: its depth is about thirty-seven inches and a half. The baptistery annexed to the splendid church of St. Sophia, at Constantinople, resembled the convocation-room of a cathedral; and was called *illuminatory*. In the middle was the bath, and around it were outer rooms for all concerned in the immersion.

The Baptistery of Florence stands opposite to the principal entrance of the cathedral. It is octangular in form, with a diameter of about one hundred feet. In the interior is a gallery, supported by sixteen large granite columns; the vaulting is decorated with mosaics, and on the pavement is a large circle of copper, with numerical figures, and the signs of the zodiac on it. The external façades are built of black and white marble, and the three great bronze doors are celebrated for the beauty of their bas-reliefs, and for the marble and bronze figures above them.

The Baptistery of Pisa is circular; its diameter is 116 feet; the walls are eight feet high, and the building is raised on three steps, and surmounted by a dome in the shape of a pear. This dome, which is covered with lead, is intersected by long lines of very prominent fretwork, terminating in another dome, above which is a statue of St. John. The proportions of the interior are admirable; eight granite



A. Gilbert R. Thew

Nº 1 Balcony
Nº 2 Ball flower
Nº 3 Barge boards
Nº 4 Battled embattled
Nº 5 Battlement
Nº 6 Bead & Butt
Nº 7 Bead & quirk
Nº 8 Bead flush & square
Nº 9 Beak head moulding
Nº 10 Bell cot
Nº 11 Belvedere
Nº 12 Billet moulding
Nº 13 Boss
Nº 14 Bracket
Nº 15 Broach spire
Nº 16 Buttress

columns, placed between four piers, decorated with pilasters, are arranged round the basement story; these support a second order of piers, similarly arranged, on which rests the dome. In the middle of the baptistery, is a large octagonal basin of marble raised on three steps. *See* FONT.

BAR, a piece of wood, or iron, for fastening any kind of closure, as a door, or shutter. It is used as an additional fastening to a door, attached to the side, and movable to and fro upon the surface, so as to be inserted, or drawn out of the jamb, head, or sill, at pleasure; and is most commonly placed on the vertical edge of the door. Doors and shutters have sometimes bars so long as to be equal to the whole breadth of the aperture, or something more; and frequently made to turn upon a centre on the side of the door or shutter.

BARS FOR THE SHUTTERS OF WINDOWS, are frequently made with one or more joints, according to the number of shutters in the breadth of the window, and are fastened by means of bolts and fore-locks.

BARS OF A BOARDED DOOR, are pieces placed on the back, to which the boards are fastened; bars of this nature are more commonly called ledges.

BARS OF A SASH, are those slight pieces of wood or metal which divide the sash-light into two or more compartments, so as to reduce the large opening into smaller ones of convenient dimensions, suitable to the size of the panes of glass.

Those bars which stand in the intersection of two vertical planes, are called angle-bars. *See* ANGLE-BARS.

BAR-IRON. *See* IRON.

BAR-POSTS, are those which are fastened into the ground, forming the sides of a field gate, and are mortised so as to admit of horizontal pieces, called bars, which may be inserted easily or taken out at pleasure.

BARBACAN, or BARBICAN, in ancient fortifications, was an advanced work, which frequently covered the draw-bridge at the entrance of a castle. The term is likewise applied to the aperture in walls, called embrasures. *See* EMBRASURES.

BARBACAN, in architecture, is a long narrow canal, or opening, left in the walls for water to come in and go out by, when edifices are placed so as to be liable to be overflown; or to drain off the water from a terrace or the like.

BARGE-BOARDS, two boards attached to the gable ends of a roof, fixed near the extremity of the barge-course, and following the inclination of the roof, used for the purpose of protecting the under or stuccoed side of the barge-course from the weather. They are found most usually in old English houses, and being carved in most rich and elaborate patterns, add great beauty and picturesque effect to the buildings. They have been of late applied in many instances, where their utility seems to have been entirely misunderstood, and where, instead of protecting, they only serve as a dead weight to the building. The word is probably derived from an old Saxon term signifying *to shade* or *cover*.

BARGE-COUPLES, two beams mortised and tenoned together, for strengthening the building. The term is not much used.

BARGE-COURSE, that part of the tiling which projects over the gable of a building, and is made up below with mortar.

BARN, a covered building, for laying up and preserving all sorts of grain, hay, straw, &c. The situation of a barn should be dry and rather elevated, and on the north or north-east side of a farm-yard; but neither contiguous to the house, nor to any offices connected with it. Barns may be constructed of either stone, brick, or timber, which last may be wooden framing, covered with weather boarding; but whichsoever of these materials is used, holes should be left in the walls at intervals, or the doors and windows should have proper air-flights, so as to admit the ingress and egress of air freely. The gable-ends are best formed of brick or stone, on account of their solidity; the covering may either be thatch or tiles. In the walls of the front and rear of the building should be two large folding doors, for the convenience of carrying in and out a cart or waggon load of corn in sheaves, or any other bulky produce: these doors should be of the same breadth with the threshing-floor, to give more light to the threshers, and admit more air for winnowing the grain. Over the threshing-floor, and a little above the reach of the flail-poles, beams are often laid across, in order to form a kind of upper-floor, upon which the thresher may throw the straw or haulm; and on the out-side, over the great doors, it is convenient to have a large penthouse made, projecting sufficiently, so as to cover a load of corn, or hay, in case a sudden storm should come on before it can be housed, and also to shelter the poultry in the farm-yard from bad weather, or too great heat. The hay-barns should usually be constructed of wood, and not too close: they are sometimes formed in such a manner, as to be capable of being moved to different places by wheels or rollers. In grazing-farms, which do not afford a supply of straw for thatching, the stacks with movable roofs, erected on strong upright posts of wood, or what is sometimes termed Dutch barns, may be useful, as they may be raised or lowered at pleasure by screws and levers, so as to accommodate themselves to the quantity of hay, either in proportion to the crop or its consumption, while, at the same time, they are cheaper, more airy, and less troublesome than close barns, in case of heating. The under-pinning of barns is best of stone or brick, which may be built to the height of about two feet above ground; the sides should be boarded, and the roof covered with straw or reeds; but those of the stables on its sides, with slate or glazed tile; because, as they must be more flat, the water which runs from the roof of the barn would injure most other coverings. At each end of the barn, and over the back-door, small doors, four feet high, should be fixed at the height of twelve feet from the ground: the two former for putting in corn at the ends, and the latter for filling the middle of the barn after the bays are full. All the bays should have a floor of clay or marl, and the threshing-floor should be laid with hard bricks, which will be suitable for all sorts of grain, except wheat or rye: for threshing these, it will be advisable to have planks of oak or red deal well fitted together, and numbered, to be laid down occasionally, and confined by a frame at their ends.

Barns should be placed upon a declivity, as by this means they are rendered more durable, less subject to vermin, and the grain can be kept more sweet and dry than on level ground: this situation also affords a commodious range of stalls for cattle.

The invention of the threshing machine has, in a great measure, altered the construction of barns, as, where they are made use of, they should be contrived chiefly with a view to the distribution of straw; the machines being built in the centre, with the grain-stacks adjoining them, in such a manner, that they may be supplied without the assistance of carts or horses. The barns, in these cases, need not to be so large, but they should have granaries provided in them, which may perhaps be most conveniently placed over the floors.

BARREL DRAIN, one constructed in the form of a hollow cylinder. *See* DRAIN.

BARROW, or TUMULUS, a hillock or mound of earth, anciently raised over the body of a distinguished person. Barrows are considered as the most ancient sepulchral monuments in the world.

BAS-RELIEF. *See* Basso Relievo.

BASALT, a hard dark-coloured rock, of igneous origin, formed of columnar or stratified parts, very useful in building, paving, &c. Basalt, when calcined and pulverized, is an excellent substitute for puzzolana, in the composition of mortar: by undergoing these operations, it acquires the property of hardening under water.

BASE, in architecture, is the lowermost part of a body, consisting of one, or an assemblage of parts, taken in its altitude, being separated from its upper part, which is a naked or plain surface.

Base of a Room, is the lower projecting part, consisting of two portions, the lower of which is a plain board adjoining the floor, called the plinth, and the upper consists of one or more mouldings, which, taken collectively, are called the base-mouldings. The plinth in the best work is tongued into a groove in the floor, by which means, the diminution of breadth in the shrinking never shows any aperture, or cavity, between its under edge and the floor; and the upper edge of the plinth is rebated upon the base. Bedrooms, lobbies, passages, and staircases, are often finished without the dado and surbase, as also sometimes vestibules and halls. Rooms which have pavement floors, have their bases, in general, consisting of stone plinths, and wooden base-mouldings, which are not so liable to be broken as stone mouldings.

BASEMENT, the lowest story of a building, on which an order is placed, consisting of a base, die, and cornice. The choragic monument of Lysicrates is a beautiful example of an antique basement. In modern buildings, the height of the basement will vary according to the character of the edifice: it is proper, however, to make the basement no higher than the order of the next story, for this would be making the base of more importance in the composition than the body to be supported. If the cellar story is the basement, and if the height does not exceed five or six feet at the most, it may be plain, or with rustics, or formed into a continued pedestal; but if the basement is on the ground story, the usual manner of decorating it is with rustics, supported on a base and surmounted with a crowning string course: the base may be either a plain or moulded plinth; and the cornice may either have a plat-band or mouldings under it, or may form a cornice of small projection. The rustics are either of a rectangular or triangular section, supposing one of the sides of these sections to be a line extending across the front of the joints. The joints of the rustics may be from one-eighth to a tenth part of their height; the depth of the triangular joints may be half their breadth; that is, making the two planes by which they are formed a right angle; and the depth of the rectangular from one-fourth to one-third of their breadth. The ancients always marked both directions of the joints of the rustics, whereas the moderns employ not only the ancient manner, but sometimes make them with horizontal joints alone; the latter, however, represent rather a boarded surface than that of a stone wall, which must have two directions of joints.

The height of the string course should not exceed the height of a rustic with its joints; nor the plinth, or zocholo, be less than the height of the string course. When the basement is perforated with arcades, the imposts of the arches may be a plat-band, which may be equal to the height of a rustic, exclusive of the joint. When the string course is a cornice, the base may be moulded, the projection of the cornice being two-thirds of its height, so as to be less prominent than that which finishes the building. The height of the cornice may be about one-eighteenth part of the height of the basement, and that of the base, about twice as much, divided into six parts, of which the lower five-sixths form the plinths, and the upper sixth the mouldings.

BASIL, among carpenters and joiners, the iron side of the angle of a tool, ground so as to bring the end of the tool to a cutting edge. If the angle be very thin, the tool will cut more freely, but is in danger of breaking into notches, if not duly tempered: to remedy this, it is sometimes found necessary to grind it thicker.

BASILICA, (from *βασιλευς*, *king*, and *οικος*, *house*, signifying *royal house*,) a building originally used as a court of justice. Among the Romans, it was a large hall adjoining the forum, where the magistrates judged the people under cover, which distinguished it from the fora, where they held their sittings in the open air. Basilicas were in plan parallelogrammic, divided lengthwise into three or more aisles, the centre one of which was called the testudo, and those at the sides porticos. The testudo was covered by a roof supported on two rows of columns, situate on either side between it and the adjoining porticos. These porticos were divided vertically by two galleries, one above the other, which ran round three sides of the building, and were covered by a lean-to roof, meeting the above-named columns below their capitals, so as to leave an open space between the roofs of the porticos and the testudo, for the admission of light. At that end of the testudo where the gallery was discontinued, stood a raised platform, on which was placed the tribunal for the magistrate. The above is as clearly as can be discovered, a correct description of the ancient basilica, and agrees in all its principal features with a building which has been discovered in the ruins of Pompeii.

The proportions of these edifices are given by Vitruvius as follows:—"The breadth," he says, "is not to be less than a third, nor more than the half of the length, unless the nature of the place opposes the proportion, and obliges the symmetry to be different; but if the basilica has too much length, *chalcidicæ* (supposed to be apartments on the sides of the tribunal, separated from the body by a partition) are taken off the ends, as in the basilica of Julia Aquiliana. The columns of the basilica are made as high as the porticus is broad; which again is equal to the third part of the space in the middle. The upper columns are less than the lower, as above written. The *pluteum* (a kind of podium or continued pedestal) which is between the upper columns, should also be made a fourth part less than the same columns, that those who walk on the floor above, may not be seen by the negotiators below. The *epistylium*, *zophurus*, and *coronæ* below, are proportioned to the columns, as in my third book.

"Nor will basilicas such as that at the colony of Julia of Fanum, which I designed and executed, have less dignity and beauty, the proportions and symmetry of which are as follows: The middle testudo, between the columns, is one hundred and twenty feet long, and sixty feet broad. The porticus around the testudo, between the walls and columns, is twenty feet broad. The height of the continued columns, including their capitals, is fifty feet, and the thickness five, having behind them parastatæ (attached pilasters) twenty feet high, two feet and a half broad, and one foot and a half thick, which sustain the beams that bear the floors of the porticus. Above these are other parastatæ, eighteen feet high, two feet broad, and a foot thick, which also receive beams sustaining the canthers of the porticus, which are laid below the roof of the testudo: the remaining space that is left between the beams which lie over the parastatæ, and those over the columns, is left open in the inter-columns, in order to give light. The columns in the breadth of the testudo, including those of the angles to the right and left, are four; and in the length, on that side which is next the forum, including the same angle columns, eight. On the other side, there are but six columns, including those of the angles, but the middle two on this side are omitted, that they may not obstruct the view of the pronaos of the Temple of Augustus, which is situated in the middle of the side-wall of the basilica, looking toward the centre of the forum and Temple of Jupiter. The tribunal, in this building, is formed in the figure of a hemicycle: the extent of this hemicycle, in front, is forty-six feet, and the recess of the curvature inward, fifteen feet, so that those who attend the magistrate obstruct not the negotiants in the basilica.

"Upon thecolumns, the compacted beams, made from three timbers of two feet, are disposed; and these are returned from the third columns, which are in the interior part, to the antæ that project from the pronaos, and on the right and left touch the hemicycle.

"Upon the beams, perpendicularly to the capitals, the pilæ (a kind of blocking for supporting the plates) are placed, three feet high, and four feet broad, on every side. Over these, other beams, well wrought from two timbers of two feet, are placed; upon which the transtræ and capareols being fixed coincident with the zophorus, antæ, and walls of the pronaos, sustain the culmen the whole length of the basilica, and another transversely from the middle over the pronaos of the temple: so that it causes a double disposition of the fastigium, and gives a handsome appearance to the roof on the outside, and to the lofty testudo within. The omission of the ornaments of the epistylium, and of the upper columns and plutei, diminishes the labour of the work, and saves great part of the expense. The columns likewise being carried in one continued height up to the beams of the testudo, increase the magnificence and dignity of the work."

In the foregoing description, the proportion which Vitruvius assigns to basilicas in general, does not agree with that which he executed at the colony of Julia of Fanum, which appears to be of a different construction from the common form; as, in the former, the ranges of columns which form the porticos, appear to have been disposed in two heights, with a gallery between; whereas, in the latter, the columns were disposed in one range in the height, with attached pilasters behind, in two rows, one above the other, and the galleries between the pilasters nearly against the middle of the columns, resting upon the lower range. Nor are the proportions the same: for in the former, the breadth is specified not to be less than a third part of the length, nor more than half, "unless the nature of the place opposes the proportion;" the breadth of the latter is, however, more than the half, for the length of the nave is one hundred and twenty feet, and the breadth sixty feet; now, adding forty feet to each, the breadth of the two opposite porticos, will make the whole length of the building one hundred and sixty feet, and the breadth of the same one hundred feet, which is more than the half of one hundred and sixty. In the general construction, no columns are mentioned at the ends, unless the chalcidæ (which are introduced in order to proportionate the building) are comparted by columns, but in the basilica constructed by Vitruvius, porticos are clearly understood in the breadth, as well as in the length; for he says, "The columns in the breadth of the testudo, including those of the angles to the right and left, are four; and in the length, on that side which is next the forum, including the same columns, eight; on the other side there are but six columns, including those of the angles; because the middle two on this side are omitted, that they may not obstruct the view of the pronaos of the temple of Augustus." When Vitruvius speaks of the length and breadth of the basilica, it is reasonable to suppose, that these were the dimensions within the walls; but whether ancient edifices of this description had walls, or were supported upon columns, is a desideratum which cannot be ascertained, but in the discoveries of ancient edifices, which are perhaps, as yet, embosomed in the earth; and it is to be regretted, that, though some buildings of a similar description have been discovered, they are by no means decided, neither in their proportion nor construction. Fragments of the plan of Rome, taken under Severus, which still exists, show a part of the basilica Æmiliana, exhibiting two rows of columns on each side, without an exterior wall, which renders it doubtful whether they ever were enclosed or not; perhaps the warmth of the climate of Italy did not require it.

"It is to Constantine, that the first Christian churches, known by the name of basilicas, are to be referred. This prince signalized his zeal by the erection of monuments, which announced the triumph of the religion which he had embraced. He gave his own palace on the Cœlian mount, to construct on its site a church, which is recognized for the most ancient Christian basilica. A modern building has so masked and disfigured the ancient, that only the situation and plan of this monument can be discovered.

"Soon after, he erected the basilica of St. Peter, of the Vatican. This magnificent edifice was constructed about the year 324, upon the site of the circus of Nero, and the temples of Apollo and Mars, which were destroyed for that purpose. It was divided internally into five aisles from east to west, which terminated at the end in another aisle from north to south, in the centre of which was a large niche or tribunal giving the whole the form of a cross. The larger aisle was enclosed by forty-eight columns of precious marble, and the lateral aisles had likewise forty-eight columns of smaller dimensions; two columns were placed on each wing of the terminating aisle. The whole was covered with a flat ceiling, composed of immense beams, which were cased with gilt metal and Corinthian brass, taken from the temples of Romulus and Jupiter Capitolinus. A hundred smaller columns ornamented the shrines and chapels. The walls were covered with paintings of religious subjects, and the tribunal was enriched with elaborate mosaics. An incredible number of lamps illuminated this temple; in the greater solemnities 2,400 were reckoned, of which one enormous candelabrum contained 1,360. The tombs of pontiffs, kings, cardinals, and princes, were reared against the walls, or insulated in the ample porticos.

"This superb temple was respected by Alaric and Totila, and remained uninjured in the various fortunes of Rome during the lapse of twelve centuries; but crumbling with age, it was at last pulled down by Julius II., and upon its site has arisen the famous basilica, the pride of modern Rome.

"The third great basilica built by Constantine, that of St. Paul, on the road to Ostia, still exists. The interior of this building resembles precisely that of St. Peter, which has just been described. Of the forty columns enclosing the great aisle, twenty-four are supposed to have been taken from the mausoleum of Adrian; they are Corinthian, about three feet diameter, fluted their whole length, and cabled to one-third: the columns are of blue-and-white marble, and antiquity presents nothing in this kind more precious for the materials and workmanship. But these beautiful remains seem only to be placed there to the disgrace of the rest of the construction, which is of the age of Constantine and Theodosius, and which most strikingly exemplifies the rapid decline of the arts.

"The churches we have hitherto described, bear a very complete resemblance to the antique basilica in plan and proportion. The only remarkable difference is, that the superior galleries are suppressed, in the place of which a wall is raised upon the columns of the great aisle, which is pierced with windows, and supports the roof.

"The church of St. Agnes out of the walls, though not one of the seven churches of Rome which retain the title, is however a perfect imitation of the antique basilica. This resemblance is so complete, that without the testimony of writers, who inform us that it was built by Constantine, at the request of Constantia, his sister or daughter, and without the details of its architecture, which forbid us to date it higher, it might be taken rather for an ancient tribunal of justice, than a modern church. It forms an oblong internally, three sides of which are surrounded with columns forming the porticos; the fourth side opposite the entrance is recessed in a semicircle; this is the tribunal. The first order of columns carries a second, forming an upper gallery, above which begins the ceiling of the edifice. The shortening of the columns recommended by Vitruvius, is observed in the upper order.

"We have hitherto observed in the Christian basilicas, but small variations from the antique construction: they were still simple quadrilateral halls, divided into three or five aisles, the numerous columns of which supported the flat ceiling; but the cross-form, the emblem of Christianity, which began to be adopted in these buildings, operated the most essential changes in their shape. The intersection of the crossing aisles produced a centre, which it was natural to enlarge and make principal in the composition; and the invention of domes, supported on pendentives, enabled the architects to give size and dignity to the centre, without interrupting the vista of the aisles. The church of St. Sophia, at Constantinople, was the first example of this form.

"The seat of the Roman empire being transferred to Constantinople, it is natural to suppose that the disposition of the ancient St. Peter's of Rome, esteemed at that time the most magnificent church in the world, was imitated in that which Constantine erected for his new capital, under the name of St. Sophia. This last did not exist long: Constantius, the son of Constantine, raised a new one, which experienced many disasters. Destroyed in part, and rebuilt under the reign of Arcadius, it was burnt under Honorius, and re-established by Theodosius the younger; but a furious sedition having arisen under Justinian, it was reduced to ashes. This emperor having appeased the tumult, and wishing to immortalize his name by the edifice he was about to erect, assembledf rom various parts the most famous architects. Anthemius of Trulles, and Isidore of Miletus, were chosen; and as they had the boldness to attempt a novel construction, they experienced many difficulties and disasters; but at last they had the glory of finishing their design.

"The plan of this basilica is a square of about two hundred and fifty feet. The interior forms a Greek cross, that is, a cross with equal arms; the aisles are terminated at two ends by semicircles, and at the other two by square recesses, in which are placed two ranges of tribunals. The aisles are vaulted, and the centre, where they intersect, forms a long square, upon which is raised the dome, of about one hundred and ten feet diameter. The dome, therefore, is supported upon the four arches of the naves and the pendentives, or spandrel, which connect the square plan of the centre with the circle of the dome.

"The general effect of the interior is grand; but whatever praises the bold invention of this immense dome may merit, it must be confessed, that there are times in which princes, however great and liberal, can only produce imperfect monuments, of which this edifice is a striking example. All the details of its architecture are defective and barbarous.

"However, from the communication established between Greece and Italy, at the revival of letters, this basilica, the last, as well as the most magnificent of the lower empire, was that which influenced most the form and architecture of the new temples. The Venetians, in the tenth century, copied with success the best points in the disposition of St. Sophia, in the church of St. Mark. This is the first in Italy which was constructed with a dome supported on pendentives; and it is also this which first gave the idea, which has been imitated in St. Peter's, of the Vatican, of accompanying the great dome of a church with smaller and lower domes, to give it a pyramidal effect.

"From this time to the erection of the basilica of St. Peter's, we find the churches approach, more or less, to the form of the ancient basilica or the new construction. The church of Santa Maria del Fiore, of Florence, from the magnitude of its dome, and the skill which Brunelleschi displayed in its construction, acquired a celebrity which made the system of domes prevail; and this system was finally established in the noble basilica of the Vatican, which has become the type and example of later ones. The form of the antique basilica was entirely lost, and the name, which has been retained, is the only remain of their ancient resemblance.

"In the pontificate of Julius II., the beginning of the sixteenth century, the basilica of St. Peter's was begun from the designs of Bramante. This great man formed the idea of suspending, in the centre of the building, a circular temple, as large as the Pantheon, or, as he expressed it, to raise the Pantheon on the temple of peace; and, in fact, we find great resemblance in size and disposition between these two edifices and the project of Bramante. He was succeeded in his office by San Gallo, who almost entirely lost sight of the original plan; but Michael Angelo, to whom at his death the undertaking was committed, concentered the discordant parts. Michael Angelo died 1564, while he was engaged in erecting the dome; but he left plans and models, which were strictly adhered to by his successors, Vignola, J. del Porte, and Fontana, who terminated the dome. The building was carried on under many succeeding pontiffs; and at last, by lengthening the longitudinal nave, it acquired the form of the Latin cross; in that particular, approaching to the original design of Bramante.

"The general form of this edifice, externally, is an oblong, with circular projections in three of the sides; the plan of the interior consists of a Latin cross, the intersection of the arms of which is enlarged and formed into an octagon; the head of the long aisles, and the ends of the cross-aisles, are terminated in hemicycles, and the great naves are accompanied with lateral aisles, and with several enclosed chapels. The octagon centre supports a circular wall, enriched with pilasters and pierced with windows, above which rises the magnificent dome.

"Thus we have traced the progress of the basilica from the quadrilateral hall of the ancients, with its single roof and flat ceiling, supported on ranges of columns, to the cross-shaped plan, central dome, and vaulted aisles, supported on massy piers, of the modern cathedral. It only remains to treat of the—

"*Modern* Basilica. We give this name, with Palladio, to the civil edifices which are found in many Italian cities, and the destination of which is entirely similar to the antique basilica.

"In imitation of the ancients, (says this celebrated architect,) the cities of Italy construct public halls, which may rightly be called *basilicas*, as they form part of the habitation of the supreme magistrate, and in them the judges administer justice. The basilicas of our time (he continues) differ in this from the ancient—that those were level with the ground, while ours are raised upon arches, in which are shops for various arts, and the merchandise of the city. There the prisons are also placed, and other buildings belonging to the public business. Another difference is, that the modern basilicas have the porticos on the outside, while in the ancient they were only in the interior. Of these halls, there is a very noble one at Padua; and another at Brescia, remarkable for its size and ornaments.

"But the most celebrated is that of Vicenza; the exterior part of which was built by Palladio, and the whole so much altered that it may pass for his work. The body of the building is of much greater antiquity, though the date of it is unknown.

"Time and various accidents had reduced this edifice to such a state of decay, that it was necessary to think seriously of preventing its total ruin: for this purpose, the most eminent architects were consulted, and the design of Palladio was approved. He removed the ancient loggias, and substituted new porticos, of a very beautiful invention. These form two galleries in height, the lower order of which is ornamented with Doric engaged columns, at very wide intervals, to answer to the internal pillars of the old building; the space between each column is occupied by an arch, resting on two small columns of the same order, and a pilaster at each side against the large columns, which leaves a space between it and the small columns, of two diameters. The upper portico of Ionic columns, is disposed in the same manner, and a balustrade is placed in the archways. The entablature of the large orders is profiled over each column.

"This edifice is about one hundred and fifty feet long, and sixty feet broad; the hall is raised above the ground twenty-six feet; it is formed by vaults supported on pillars, and the whole is covered with a wooden dome."—*Rees's Cyclopædia.*

BASKET, a kind of vase in the form of a basket, filled with flowers, or fruits, or both, used for terminating a decoration.

BASSE-COUR, a court separated from the principal one and destined for the stables, coach-horses, and livery-servants. In a country place, it denotes the yard where the cattle, fowls, &c., are kept: it is called by the French *menagerie.*

BASSO-RELIEVO, (*Italian;* Bas-relief, *French,*) in sculpture, is the representation of figures projecting from a back ground, so as to give relief. It is a general term, comprehending three distinct species of sculpture. Low relief, sometimes also called basso-relievo, is that in which no part of the sculpture is detached from the back ground: high-relief, or alto-relievo, is that in which the grosser parts are only attached, while the smaller parts are free: mean-relief, or mezzo-relievo, is a term which some use for a kind of sculpture between the two. Mezzo-relievo is distinguished from alto by having no part entirely disconnected from the plane surface, and from basso-relievo in having the parts most remote from the back ground, most relieved, whereas the latter has such parts least relieved. In the former the outline is less, in the latter more apparent than the forms within it.

These terms are of modern date, and probably invented in the eleventh and twelfth centuries. The Greeks denominated relievo, or low-relief, by the term *anaglypta* (Pliny, lib. 33, c. 11,) and alto-relievo was distinguished by the word *toreuticeu*, or rounded, (Pliny, lib. 34, c. 8,) although this term was occasionally applied to any kind of relief. As architecture is highly indebted to sculpture for some of its most elegant decorations, it will be proper to give some account in this place of the basso-relievos of the ancients.

In point of antiquity, the Egyptian stands first: a knowledge of their sculpture will be best obtained from the writings of those who have actually visited and surveyed their ruined edifices; in conformity with this, the following description from Denon will, perhaps, be acceptable:—"The hieroglyphics, which are executed in three different manners, are also of three species, and may take their date from as many periods. From the examination of the different edifices which have fallen under my eye, I imagine that the most ancient of these characters are only simple outlines, cut in without relief, and very deep; the next in point of age, and which produce the least effect, are simply in a very shallow relief; and the third, which seem to belong to a more improved age, and are executed at Tentyra more perfectly than in any other part of Egypt, are in relief below the level of the outline. By the side of the figures which compose these tabular pieces of sculpture, there are some hieroglyphics which appear to be only the explanation of the subjects at large, and in which the forms are more simplified, so as to give a more rapid inscription, or a kind of short-hand, if we may apply the term to sculpture.

"A fourth kind of hieroglyphics appears to be devoted simply to ornament: we have improperly termed it, I know not why, the *arabesque.* It was adopted by the Greeks, and, in the age of Augustus, was introduced among the Romans; and in the fifteenth century, during the restoration of the arts, it was transmitted by them to us, as a fantastic decoration, the peculiar taste of which formed all its merit. Among the Egyptians, who employed these ornaments with equal taste, every object had a meaning or moral, and at the same time formed the decoration of the friezes, cornices, and surbasements of their architecture. I have discovered at Tentyra the representations of the peristyles of temples in caryatides, which are executed in painting at the baths of Titus, and have been copied by Raphael, and which we constantly ape in our rooms, without suspecting that the Egyptians have given us the first models of them." Again, in describing the temple of Latopolis, Denon says, "The hieroglyphics in relief, with which it is covered within and without, are executed with great care; they contain, among other subjects, a zodiac, and large figures of men with crocodiles' heads: the capitals, though all different, have a very fine effect; and as an additional proof that the Egyptians borrowed nothing from other people, we may remark, that they have taken all the ornaments, of which those capitals are composed, from the productions of their own country, such as the lotus, the palm-tree, the vine, the rush, &c., &c." The most ancient and most simple kind of basso-relievos, used by the Egyptians, were cut by recessing the grounds as much as the projection of the figures, so that the surrounding surfaces, by forming a kind of border, both threw a shade upon the figures and defended them from injury, which they were liable to, as the granite out of which they were cut was of a very brittle nature; by this means much labour was saved in the execution.

The Egyptians also employed basso-relievo without any surrounding border, all the figures being raised from the same naked, such as in the palace of Karnac, and those described in the Bird's Well, of which there is a specimen in the hall of the British Museum. The material is soft calcareous stone, in very low relief. The outlines of Egyptian sculpture are ungraceful, and the execution shows a want of the knowledge of anatomy: it may be remarked as somewhat singular, that quadrupeds are more accurately represented in their sculpture than human figures.

The basso-relievos found in the excavations of the Indian temples bear a strong resemblance to those of the Egyptians, but are inferior in point of proportion; the heads are too large. Whether the Indian or Egyptian sculpture is the most ancient is not known; but if simplicity is to be our criterion, we would say the latter. See *Daniell's Ant.*

The Persians employed basso-relievos in their architectural decorations, as may be seen in the palace of Persepolis, and in the royal tombs. The figures are arranged in horizontal and vertical lines, and resemble the later hieroglyphics of Egypt, though the dress is very different: those of the Egyptians being particularly distinguished by the hair artificially curled, the hood, the mitre, the close tunic, and apron of papyrus; the Hindoos, by the necklaces, bracelets, and anklets; the Persians, by long beards, and hair ending in small curls, caps, and full tunics, with regular folds and large sleeves; the Medes, by close tunics. The drapery of the Persian figures is more natural than that of the Egyptians: but it cannot be inferred from this, that the figures themselves are of better sculpture, as instances may be shown to the contrary, in the obelisk of Sesostris, in the palace of Karnac, and in the Theban tombs, where the execution is not only more perfect, but the positions of the human figures more varied. See *Denon's Egypt*, and *Le Bruyn's Travels*.

The Grecians excelled all contemporary nations in the art of sculpture, as well as in architecture and geometry; the numerous remains of their edifices show the perfection which they had attained in exquisite workmanship, beautiful proportion, and easy and graceful attitudes. They profess to have had their first rudiments from Egypt, and this is completely verified in their first productions, which were similar to those of the Egyptians; however, the art did not long remain stationary; from daily observation, and a strict adherence to nature, they advanced rapidly in the science, and at last, by a knowledge of anatomy, it was brought to such a degree of perfection, that their remaining sculptures have become the very standard of excellence, a criterion which the moderns have never surpassed, and but seldom equalled. Who can behold the sculpture in the pediments and friezes of the Parthenon, and other remains of Athenian grandeur, without astonishment?

The pediments of this temple were adorned with entire and separate statues, although from their situation, and the deep shadows cast by them on the tympanum, they must have had the appearance of figures in high relief. The figures in the metopes were in alto, whilst those in the cella were in basso-relievo. This arrangement leads us to notice the great judgment which the Greeks exercised in the selection of the different kinds of sculpture, according to the nature of the situation they were intended to occupy. We find that they almost invariably placed separate statues, and sculptures in high relief, on the exterior of their buildings, or in such places as had the advantage of the open light; while, on the contrary, they reserved those in basso-relievo for interiors, where the light was not freely admitted; and this they did evidently for this reason, viz. that in all situations, and under all circumstances, their sculptures might be distinct and intelligible. It needs no argument to prove that figures in high relief are more readily discernible, when the light is permitted to play equally on all sides of them. Were such figures placed in an imperfectly lighted situation, they would be almost unintelligible, from the shadows which they would throw upon each other. On the other hand, the flatness of basso-relievo, while it obviated the projection of shadows beyond its own surface, ensured the distinctness of the outlines, and gave to the figures an appearance of rotundity. Mezzo-relievo is only adapted for near inspection. The temples of Theseus and Phigaleia, as well as that of Minerva, were remarkable for the beauty of their sculptures.

The basso-relievos of the Romans were, perhaps, at first, confined to their tombs. They never attained a just knowledge, or taste, of the art of sculpture. Their best works were executed by Grecian artists, and are chiefly to be found in the triumphal arches, which are richly charged with basso-relievos. The art attained its greatest perfection in the reign of Augustus, and was greatly on the decline in the time of Constantine. In more modern times, the Italians and Florentines are the only people who arrived at any degree of excellence in sculptures of this kind; and even they departed from the original purity of the Greeks, by attempting to express in their works the effect of perspective. We are indebted to Flaxman for the introduction of a purer taste into this country; his style may be considered as a nearer approach to the simplicity of the ancients, than that of either the Italians or the Florentines.

BASTION, or BATOON. *See* TORUS.

BAT, a part of a brick.

BATH, a house with accommodation for bathing. The ancient baths at Rome were very spacious and magnificent structures, and contained hot and cold baths, gymnasia, ambulatories, and even libraries. The most remarkable are those of Agrippa, Titus, Diocletian, and Caracalla.

The practice of bathing having been more generally adopted in this country within the last few years, has caused various structures to be erected for the purpose. These, however, are but of small dimensions, and have little pretensions to architectural embellishment.

BATTEN, a scantling of stuff, from two to six inches broad, and from five-eighths to two inches thick. Battens are employed in the boarding of floors, and also upon walls, in order to secure the laths on which the plaster is laid.

BATTEN-DOOR. *See* DOOR.

BATTEN-FLOOR. *See* BOARDED-FLOORS.

BATTENING, the act of fixing battens to walls, in order to secure the laths over which the plaster is laid; or, the battens in the state of being fixed for that purpose. The battens employed are generally about two inches broad, and three-fourths of an inch thick; they may, however, be of various thicknesses, according to the distances the several fixed points in their length are from each other. Their distance in the clear is from eleven inches to one foot. Previous to the fixing of battens, either equidistant bond-timbers should be built in the wall, or the wall should be plugged equidistantly, and the plugs cut off flush with its surface. In London, plugs are generally placed at the distance of one foot or fourteen inches from centre to centre in the length of the batten. Battens upon exterior walls, quarters in partition walls, the ceiling and bridging joists of a naked floor, also the common joists for supporting the boarding of a floor, are fixed at the same distance, viz. from eleven to twelve inches in the clear. When battens are fixed against flues, iron holdfasts are necessarily employed instead of bond-timbers or plugs. When battens are attached to a wall, they are generally fixed in vertical lines; and when fixed to the surface of a brick or stone vault, the intrados of which may be generated by a plane revolving about an axis, they ought to be placed in planes tending to the axis;

as, in this position, they have only to be fixed in straight lines, in cases where the intrados is straight towards the axis: such cases occur when the vault is a portion of a cone or cylinder. When the intrados is curved towards the axis, the battens will bend very readily. Great care should be taken to regulate the faces of the battens, so as to be as nearly equidistant as possible from the intended surface of the plaster. Though battens are employed in floors, neither the act of laying them, nor the floor formed of them afterwards, is called *battening;* they are more commonly called *boarding.* Every piece of masonry or brick-work, which is not sufficiently dry, should be battened for lath and plaster; particularly that which is executed in a wet season. When the windows are boarded, and the walls of a room not sufficiently thick to contain the shutters, the surface of the plastering is brought out so as to give the architrave a proper projection, and quarterings are used for supporting the lath and plaster, instead of battens. The like practice is observed, when the breast of a chimney projects into the room, in order to cover the recesses, and make the whole side flush, or in the same surface with the breast.

BATTER, the declension of a wall from the perpendicular: if a plummet be freely suspended from any part of a wall by a plumb-rule, the line coinciding with the draught, and the bottom part of the rule only touching the wall, then the wall is said to batter. This property applies both to straight and circular walls. A wall may be made to batter in any degree, by using a battering-rule, instead of a plumb-rule; that is, a rule which has the plummet draught oblique to the edge of the rule which is to be applied to the wall. This obliquity is best calculated by the rule of proportion, *viz.* if the whole height of the building batters at a given distance, what will a given length of rule batter? This distance being found, the top of the rule must be so much broader than the bottom, that is, reckoning from the draught to the edge applied to the wall, for the direction of the other edge is of no consequence. Upon this principle, even a body with a curved vertical section may be built; but in this case the rule will not shift; if the building stands on a circular plan, it can only be applied at the same altitude all round; and to carry the building to the summit, a new rule must be made at convenient portions of each successive altitude.

BATTLED-EMBATTLED, is when the top of a wall has a double row of battlements, formed of a conjunction of straight lines at right angles to each other, both embrasures and rising parts being double; the lower part of each embrasure less than the upper, and consequently the lower part of each riser broader than the upper.

BATTLEMENTS, indentations on the top of a wall, parapet, or other building. They were first used in ancient fortifications, and were afterwards applied to churches and other buildings, as mere ornaments. Their outline is generally a conjunction of straight lines at right angles to each other; each indentation having two interior right angles, and each raised part two exterior right angles. Sometimes the horizontal section of the rising part is a rectangle, while the bottom of the battlement, and top of the projecting part, slope downward, so as to form an obtuse angle with the face of the wall; occasionally, however, the plans of the upright sides of the battlements form the same obtuse angle as the bottom and top of the rising part. At other times both vertical and horizontal sections are right angles, ornamented equally all round with mouldings, or with a small square projecture: when the vertical sides of the embrasures are perpendicular to the face, the sloping cope generally terminates with a torus or large astragal. In process of time battlements were not confined to crown the principal walls of the building; but were employed in the finish of subordinate parts: they are to be found in the decorations of the transoms of windows, as in those of King Henry the Seventh's chapel, at Westminster. In this, and in every other case, they are proportioned to the architecture they accompany. The battlements employed in the florid style, were perforated in a most beautiful manner, with openings variously formed in symmetrical figures: such are the latticed battlements, and those formed of polyfoils, &c. The battlements used in this style of building, have not always their parts at right angles to each other, but frequently the standing parts, or those which form the sides of the openings, are raised in the manner of a pediment.

BAULK, a piece of timber, from four to ten inches square.

Baulk-Roofing, is when the framing is constructed of baulk-timber.

BAY, the open space in a window included between the mullions, otherwise called a *day* or *light.* Also the quadrangular space between the principal ribs of a groined roof, across which the diagonal ribs are extended; or the spaces between the principal divisions of a timber roof. The term is also applied to that part of a building situated between two buttresses.

Bay of a Barn, that part situate between the threshing floor and the end of the building, used for depositing the refuse hay or the corn previous to threshing.

Bay of Joists, the joisting between two binding joists, or between two girders, when there are no binding joists.

Bay Window, a projecting window of a polygonal plan, and rising from the ground or the basement of the building. *See* Bow and Oriel Windows.

BAZAR, or Bazaar, among the Turks and Persians, an exchange, where the finest stuffs and wares are sold. Some are open like market-places, others are covered with lofty ceilings, with pierced domes to give light. In these, jewellers, goldsmiths, and other dealers in the richest wares, have their shops.

BEAD, in joinery, a moulding of a circular section, stuck on the edge of a piece of stuff, by a plane of the same name. Beads are of two kinds, one of which is flush with the surface, and the other raised: the former is called a *quirk-bead,* and the latter a *cock-bead.*

Bead and Butt Work, in joinery, a piece of framing having the panels flush with the framing, and stuck or run upon the two edges, which have the grain of the wood in their direction.

Bead and Quirk, is when a bead is stuck on the edge of a piece of stuff, flush with the surface, with one quirk only, or without being returned on the other surface.

Bead and Double Quirk. *See* Return Bead.

Bead and Flush Work, in joinery, a piece of framed work, having a bead run upon every edge of the framing which adjoins to each edge of the included panel.

Bead, Butt, and Square Work, a piece of framing, having bead and butt upon one side, and square on the other. Bead, butt, and square work is chiefly used in doors.

Bead, Flush, and Square, a piece of framing, having bead and flush on one side, and nothing but square work on the other; chiefly used in doors.

BEAK, a little pendent fillet, left on the edge of the larmier, which forms a canal behind, for preventing the water from running down the lower bed of the cornice. Sometimes the beak is formed by a channel or groove, recessed on the soffit of the larmier upwards. In the Ionic temple on the Ilyssus, at Athens, the canal occupies the whole breadth of the soffit, and so deeply recessed, that the lower bed of the cornice is wrought almost out of the height of the recess.

Beak-head Moulding, a moulding used very commonly in Norman architecture, consisting of ornaments of a peculiar character, placed at regular intervals on a simple moulding. The ornaments may be described as grotesque heads, some apparently of animals, and some approaching the human form, but all invariably terminating in a pointed mouth, or beak as it were, whence their name. Although such ornaments were very frequent, they were of very various designs, two similar ones being seldom found in the same moulding.

Beaking Joint, in carpentry, is when the heading joints of the boards of a floor fall in the same straight line. This word is not used in London.

BEAM, when used in a building, is a piece of timber, or sometimes of metal, for sustaining a weight, or counteracting two equal and opposite forces, either drawing or compressing it to the direction of its length: when it is employed as a lintel, it supports a weight; when as a tie-beam, it is drawn or extended; and when as a collar-beam, it is compressed. The word *beam* is most frequently subjoined to another word, used adjectively, or in apposition, which shows the use, situation, or form of the beam: as tie-beam, collar-beam, dragon-beam, straining-beam, camber-beam, hammer-beam, binding-beam, girding-beam, truss-beam, summer-beam, &c. Some of these are also used simply, as, collar, instead of collar-beam; lintel, instead of lintel-beam; girder, instead of girding-beam; summer, instead of summer-beam. Lintels and girders are almost constantly used alone, and bressummers and joists are never used in composition. What is here called *collar-beam*, is, in old writers, termed *wind-beam*, *strut-beam*, or *strutting-beam*.

A beam is either lengthened by building it in thicknesses, or by lapping or splicing the ends upon each other, and bolting them through. *See* Building of Beams and Scarfing. For the manner of strengthening beams, see Truss-Beams.

Beam-Compass, an instrument, consisting of wood or metal, with sliding sockets, carrying steel or pencil points, used for describing large circles, beyond the reach of common compasses.

Beam-filling, the building of masonry, or brick-work, from the level of the under edges of the beams, to that of their upper edges. Beam-filling occurs either between joists, or floor-beams, or in filling up the triangular space between the top of the wall-plate of the roof, and the lower edges of the rafters, or even to the under surface of the boarding or lath, for slates, tiles, or thatching. This operation is necessary in garret-rooms, where the walls form sides of apartments; where the tie-beams are placed above the bottom of the rafters, and where the sides of the apartments are not to be battened and lathed for plaster, in order to straight the walls. Even in all other cases it is preferable, for the sake of comfort, to beam-fill the spaces.

BEARER, a prop, or anything that supports a body in any place; as a wall, post, strut, &c. In guttering, bearers are short pieces of timber for supporting the boarding.

Bearing of a Piece of Timber, the unsupported distance between the two points or props from which it is suspended; or the distance between two props where there is no intervening support.

A piece of timber, having any number of supports, one being placed at each extreme, will have as many bearings, wanting one, as there are supports: thus, a piece of timber extended in length over two rooms as joists, will have three supports and two bearings: here the bearers are the two most distant walls and the partition.

Bearing, at the ends of a piece of timber, in building is the distance which the ends of that piece are inserted in the walls or piers; as joists are inserted at least nine inches in walls, and the lintel or lintels of an aperture, nine inches at least into each pier.

Bearing Wall, or Partition, in a building, is a wall which rests upon the solid, and which supports some part of the building, as another wall or partition, either transversely, or in the same direction. When the supporting wall, and the wall supported, are both in the same direction, the wall supported is said to have a *solid bearing;* but if a wall, or partition, is not supported below throughout its length, it is said to have a *false bearing*, or as many false bearings as there are intervals below the wall or partition.

BEATER, an implement in plastering, used by the labourers, for tempering or incorporating the lime, sand, and hair together; which make the composition called lime and hair, used in first and second coatings, and sometimes, in ordinary rooms, even for finishing coats.

BED-CHAMBERS, or Bed-Rooms, are those in which beds are placed; when very small, they are called bed-closets.

Beds of a Stone, the two surfaces which generally intersect the face of the work in horizontal lines, or in lines nearly so: the higher surface is called the *upper-bed*, and the lower the *under-bed*. In the general run of walling, they are the two surfaces which are placed level in the building. In the parapets of bridges they intersect the facing, most frequently in lines parallel to the road-way, but are level in the thickness. In every species of vaulting, where all the sections of the intrados of a vault are similar figures, or parallel straight lines, the beds are those surfaces which intersect the intrados in horizontal lines. Of this class are the heads of circular domes, which have spherical or spheroidal intradosses; vaults with conic intradosses, and vertical axes; and vaults with cylindrical intradosses and horizontal axes, &c.

Beds of a Stone, in cylindrical vaulting, are those two surfaces which intersect the intrados of the vault, in lines parallel to the axis of the cylinder.

Beds of a Stone, in conic vaulting with a horizontal axis, are those two surfaces which, if produced, would intersect the axis of the cone. The beds of stones, in spherical vaulting, are, or should be, parts of the surfaces of so many cones, ending in a common vertex, as there are courses of stone. If the vault be a hemisphere, the under beds of all the stones in the lowest course or planes, and the upper beds, form part of the surface of a very obtuse-angled cone. In every course of stones, the conic surface formed by the lower beds is that of a cone, with a more obtuse angle than the surface formed by the upper beds of the same course; hence the cones of every successive joint upwards, have their vertical angles continually less, so as to end at last with the axis itself. In vaulting with a conic intrados and vertical axis, the joints form the surfaces of so many distinct cones, which have their vertex in the axis, and which have equal vertical angles, and their surfaces equidistant. In cylindrical, or conic vaulting, with a horizontal axis, the beds of the stones are in planes tending to the axis.

In arching, the beds are called *summerings;* but more properly, *radiations*, or *radiated joints*.

Bed of a Slate, the lower side placed in contiguity with the boarding or the rafters.

Bed Moulding, that portion of a cornice which is situated immediately below the corona.

BEETLE, a large mallet for driving piles, and cleaving wood.

BELECTION MOULDINGS, in joinery, are those which surround the panels, and project without the surface of the framing in doors, or other panelled framing. Belection mouldings are never stuck on the framing, which is frequently the case with those which are within or below the surface. They are used in the best work of grand finishings.

BELFRY, that part of a steeple wherein the bells are hung. This is sometimes called, by writers of the middle age, *campanile.* Bells are generally suspended by means of frame-work, which is supported on stone corbels; sometimes however, the framing is made to bear on a recess formed in the wall, which is the better method, as the vibration caused by ringing has less power to disturb the masonry. Bells for the same reason should be hung as low as practicable.

Belfry, is more particularly applied to the timber-work, by which the bells are supported.

BELL, of the Corinthian and Composite capitals, is the vase or tambour concealed beneath the acanthus leaves, or other ornament: its horizontal section is everywhere a circle; the bottom part rises vertically from the top of the shaft, and proceeds upwards in a straight line to a considerable distance; from thence it changes into a concavity, which terminates with the fillet, in the manner of the scape or apophyge.

BELL-COT, Bell-Gable, or Bell-Turret. A small open turret situate on the apex of the gable of small Gothic churches, generally at the east or west end of the nave, for the purpose of sustaining one or two bells. It is sometimes of an hexagonal or multangular plan, covered with a pyramidal roof, or spire, of which kind there is a beautiful specimen at Corston Church, Wiltshire; it most generally, however, consists of a continuation of a certain width of the gable wall to a considerable height above the apex, the part above which is perforated with one or more arched apertures in which the bells are hung; above this again the roof is finished in the form of a gable, and the whole is surmounted by a finial or cross. Examples of such gables frequently occur; we may instance an elegant one at Skelton, near York. Plain timber bell-cots of square plan and low pyramidal roof, are very common in Essex.

Bell-gables at the eastern extremity of the nave were generally appropriated to the sanctus or sacringe bells, which was rung when the priest pronounced the Ter-sanctus, as also at the elevation of the host.

Bell-Roof, that of which the vertical section perpendicular to the wall, or to its springing line, is a curve of contrary flexure; it being concave at the bottom, and convex at the top. A bell-roof is of that kind of ogee-roofs, called the *sima recta roof.*

BELT, in masonry, a course of stones projecting from the naked, either moulded, plain, fluted, or enriched with pateras at regular intervals, which again may be either plain or fluted.

BELVEDERE, or Look-Out, is a turret, or some part of an edifice raised above the roof, for the purpose of affording a view of surrounding scenery. This term is also applied to single edifices or temples, sometimes erected in gardens and pleasure-grounds, used for the above purpose, as well as to beautify the landscape. Belvederes are very common in Italy and France, and some of them are very magnificent: the most celebrated is that built by Bramante in the Vatican.

BENCH, the table on which joinery for the use of building is prepared. *See* Joinery.

Bench-Hook, a movable pin, passing through a mortise in the top of the bench, for preventing the stuff wrought by the plane from sliding.

BEND. *See* Bending.

BENDA. *See* Fascia.

BENDING, the act of the incurvation of a body from a straight to a crooked form. A piece of timber, such as a plank, may be very conveniently bent, by placing it within a long hollow prismatic trunk, opened only at one end for its insertion; the end through which it is introduced is then shut close, and the one extremity of a steam-pipe having been inserted in a hole in one of the sides or ends of the trunk, all the crevices are shut, and the steam is admitted.

When the plank has remained for a certain time, it may be taken out, and should be immediately bent round the convex surface of an inflexible body, made on purpose; when it has been properly fixed to the body, it is to remain till it is quite cold, or properly stiff, and it will retain its form: after this, it may be taken off and dressed, and lastly fixed in its intended situation. The practice of ship-building proves that plank-wood, of almost any thickness, may be brought to any degree of curvature, by the effect of heat, which seems to mollify the cementing matter, so as to permit the fibres to slide overone another. This may be effected either by boiling or heating; but by heating, it is very difficult to introduce a uniform temperature throughout the parts of the body to be bent. For thick planks a sand-stove, similar to the sand bath used in chemical operations, is employed; but for thin planks, a vapour-stove.

BERNINI, GIOVANNI LORENZO, born 1598, died 1680. His father, Pietro Bernini, a Florentine, was a painter and sculptor of more than common talents. Giovanni's first work in architecture was the great central altar of St. Peter's, remarkable for its twisted columns; its novelty, singularity, and the difficulty of its execution surprised, and had many imitators. By desire of the pope, he adorned with niches the four great piers which support the cupola of St. Peter's. He was employed in the construction of the palace Barberini, particularly in that of the stairs, the great hall, and the principal front. The front has on the lower floor a Doric, very well understood; but the application of so many cornices, and the great arched windows, do not add to the beauty of the structure. The front of the Propaganda Fide is also the work of Bernini: that building threatened ruin, to prevent which he erected a battering basement, which increased at the same time both the beauty and strength of the structure. Urban VIII. wishing to complete the front of St. Peter's, which, according to the design of Maderno, required, at its extremities, two steeples, gave the commission to Bernini. He designed and executed the fine fountain of the Piazza Navona. For Prince Ludovisi, he begun a great palace, which in its principal front presented five faces; this edifice was afterwards converted into a great law-court, called *Curia Innocenziana*, one of the finest palaces in Rome. Alexander VII. gave him many works to execute, among which is the piazza before St. Peter's. By order of this pope, he planned many buildings, among which is remarkable, the palace of Santi Apostoli. The very elegant church, of an elliptic figure, of the Novitiate of the Jesuits, is likewise his. Louis XIV. and Colbert his minister, both admirers of the fine arts, ordered Bernini to make drawings for the palace of the Louvre, for which building the first architects were stimulated; these drawings pleased so much, that the monarch sent him his portrait set in gems, and wrote very engaging letters to the pope, and to Bernini himself, that he might go to France to execute them. In consequence of which, though an old man, he left Rome, and went to Paris, where he was received as if the only man worthy to work for Louis XIV. When Bernini had seen the front of the Louvre, by Perault, he said publicly, that his coming to France was useless, where there were architects of the first class. This trait does more honour to Bernini, than all his abilities as an architect. In fact, with regard to architecture, which he was sent principally for to France, he did nothing. He made the king's bust, and during the eight months he staid in France, he was paid at the rate of five pounds a day; and received at last a gift of 50,000 crowns, and an annual pension of 2000, and a pension for his son, whom he took with him, of 500. When he returned to France, in gratitude to his majesty, he made an equestrian statue, which was placed in Versailles. Under Pope Clement IX. he embellished the bridge of St. Angelo with an elegant iron balustrade.

BEVEL, the oblique angle which the two surfaces of a body make with one another; the name also of an instrument for taking oblique angles. That which is most commonly used, has the stock mortised to receive the blade, which is fixed to the stock by a pin, and made to form any angle by that means: this is particularly useful when one or a few angles are to be taken. In some places, for the want of space, this bevel cannot be applied: to accommodate this circumstance, the blade is made to shift in the stock; so that either part from the pin may be of any given length. The blade is made to pass through the pin by a longitudinal mortise, and fixed fast to the stock by means of a screw, after setting it to the angle When many things are to be wrought to the same angle, an immovable bevel should be used, particularly when the blade, or stock, or both, are incurvated: when the interior angle is used, this bevel is called a *joint-hook*. In working the intradosses, and radiating beds of stone arches, a joint-hook should be employed; one of the sides is incurvated to the arch, and the other straight side is a part of the radius produced: the workman must here observe, that this hook will apply, whatever be the thickness of the stones.

BILLET MOULDING, a moulding peculiar to Norman architecture, consisting of small cylinders placed lengthwise at regular distances in a concave semicircular moulding. The entire moulding consisted generally of two rows or tiers; the cylinders in each tier ranged in such a manner that one cylinder should not come immediately above or below another, but they were placed alternately so that a space was always opposed to a cylinder, and *vice versâ.* A square billet, called also corbel-bole, is likewise found. This differs from the above, inasmuch as the billets are cubes instead of cylinders, and are placed on a flat band, or on the naked walling, their usual office being to support a blocking course.

BINDING JOISTS, those beams in a floor, which support transversely the bridgings above, and the ceiling joists below. *See* BRIDGING FLOORS.

When binding joists are placed parallel to the chimney-side of a room, the extreme one on this side ought never to be placed close to the breast, but at a distance equal to the breadth of the slab, in order to allow for the throwing of the brick trimmer for the support of the hearth.

BINDING-RAFTERS, the same as PURLINS.

BIRD'S-MOUTH, an interior angle cut on the end of a piece of timber, in order to rest firmly upon an exterior angle of another piece.

BIT, a boring instrument, so constructed as to be inserted or taken out of a handle, called a *stock*, by means of a spring. The general form of the handle is divided into five parts, all in the same plane, the middle and two extreme parts being parallel. The two extreme parts are in the same straight line, one of them has a brass end, with a socket for containing the bit, which when fixed falls into the same straight line with the other end of the stock; the farther end has a knob so attached as to remain stationary; while all the other parts of the apparatus may be turned round by means of the projecting part of the handle.

BITS are of various kinds, depending on their use:

Shell BITS are used for boring wood, and have an interior cylindric concavity for containing the core.

Centre BITS, are those which run upon a centre in the middle of the breadth; one extremity is formed into a cutting edge, which cuts the wood across the grain around the circumference, and the radius on the other side of the centre contains a cutting edge, the whole length of this radius, and projects forward from the face of the bit, so as to take out the core, which in the act of boring forms a spiral.

The use of the centre-bit, is to form a large cylindric hole or excavation, having the upper point of the axis of the cylinder given on the surface of the wood. The centre of the bit is fixed into this point, then placing the axis of the stock and bit in the intended direction, the head being placed against the breast, turn it swiftly round by the handle, and the core will be discharged by rising upwards. Centre bits are of different diameters.

Countersinks, are bits for widening the upper part of a hole, in wood or iron, to take in the head of a screw or pin, so as not to appear above the surface of the wood. Countersinks have from two to twelve cutters around the surface of a cone, which contains a vertical angle of ninety degrees. Countersinks for iron have two cutting edges, and those for wood and brass, the greatest number.

Rimers, are bits for widening holes, and for this purpose are of a pyramidal structure, having their vertical angle about $3\frac{1}{2}$ degrees. In the use of rimers, the hole must be first pierced by means of a drill or punch. The operation of a rimer is rather scraping than boring. Rimers for boring brass, have their horizontal sections of a semicircular figure, and those for iron, polygonal.

Taper Shell BITS, are conical within and without, with their horizontal sections crescent-formed. The use of shell-bits is to widen holes in wood.

Besides the above bits, some stocks are provided with a screwdriver, for sinking small screws into wood with greater rapidity that could be done by hand.

BITUMEN, a tenacious matter, used in early Eastern structures, instead of mortar. The walls of Babylon, we are informed, were cemented with this matter. *See* ASPHALTUM.

BLANK DOOR, is that which is either shut to prevent passage, or placed in the back of a recess, where there is no entrance, so as to appear like a real door.

BLANK WINDOW, is that which is made to appear like a real window; but is only formed in the recess of a wall. When it is necessary to introduce blank windows, in order to preserve the symmetry, it is much better to build the apertures as the other real windows, provided that flues or funnels does not interfere, and instead of representing the sashes with paint, real sashes should be introduced: the panes of glass may be painted on the back.

BLINDS, screens forming an appendage to a window, for the purpose either of excluding light, or of preventing persons outside from seeing into the interior of an apartment. Blinds are made of various materials, and of forms too numerous and too well known to need description in this work.

BLOCKING-COURSE, or simply BLOCKING, in masonry, a course of stones laid on the top of the cornice, crowning the walls. The blocking-courses were used by the ancients to terminate the walls of a building, as well as attics. Tho pilastrade of the arch of the Goldsmiths, at Rome, is surrounded with a blocking-course, the height of which is nearly equal to the breadth of the pilasters. The height of that on the Colosseum is nearly once and a half of the pilasters, or nearly equal to the cornice and frieze taken together: the same may be said of the amphitheatre at

Verona. The blocking-course of the temple of Jupiter, at Spalatro, is in height something less that the upper diameter of the column.

Blockings, in joinery, are small pieces of timber fitted in, and glued or fixed to the interior angle of two boards, or other pieces, in order to give additional strength to the joint. In gluing up columns, the staves are all successively glued, and strengthened with blockings; also the risers and treads of stairs, and all other joinings that require more additional strength than what their own joints will give. Blockings are always concealed from the sight.

BLONDEL, John Francis, died 1773, at Metz. He constructed the royal abbey of St. Louis, with a square and street, leading directly opposite to the cathedral; he erected also the town-house, with a building opposite, and farther on barracks, with magazines over them. The fine front of the parliament-house, and the sumptuous palace of the bishop, are also his works. He showed no less ability at Strasburg, where, in 1768, he took the plan of that city, and built there barracks for infantry and cavalry, a hall or amphitheatre, with three tiers of boxes, a royal square, a senate-house, a market, and various stone bridges. This celebrated architect, besides other works executed at Paris and elsewhere, furnished the plates of the last edition of D'Avilen on French architecture, in three volumes, with six hundred plates of the principal edifices in France. These three volumes were to have been followed by five others. He established an architectural school at Paris, in 1744. In the middle of all this work, he became a writer for the French Encyclopedia; but his great work, of universal utility, is the *Course of Architecture*, the result, as he says, of forty years' experience and researches. The work is divided into three parts; the first regards beauty or decoration, and is comprised in two volumes in octavo, with the volume of figures; the second treats of convenience or distribution, and contains the like number of volumes; the third part, on the solidity of building, the author did not live to complete.

BOARD, a piece of timber, of an oblong or trapezoidal section, and of any length. All timbers less than two inches and a half in thickness, and more than four inches broad, may be called boards.

When boards are of a trapezoidal section, that is, thinner on one edge than the other, they are called *feather-edged boards*. Boards broader than nine inches, are called *planks*. Fir boards are called *deals;* these are generally imported into England ready sawed, because they are prepared cheaper abroad, by means of saw-mills. Fir boards, one inch and a quarter thick, are called *whole-deal;* and those full half an inch thick, are called *slit-deal*.

BOARDED FLOORS, are those covered with boards. The operation of boarding floors may commence as soon as the windows are in, and the plaster dry. The preparations of the boards for this purpose are as follow. They should be planed on their best face, and set out to season till the natural sap has been quite expelled. *See* Seasoning of Wood. They may next be planed smooth, shot and squared upon one edge; the opposite edges are brought to a breadth, by drawing a line on the face parallel to the other edge with a flooring guage; they are then guaged to a thickness with a common guage, and rebated down on the back to the lines drawn by the guage. The next thing to be done is to try the joists, whether they be level or not; if they are found to be depressed in the middle, they must be furred up; and if found to be protuberant, must be reduced by the adze: the former is more generally the case. The boards employed in flooring are either battens, or deals of greater breadth. With reference to quality, battens are divided into three classes; the best kind is that free from knots, shakes, sap-wood, or cross-grained stuff, and well matched, that is, selected with the greatest care; the second best is that in which only small but sound knots are permitted, and free from shakes and sapwood; the most common kind is that which is left after taking away the best and second-best.

With regard to the joints of flooring-boards, they are either quite square, plowed and tongued, rebated, or doweled: in fixing them they are nailed either upon one or both edges. They are always necessarily nailed on both edges when the joints are plain or square, without dowels. When they are doweled, they may be nailed on one or both edges; but in the best doweled work, the outer edge only is nailed, by driving the brad obliquely through that edge, without piercing the surface of the boards, so that the surface of the floor, when cleaned off, appears without blemish. In laying boarded floors, the boards are sometimes laid after one another; or otherwise, one is first laid, then another, leaving an interval something less than the breadth of three, four, or five boards in contact; so that if the first and sixth boards are laid, there will be an interval something less than the breadth of four boards. Now place the four intermediate boards in contact with each other, and the two outer edges in contact with the edges of the first and sixth boards already laid. The space left, as above mentioned, being somewhat less than the width of four boards, will not allow this number to lie flat, but will cause them to assume the form of an arch, having the under parts of the edges in close contact, while the upper parts will remain open. In order, therefore, to bring them to a level and the joints close, two or more workmen must jump upon the ridges till they have brought the under sides of the boards close to the joists, when they are fixed in their places with brads. In this last method the boards are said to be folded. This mode is only adopted when the boards are not sufficiently seasoned, or suspected to be so. In order to make close work, it is obvious that the two edges, forming each of the three joists of the second and third, third and fourth, fourth and fifth boards, must form angles with the faces, each less than a right angle. The eleventh board is fixed as the sixth, and the seventh, eighth, ninth, and tenth, are inserted as the second, third, fourth, and fifth; and so on till the completion. The headings are either square, splayed, or plowed and tongued. When it is necessary to have a heading in the length of the floor, it should always be upon a joist, and one heading should never meet another. When floors are doweled, it is more necessary to place dowels over the middle of the inter-joist than over the joists, in order to prevent the edge of the one board from passing that of the other. When the boards are only bradded upon one edge, the brads are most frequently concealed, by driving flooring-brads slantingly through the outer edge of every successive board without piercing the upper surface.

In adzing away the under-sides of the boards opposite to the joists in order to equalize their thickness, the greatest care should be taken to chip them straight, and exactly down to the rebates, as the soundness of the floor depends on this. Boards employed in flooring houses are from an inch to an inch and a half thick. The best floors are those that are laid with the best battens.

BOARDING-JOISTS, are those joists in naked flooring to which the boards are fixed.

Boarding, *Luffer*. *See* Luffer-Boards, and Lever-Boards.

Boarding for Pugging or Deafening. *See* Sound-Boarding.

Boarding for Slating, are boards nailed to the rafters for fixing the slates. They are in general about three-quarters or seven-eighths of an inch thick, the sides are most commonly rough, the edges either rough, shot, plowed and tongued, or rebated, and sometimes sprung, that is, beveled, so as to prevent the rain from running through the joists. Boarding for slates may be made so as to take away the lateral pressure from the walls, by disposing the boards in the form of a truss. Upon the lower edge of the boarding must be fixed the eaves-lath or board, and also against all walls that are either at right angles to, or forming an acute angle with the ridge, or a right or obtuse angle with the wall-plate. The eaves-lath at the bottom is for raising the lower ends of the under row of slates which form the eave. Those placed against walls in the positions now mentioned are for raising the slates, in order to make the water run off from the wall, as otherwise it would make its way below the lead and down the joint, between the end of the slates and the wall. Boarding for slates should be yellow deal without sap, which, as well as weather-boarding, is measured by the superficial foot, and valued in the bill by the square of one hundred superficial feet.

Boarding for Leaden Platforms and Gutters, is seldom less than one and one eighth, or one and one-quarter inch thick, most frequently with rough joints only.

Boarding for Lining Walls, is commonly about five-eighths or three-quarters of an inch thick, plowed and tongued together.

Boarding for outside Walls. *See* Weather-Boarding.

BOARDS, *Listed*, are those reduced in their breadth by taking away the sap-wood.

Boards, *Lever*, are those placed in the opening of an aperture made to turn on centres at the ends, in one movement, so as to admit or exclude the air at pleasure.

Boards for the Valleys of a Roof. *See* Valley-Boards.

BOASTER, or Boasting-Tool, in masonry. *See* Masonic Tools.

BOASTING, in stone-cutting, is pairing the stone with a broad chisel and mallet, but not in uniform lines.

Boasting, in carving, is the rough cutting round the ornaments, so as to reduce them to their contours or outlines, before the incisions are made for forming the raffels or minute parts.

BODY of a Niche, is that part of the recess which has its superficies vertical. If the lower part is cylindrical, and the upper part spherical, the lower part is the *body*, and the upper part is called the *head*. *See* Niche.

Body of a Room: where there are recesses in the ends or sides, the principal part, from which the recesses are made, is called the body.

Body Range of a Groin. When two openings intersect each other, the widest is called the *body range*. *See* Groin.

BOFFRAND, Germain, an architect born at Nantes, in 1667, and died at Paris, aged eighty-seven. He built several grand edifices, and executed a number of bridges, canals, &c. He also wrote on the principles of architecture.—*D'Argenville Du Fresnoy.*

BOLSTERS. *See* Balusters of the Ionic Capital.

BOLT, in joinery, an iron fastening for a door, moved by the hand, and catching in a staple or notch to receive it.

Bolts are of various kinds: *plate*, *spring*, and *flush bolts*, are for fastening doors and windows.

There are also round bolts of various sizes, for large doors and gates, and some curious brass bolts for folding-doors, which have plates set on the edge of the door, extending the whole length, so that by a turn of the knob-handle in the centre of the door, the bolts shut up and down at the same time; and by turning the contrary way the bolts are relieved, and both doors open at once, without further trouble; these are mostly used when it is necessary to lay two rooms into one. As these bolts are expensive, there are others nearly on the same principle, denominated *spring-latch bolts*, about thirteen inches long, with a stout plate: two of these are required to a pair of doors, one at the top, and the other at the bottom: each bolt is shut by a spring, against which the right hand presses, and being shut, both are secured.

Bolt of a Lock, the iron part by which it is fastened into the jamb, in the act of turning it by the key. Of these there are two kinds: one, which, in the closing of the door, shuts of itself, and is called a *spring-bolt;* the other, which is shut by the key, is called a *dormant-bolt.*

Bolts, are also large iron cylindrical pins, with round knobs at one end of a greater diameter, and a slit at the other end, through which a pin or fore-lock passes, for making fast the bar of a door, window-shutter, or the like. These are particularly called *round-bolts*, or *window-bolts.*

Bolts of Iron, in carpentry, are those square or cylindrical pins which pass through two or more pieces of timber, with a broad knob at one end, and a nut screwed to the other, for securing them together. Bolts of this description must always be proportioned to the size and stress of the timbers so connected.

BOMON, in Grecian antiquity, an altar to a god.

BONANNO, an architect who flourished about 1174. He built the famous tower at Pisa, in conjunction with Guillaume, a German.—*Felebien.*

BONARROTTI, Buonaroti, or Bonarota, Michael Angelo, a celebrated painter, sculptor, and architect, born at Chiusi, in Tuscany, in the year 1474. His talents were so early developed, that he is figuratively said to have been *born a painter;* and his parents, observing the turn of his genius, put him under the tuition of Dominico Ghirlandaio, whom he soon surpassed; for at the age of sixteen he executed some pieces rivaling even those of antiquity. Under the auspices of that great patron of the arts, Lorenzo di Medicis, he established an academy for painting and sculpture at Florence; which on account of the troubles of the house of Medici, he afterwards removed to Bologna. At the age of twenty-nine, he was employed by Pope Julius II. to construct a grand mausoleum; but before it was finished, he returned to Florence in disgust, on account of some pecuniary matters. From Florence he would have gone to Constantinople, whither he had been invited by the grand signor, to build a bridge from that city to Pera, had he not been prevailed upon to return to Rome by Soderini, the gonfalonier, or holy standard-bearer. This officer recommended him to his brother, Cardinal Soderini, who introduced him to the pope, at Bologna. Here he met with an envious competitor, in the person of Lazzari Bramante d'Urbino, who had been employed by the pope, and was unwilling to share his honours and profits with another. He endeavoured to excite a spirit of discontent in Bonarrotti, by insinuating that the pope was too much offended at his former conduct, to permit him to resume the building of the mausoleum; and to the pope he represented, that as Bonarrotti was a painter, he might be more advantageously employed in painting the arch of the Sextine chapel, at Rome, than in any other work. It should seem from this, that Bonarrotti had not yet displayed those talents as a painter, with which he afterwards fascinated the world; for it is certain that Bramante, considering him as a dangerous rival, meant nothing less than his complete disgrace. Bonarrotti, however, though contrary to his inclination, painted the arch, so much to the pope's satisfaction, that he was taken into greater favour than ever.

Pope Leo X. ordered him to make a design for the front of the church of St. Laurenco, at Florence, for which also several other architects had given a drawing, but Bonarrotti's being preferred, he was sent to Florence to superintend the building; the vestry of which is reckoned among his best productions. In this city he also built the Medicean Library, the niches and staircase of which are of very curious construction.

On the death of Sangallo, in 1546, the pope, Paul III., appointed Bonarrotti architect of St. Peter's, at Rome, an appointment which he at first declined; but being vested with unlimited powers for carrying on the work, he not only accepted it, but even refused any remuneration for his labours. Sangallo had left a model for finishing the building, which had cost 4184 Roman crowns, and occupied some years in making; according to which the edifice itself could not have been completed in fifty years and upwards. The first use Bonarrotti made of his extensive commission was to set this model aside; and in fifteen days he produced another, for the small cost of twenty-five crowns, by which he proposed to raise that venerable pile with far greater facility and expedition, and with more majestic grandeur, than the plans of any of his predecessors could have given it. The four great piers, by which the cupola was to be supported, had been erected by Bramante, but they were so very weak, that succeeding architects had found it necessary to strengthen them. Bonarrotti thinking them still insufficient for the purpose, he enlarged them to their present gigantic size, and contrived to leave voids, like wells, in them, probably for the purpose of keeping them dry. Similar vacuities he left in the principal walls, through which he carried a winding staircase, so wide, and upon so gentle an ascent, that he was enabled to convey materials to the height of the level of the arches on beasts of burden. The great cornice over the arches differs from the common cornice, in having less projection and fewer members; and the imposts of the pilasters have a greater projection. In each of the two curved extremities of the transept, it had been intended by former architects to place eight tabernacles, or altars; but Bonarrotti reduced their number to three, and threw an arch over them, subdivided into a few well-proportioned compartments; and to prevent any alteration in his design by future architects, he built the whole so solid that it could not conveniently be changed. He lived, however, to see the building carried to the height of the tambour on which the cupola was to be laid, when, on account of his age, his friends urged him to frame a model of the dome, lest what he had already done should be spoiled by the incapacity or whim of a succeeding architect. With this request he complied, and formed one of clay, which he afterwards caused to be made of more durable materials, by Giovanni Farnese. This model was universally approved, and finally executed in the pontificate of Sextus V. While Bonarrotti was engaged in the building of St. Peter's, the officers called *conservators*, in the time of Paul III., resolved to reduce the Capitol to a useful and convenient shape, for which purpose they applied to Bonarrotti. He accordingly began the Senators' Palace, in the centre, ascended from without by a double flight of steps, landing on a level introduced between the two flights. The wing, denominated the *Conservatorium*, is entirely from his design. The ground-floor consists of an external and an internal portico, supported by sixty-eight columns of the Ionic order, surmounted with that elegant capital, the invention of which is attributed to himself. There is, however, a great blemish in this part of the building; for, in order to give a due proportion to the width of the portico, the columns are niched into the wall, an expedient never productive of beautiful effect. About this time, he also finished the Farnesian Palace, which had been begun by Sangallo. He likewise designed and executed the gate, called *Porta Pia*, the architecture of which is not very regular; of many other gates designed by him, it is uncertain whether any of them were ever constructed, but they are all of the same irregular taste. The great central hall of the Dioclesian baths was converted into a church from a design of his; as were the chapel of the Strozzi family at Florence, and the college of the Sapienza. except the part where the church is situated; it is upon the whole a very fine edifice.

Old age having at length rendered this great architect incapable of personal exertions, Nanni Bigio was secretly commissioned by the pope to superintend the building of St. Peter's, but with strict orders to adhere minutely to the plans and model of Bonarrotti, who died in 1564, in his 90th year, before the dome was completed. His body was transported to Florence by order of Comes de Medicis, where it received the most splendid funeral honours, and a superb mausoleum was erected to his memory, at the expense of the grand duke.

BOND, in building, in a general sense, is the manner of making two or more bodies fast together.

Bond, in masonry, or brickwork, is the disposition of stones or bricks in building. It is a principle in every kind of bond to prevent vertical joints falling upon one another. When a course of masonry has any number of stones placed at regular intervals in the length of that course, and the lengths of the stone placed in the thickness of the wall, and when there are two or more intermediate stones in the same course, with their lengths placed horizontally on the facing or surface, between each two of the former stones: this kind of bond is called *header and stretcher*. The stones which have their length placed in the thickness of the wall are called *headers*, and those which have their longest horizontal dimensions placed in the exterior, or front, are called *stretchers*.

Where masonry consists of rubble-work, and where the stones are not disposed in courses, the jambs of apertures, should there be any, are generally built with ashlar; every second stone in the height of each jam is inserted so as to pass through the whole thickness of the wall; and the horizontal dimension on the facing of every intermediate stone is much greater than that of those which are inserted the whole thickness. The stones that are inserted the whole thickness of the wall are called *heading jambs*, and the intermediate stones which have their length placed horizontally in the face, are called *stretching jambs*.

Bond, *Heart*, in masonry, is, when two stones which appear in the front and rear of a wall meet in the centre of it, and when a third stone is placed over the joint, in order to bind the facing and backing together, where otherwise it would be expensive to insert stones the whole thickness of the wall.

Bond-Stones, are those used in uncoursed rubble walling, that have their longest horizontal dimensions placed in the thickness of the work: these should be placed at regular intervals, both altitudinally and horizontally, so that every stone of one row may fall between every two of each adjacent row. Bond-stones that are inserted the whole thickness of masonry are called *perpends* or *perpend-stones*. Bond-stones only differ from headers in this, that bond-stones are used to bind rubble and brickwork, and headers are laid in regular courses, with an equal number of headers between every two stretchers.

Bond, *English*, is, when every two courses of bricks with the length of the bricks inserted in the thickness of the wall, has one course between them, with their lengths placed horizontally in the front of the wall: the courses in which the length of the bricks is placed in the thickness of the wall, are called *heading-courses;* and those which have the length of the bricks placed horizontally in the face of the work, are called *stretching-courses.*

Bond, *Flemish,* in brickwork, is that which has one header between every two stretchers, and one stretcher between every two headers throughout the same course.

This is considered the neatest and most beautiful; but is attended with great inconvenience in the execution, and in most cases does not unite the parts of a wall with the same degree of firmness as the English bond.

Those who are desirous to enter into an examination of the comparative merits of these two species of Bond, will be gratified in the perusal of Mr. G. Saunders' Tract on *Brick-bond;* it is sufficient in this place to observe generally, that whatever advantages are gained by the Flemish Bond in tying a wall together in its thickness, are lost in the longitudinal bond; and *vice versâ.* To remove this inconvenience, in thick walls, some builders place the bricks in the core at an angle of forty-five degrees, called *herring-bone*, parallel to each other throughout the length of every course, but reversed in the alternate courses; so that the bricks cross each other at right angles. But even here, though the bricks in the core have sufficient bond, the sides are very imperfectly tied to the core, on account of the triangular interstices formed by the oblique direction of the internal bricks against the flat edges of those on the outside.

With respect to English bond, it may be remarked, that as the longitudinal extent of a brick is nine inches, and its breadth four and a half; it is usual—to prevent two vertical joints from running over each other at the end of the first stretcher from the corner, after placing the return corner stretcher, which becomes a header in the face that the stretcher is in below, and occupies half the length of this stretcher—to place a quarter brick on the side, so that the two together extend six inches and three-quarters, leaving a lap of two inches and a half for the next header. The *bat* thus introduced is called a *closer.* A similar effect might be obtained by introducing a *three-quarter bat* at the corner of the stretching course, and then the corner header being laid over it, a lap of two inches and a half will be left at the end of the stretchers below, for the next header, which being laid, the joint below the stretchers will coincide with its middle.

Bond-Timbers, are those horizontal pieces, built in stone or brick walls, for strengthening the building, and securing the battening, lath, and plaster: also the horizontal mouldings, or finishings of wood.

Bond-timbers disposed in tires, at altitudes corresponding to those of the horizontal mouldings, in the finishing of apartments, as behind skirtings, bases, and surbases, are called *common-bond;* the scantling of which is generally four inches broad in the thickness of the wall, and two inches and a half thick in the altitude of the wall, so as to be equal in thickness to a course of bricks. Bond-timbers placed in or near the middle of the story, of eight inches wide in the thickness of the wall, and five inches and a half deep (or about the length and thickness of two bricks) in the altitude of the wall, are called *chain-timbers*, or *chain-bond.* In brick buildings, when the lintels of a range of windows are considerably below the ceiling, the lintels may be continued through the walls as bond-timbers: in this case the thickness of the bond-timbers should be regulated by the necessary thickness of the lintels. When bond-timbers are also the wall-plates of floors or roofs, their scantling is generally the same as that of the chain-bond. The whole of the plate and chain-bond should be continued on one side of each internal wall, where the funnels or flues permit, as well as on the inside of the external walls, and properly notched and fastened at the angles. Bond-timbers will, in most cases, prevent a building from cracking, where the foundation is infirm: they are easily executed in brickwork, or in coursed stone-work; but in rubble-stone it is difficult, as the work must be leveled at every height in which they are disposed; for which reason plugging is preferable in such work. Plugging has one very material advantage over bond-timbers, that in case of fire, the walls are less liable to tumble or warp, for they are not reduced in their thickness; but this must be the case where bond-timbers are employed, as they form a part of the thickness of the walls themselves. Bond-timbers should be avoided in damp situations, such as basements of houses, as they are liable to rot and thus render the buildings insecure.

Within the last few years, a practice has arisen of introducing iron-hoop in place of bond-timber. Several strips or lengths of hoop are laid on at every four or five courses of bricks, and worked in as bond-timbers are—sometimes they are placed at intervals of three or four feet in the height of walls. It is pretended that great advantages, as regards danger from fire, result from this practice, but we are strongly inclined to the opinion that whatever good may arise from the incombustible nature of the material, is more than counterbalanced by the absence of the same strength as that given by timber-bond.

Bonds, are all the timbers disposed in the walls of a house, such as bond-timbers, lintels, and wall-plates. *See* Fir, in Bond.

Boning, in carpentry and masonry, is the act of making a plane surface by the direction of the eye. It is by boning with two straight edges that joiners try up their work, whether it be in or out of winding, that is, whether the surface be twisted or a plane. Many country masons and bricklayers level the tops of their walls without an instrument, by boning them with the contour of the surface of the sea, where it is not apparently terminated with land on the other side. This mode comes so near the truth, even though the building be raised a considerable distance above the surface of the water, that the difference cannot be perceived upon the common levels.

BONOMI, Joseph, an architect, born in Italy, and died in 1808. He was an associate of the Royal Academy in London. He built several mansions and villas, and was esteemed an artist of superior ability.

BOOTH, a temporary wooden building.

BORDERS, are three pieces of wood which are generally mitered together round the slab of a chimney, flush with the surface of the floor.

BORING, the act of perforating a solid. For the purpose of boring wood, joiners use a centre-bit, nose-bit, shell-bit, and auger-bit, each kind of which is of many sizes. *See* Bit.

BORROMINI, Francisco, born in 1599, in Bissone, diocese of Como. His father was an architect, and much employed by the Casa, or family of Visconti. Francisco was sent, at an early age, to Milan, to study sculpture; and, at seventeen years of age, he went to Rome to be instructed in architecture, by his relation, Carlo Maderno, who also had him instructed in geometry. Maderno set him to take fair copies of his drawings, and made him execute the cherubim on either side of the small doors of St. Peter's, which, with the drapery and festoons over the arches, are the only works of Borromini's chisel. He delighted in painting, and some of his pictures are very good, among which is one of the fathers della Chiesa Nuova, in Rome. On Maderno's death, Borromini was made architect of St. Peter's and remained a little while under the direction of Bernini; but becoming first emulous of him, then envious, and finally his enemy, he endeavoured to get more commissions for work, and in fact was employed in a vast number of buildings, where, trying to surpass Bernini in novelties, he laid aside the common rules, and bewildered his imagination and talents in a labyrinth of extravagances. At the bottom of the court of the Sapienza, he built a church with a concave front, on a polygonal plan, with its sides alternately concave and convex; the exterior of the cupola, which is surrounded above by a balustrade, has a similar figure; the convex part being formed into steps, interrupted by buttresses. But the lantern is still more whimsical, having its vase in a zig-zag form, on which is erected a spiral staircase, sustaining a crown of metal with a ball and cross at top. However, the greatest delirium of Borromini, is the style of the church of San Carlino alle Quattro Fontane. So many right, concave, and convex lines, so many columns upon columns of different proportions, with windows, niches, and sculptures, in so small a front, cannot but excite pity for the derangement of the mind by which they were projected. The oratory of the fathers della Chiesa Nuova, has likewise its front composed of orbiculated and right lines; where everything is deranged and out of order: undulating coronæ, which, instead of helping the discharge of the water, retain it; delicate mouldings under great weights; mouldings of a strange and new form; breaks only in the architrave of the entablature; prominences, contortions, and every kind of absurdity. There appears, nevertheless, in this building a something harmonious and handsome, but better adapted (as Bernini said) to a country-house or villa, than to the second edifice of a city. The flat arch of the oratory is rather wonderful, being of a much larger size than that of Santa Martina, made by Cortona. Though it supports above it the weight of the great library, the wall of one of its larger sides is not flanked with counterforts, but stands insulated, fronting the street. The habitation of these fathers of the oratory, is one of the best buildings of Borromini, yet it is not without its whimsicalities, in the porticos and loggias of the cloisters, supported by a single Composite pilaster: the tower of the clock is likewise mixtilinear. The best work of Borromini, is the front of St. Agnes, in the Piazza Navona. The king of Spain, wishing to modernize and enlarge his palace at Rome, Borromini was commissioned to do it; for which purpose he made a drawing, and though it was never executed, it gave such satisfaction, that the monarch honoured the author with the cross of St. James, and made him a present of 1000 dollars. Pope Urban VIII. likewise created him knight of Christ, gave him 3000 dollars, and settled an annual pension on him. Part of the palace Barberini; the whole of the monastery and church of the Madonna de' Sette Dolori, at the foot of San Pietro Montorio; and the palace of Rufina, at Frescati, were built by this architect; he also modernized the palace Falconnier, and embellished that of Spada. Besides these, he executed many other works, and sent to various countries designs of buildings, which produced him fame and riches. Borromini was one of the first men of his age for the elevation of his genius, and one of the last for the ridiculous use he made of it. The frenzy which he had displayed in scientific pursuits, extended, as he advanced in years, to moral objects; and he at length died, a lunatic, by his own hands, in 1667.

BOSS, a projecting ornament placed on the intersections of groins, usually carved in the form of a leaf or other ornamental foliage, or, in the later periods of Gothic architecture, richly sculptured with armorial bearings. Bosses were employed in vaulting, not for mere ornament, but formed an essential feature in the construction, as they tended by their weight to retain the voussoirs in their respective positions, and to confine the arches, so as to counteract any tendency to upward motion; they formed, in fact, the key-stones of the vault, binding the whole work firmly together.—Bosses are used in other situations as ornaments to mouldings, &c.

Boss, among bricklayers, a wooden vessel in which the labourers put the mortar to be used in tiling. It has an iron hook, with which it is hung on the laths or on a ladder.

BOSSAGE, the projection of stones laid rough in a building, to be afterwards carved into mouldings or ornaments. Bossages are also projecting rustic quoins in a building, with indentures or channels at the joints. The channels are sometimes square, sometimes chamfered, or beveled, and sometimes circular.

BOULANGER, Nicholas Anthony, an architect, born at Paris, 1722, and died in 1759, aged thirty-seven. He became so eminent in architecture and mathematics, though entirely of his own study, that he was made engineer to the baron of Thiers, and afterwards appointed superintendent of the highways and bridges. He was author of some articles in the Encyclopedia, and several other works.

BOULDER WALLS, are those built of round flints, or pebbles, laid in strong mortar, used where the sea has a beach cast up, or where there are plenty of flints.

BOUND MASONRY. *See* Stone Walls.

BOUNDARY COLUMN. *See* Column.

BOW, a part of some buildings projecting forward from the face of the wall, and raised from a plan generally on the arc of a circle, so as to form the segment of a cylinder. It is sometimes, however, raised from a plan consisting of three sides, two external obtuse angles, formed by each two contiguous sides, and two internal obtuse angles, formed by the wall and the sides which adjoin thereto. A bow. raised from a polygonal plan, with three, four, or five vertical sides; or a prism so disposed, is termed a *canted* or *polygonal bow*. In some buildings the bow is carried to the whole height, in others, only to one or two stories.

Bow, among draughtsmen, denotes a beam of wood or brass, with three long screws that direct a lath of wood or steel to an arch, used in drawing flat arches, or in projections of the sphere.

BOW-WINDOW, a window projecting from the general face of a building on a curvilinear plan, and rising from the ground or basement. *See* Bay and Oriel Windows.

BOX, in its most general acceptation, denotes a case for holding anything.

Box of a Bib-Saw, two thin iron plates fixed to a handle. In one of the iron plates is an opening to receive a wedge, by which it is fixed to the saw.

Box for Mitering. *See* Mitre-Box.

Box of a Theatre, one of the compartments of a gallery.

Boxings of a Window, are the two cases, one on each side of the window, into which each of the adjacent shutters is folded, when light is requiro in the room. The leaves which appear in the front of each boxing, are denominated *front shutters*; and those in the back, are called *back flaps*. In order to estimate the breadth of flaps, and the depth of boxing-room; suppose each boxing to be filled with the shutters which are to cover half the breadth of the opening: add the thicknesses of all the folds together, with as many one-sixteenths of an inch as there are breadths, and the sum is the depth of the boxing. Thus, suppose a window to be four feet wide, placed in a brick wall eighteen inches thick, let the sash-frame be six inches thick, and placed four inches and a half from the face of the wall, or the breadth of a brick; this will reduce the wall to seven inches and a hal.

thick; to this add the necessary thickness for lath and plaster, about two inches, gives nine inches and a half for the breadth of the shutter: nine inches and a half will be contained in twenty-four inches, or the half of four feet, twice, with a remainder; therefore there must be three leaves or folds in a shutter, viz., a front leaf, and two back flaps. The front leaf should be necessarily the whole breadth of the boxing, or nine inches and a half; and the two back flaps between them, the remainder between nine inches and a half and twenty-four inches, that is, fourteen inches and a half. The back flap should always be the least, in order that the shutters may go freely into the boxing; the middle one, therefore, may be eight inches, and the back one six inches and a half, for $9\frac{1}{2}+8+6\frac{1}{2}=24$; but if the flaps are rebated into one another, which is most commonly the case, whatever be the breadth of the rebate and the number of them, then so much more ought to be added to the whole breadth. In the present example, the three folds will require two rebates; let each rebate be a quarter of an inch, then, instead of reckoning twenty-four, it must be twenty-four inches and a half, and as no alteration can be made on the front flap, it must be added to one of the back flaps; the three flaps may therefore stand thus, $9\frac{1}{2}+8\frac{1}{2}+6\frac{1}{2}=24\frac{1}{2}$. Besides this allowance in breadth, there is another for the rebate at the meeting in the middle of the window of the two back flaps; if this rebate be a quarter of an inch also, it may be added to the shutters on either side of the window, or it may be divided in any proportion between; let it be equally divided, then the breadth of the flaps may stand thus, $9\frac{1}{2}+8\frac{1}{2}+6\frac{5}{8}=24\frac{5}{8}$. To find the thickness, suppose the front flap to be one inch and a half, the two back flaps each one inch and a quarter, then $1\frac{1}{2}+1\frac{1}{4}+1\frac{1}{4}+\frac{3}{16}=4\frac{3}{16}$, for the depth of the boxing-room. If there is a back-lining, that must be taken also into the account. When shutters are in many folds, they are troublesome to shut, and this must always be the case in thin walls, or with wide windows. To remedy this, the architraves are either made to project considerably before the plaster, or the lath and plaster are brought to a considerable distance from the rough wall.

BOYLE, Richard, Earl of Burlington. Never was protection and great wealth more generously and more judiciously diffused than by this great person, who had every quality of a genius and an artist, except envy. He spent great sums in contributing to public works, and was known to choose, that the expense should fall upon himself, rather than that his country should be deprived of some beautiful edifices. His enthusiasm for the works of Inigo Jones was so active, that he repaired the church of Covent-Garden, because it was the production of that great master. With the same zeal for pure architecture, he assisted Kent in publishing the designs for Whitehall, and gave a beautiful edition of the *Public Baths*, from the drawings of Palladio, whose papers he procured with great cost. Besides the works on his own estate at Lonsborough, in Yorkshire, he new-fronted his house in Piccadilly, built by his father, and added the grand colonnade within the court. The other works designed by Lord Burlington, were the dormitory of Westminster school; the Assembly-Room at York; Lord Harrington's at Petersham; the Duke of Richmond's house at Whitehall; and General Wade's in Cork street.

BRACE. *See* Truss, and Angle-Braces.

BRACKET, a small support fixed against a wall to sustain anything. Brackets are composed out of various materials—wood, stone, metal, &c., and may be made susceptible of any ornamentation.

Bracket for Shelves. When the shelves are broad, the brackets are small trusses, consisting of a vertical piece, a horizontal piece, and a strut; but when the shelves are small, the brackets are solid pieces of boards, most commonly with an ogee figure on their outer side.

Brackets in Gothic architecture are usually of very elegant design, and are mostly sculptured to represent angels, heads, foliage, and many other beautiful devices. They are used to support statues under niches, pillars which have their basis on a height above the ground, and for various other purposes.

Brackets for Stairs, are sometimes used under the ends of wooden steps, next to the well-hole, by way of ornament, for they have only the appearance of support.

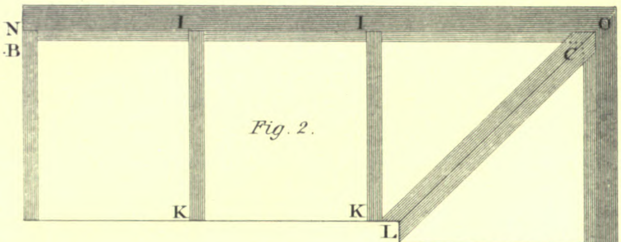
BRACKETING, a disposition of small pieces of board, equidistantly placed in the angles formed by the ceiling and the walls of an apartment, with their planes at right angles to the common intersection, so as to be partly upon the ceiling and partly upon the walls; their faces or hedges being so arranged, as to touch any level line that is everywhere equally distant from the wall or walls which may form the perimeter or circumference of the apartment. The level line equidistant from, or parallel to the walls, will either be a straight line or curve, according as the walls are carried upwards from a straight or circular plan.

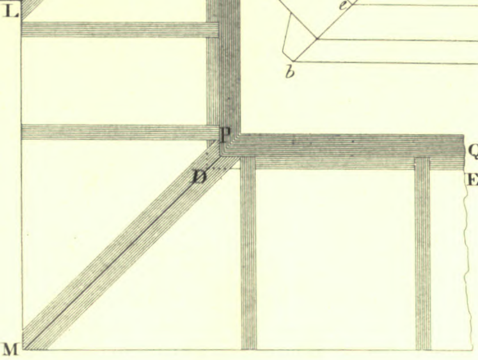
Bracketing is necessary in supporting the lath and plaster of cornices and coves. The edges of the brackets to which the lath is fixed, are so formed as to be as nearly equidistant from the surface of the intended cornice or cove as possible, and may be placed about an inch within the said surface. Their common distance from middle to middle may be about a foot or fourteen inches. Small cornices require no brackets; but in large cornices, and particularly in coves, they are indispensably necessary, to save the plaster. In apartments formed by walls with plain surfaces, besides the brackets which are arranged at right angles to the line of concourse of the ceilings and the walls, there are other brackets placed, one in each angle, in a vertical plane, bisecting the angle formed by each two adjacent sides of the room, at the mitre of the cornice, denominated *angle-brackets.*

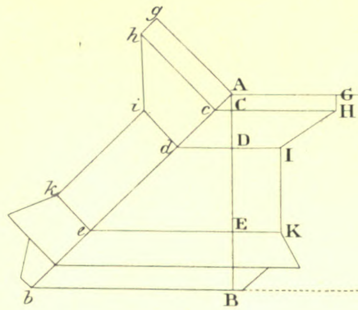
Let Fig. 1 be the plan of the end of the room, the internal side being A B C D E F G H, and let there be a break, C D E F, as the breast of a chimney. Let Fig. 2 be part of the plan enlarged, showing an internal angle at C, and an external angle at D: let N O P Q represent the face of the rough wall, and B C D E the finish of the plaster; then the space between N O and B C, O P, and C D, P Q and D E will be the space for the battening, lath, and plaster. Let Fig. 3 be a section of the cornice, intended to be run by the plasterer, and let the shadowed part be the form of the common brackets: let I K, I K, &c., Fig. 2, be the projections or seats of the common brackets, each equal to A B, Fig. 3, and let L O and M P be the seats of the angle-brackets; L O being that of the internal bracket, and M P that of the external bracket. Besides the projection beyond the finishing surface of the plaster, there must be added the thickness of the battening, lath, and plaster. As the lath terminates upon the angle-brackets, and as they require to be ranked in the same surface with the edges of the common brackets, they are here made double, or in two thicknesses. Let it now be required to find the form of the brackets, either for mouldings, as Fig. 3, or for a cove: make A B, Figs. 4 and 5, equal to the projection of the common bracket; draw B *b* perpendicular and equal to A B, and join A *b*: place or draw the form of the bracket with the ceiling edge of it upon A B: take any number of points, G, H, I, K, &c., in the ranging edge of the bracket, at the concourse of every two lines, or in the curve, and draw G A, H C, I D, K E, &c., perpendicular to A B: produce H C, I D, K E, &c., to meet A *b* in *c*, *d*, *e*, &c., draw A *g*, *c h*, *d i*, *e k*, &c.,

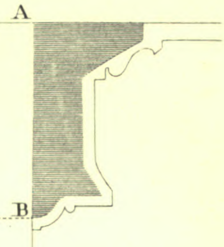
BRACKETING.

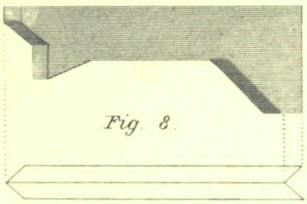
Fig. 1.

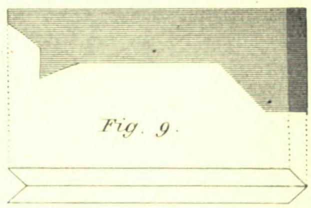


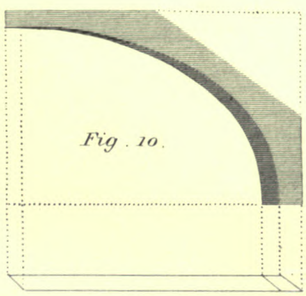


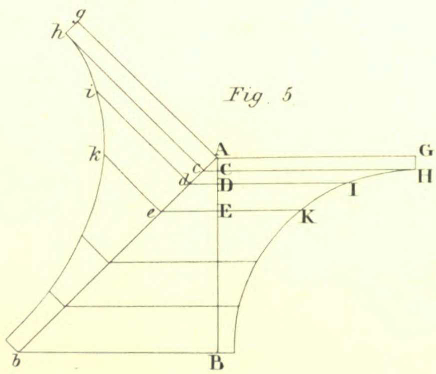












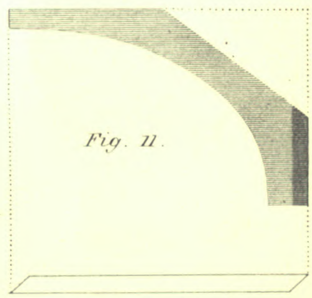


Fig. 6.

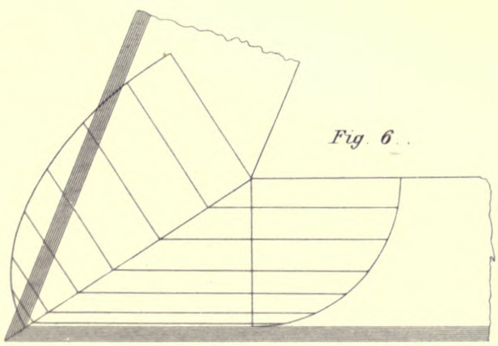
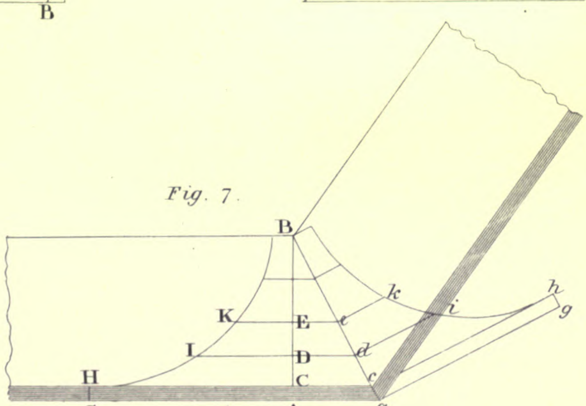


Fig. 7.



...wn by M A Nicholson.
...ed. by Thos. J Hay.

Engd by R. Thew.

perpendicular to A b, and make A g, c h, d i, e k, &c., each equal to A O, C H, D I, E K, &c., and join the points g, h, i, k, &c. if the ranging edge of the common bracket is made of straight lines; or draw a curve if the common bracket is a cove: then will A g, h, i, k, &c. to b, be the form of the angular bracket, whether for the external or internal angle, and g, h, i, k, &c., the ranging edge; the parts G H and g h are supposed to be within the finished surface of the plaster. Fig. 6 shows the bracket for an acute angle, and Fig. 7 for an obtuse angle; but except the quantity of the angle, the method of finding the forms is exactly the same as in Figs. 4 and 5. The common bracket of Figs. 4, 5, and 7, is laid down upon the ceiling line; but that of Fig. 6 is laid down upon the base line. In the common brackets of Figs. 5 and 6, the projections and heights are equal; but in Fig. 7, the height B C is greater than the projection A B: the shadowed parts of Figs. 6 and 7 represent the thickness of the battening, lath, and plaster. Figs. 8, 9, 10, 11, show the ranging both for external and internal angles. *See* RANGING.

BRACKETING, for lath and plaster, is variously named according to the figure of the ceiling which it sustains: as *groin-bracketing*, *spandrel-bracketing*, &c. In all cases the brackets are so disposed, that their edges will be parallel to the surface of the plaster when finished: the distance between the edges of the brackets and the surface of the plaster, is, in general, about three-fourths or seven-eighths of an inch, which includes the space for battening, lath, and plaster. *See* COVE, DOME, GROIN, PENDENTIVE, SPANDREL, SPHERICAL, and SPHEROIDAL BRACKETING.

BRADS, in joinery, are slender nails without spreading heads, except a projection from one of their narrow sides. The intention is to drive them within the surface of the wood, by means of a hammer and punch, and fill the cavity to the surface with putty, and thus conceal them entirely. There are several kinds of them, as *joiners' brads*, *flooring brads*, &c.

BRAMANTE, LAZZARI, D'URBINO, a celebrated architect, born at Castel Durante, (or according to some accounts, at Femagnano,) in the province of Urbino, about the year 1444. The family of which he was a branch, was poor, though respectable, by whom he was designed for a painter: his early years were spent in the study of this art, but his taste and talents for architecture outran every other consideration, till at length he devoted himself altogether to it. He travelled first in Lombardy, and having made some observations on the cathedral of Milan, he went to Rome, where he executed some paintings for the church of St. John de Lateran, which are now lost. His great care was to examine and measure all the precious remains of antiquity, both within and out of Rome: he measured all that he could of the Villa Adriana, at Tivoli; and in pursuit of similar objects, went even so far as Naples.

This devotedness to his favourite science attracted the notice of many patrons of the fine arts, and among the rest, of Cardinal Oliviero Caraffa, who employed him to rebuild the convent della Pace, at Naples, which established his reputation. The work itself is not of the most exquisite character, but it procured him the title of architect to his holiness Pope Alexander VI., there being at that time no artists of superior talents in the papal dominions. The fountain of Trastevere, and another fountain, which formerly stood in the square before St. Peter's, were of his workmanship. He also had a considerable share in building the palace della Cancellaria, the church of St. Lorenzo Damaso, and the palace of San Giacomo Scosciacavalli; all these, as well as the convent della Pace, above noticed, are built in travertine, on the outside; but their meagre style is a striking evidence that in the days of Bramante architecture was only reviving, and was not completely purged from barbarous intermixtures. In such an age the genius of Bramante could not but shine, and he retained his lustre as being without an equal in invention, as well as in execution, till, towards the decline of his life, the superior powers of Michael Angelo Bonarrotti bore away the palm of science, and the voice of public applause. *See* BONARROTTI.

When Julius II. obtained the papal chair, he appointed Bramante superintendent of his buildings, and employed him to execute his grand project of uniting the Belvedere to the palace of the Vatican, by means of a magnificent court. In his turn, Bramante engaged the pope in the favourite design of pulling down the church of St. Peter's, and erecting a new basilica, after the model of the Pantheon, on a scale that should astonish the world. With this view, he made many drawings, and used great diligence to produce one having two steeples with the front between them, as may be seen on the medals struck by Corodasso, in honour of Bramante and his patrons Julius II. and Leo X. The plan was that of a Latin cross, and was well constructed, though of an unequalled magnitude. Three naves were formed by means of colonnades; the principal nave of very fair proportions, and the whole productive of the finest effect. The cupola had the same dimensions with that of the Pantheon; the external steps were also similar. Indeed, the plan of the whole basilica bore a strong resemblance to the Pantheon, having eight piers, between each two of which were two columns, forming three openings, or passages. This design being approved of by the pope, part of the old church was pulled down, and the foundation of the new structure laid, in the year 1506. The building was carried on with great celerity as high as the entablature, the arches over the four great piers were turned, and the principal chapel, opposite the door, was erected, when death put an end to his labours, in 1514, in his 70th year. The continuation of this work was given to Michael Angelo Bonarrotti, who also did not live to see it completed. Bramante's successors made so many alterations upon his original design, that scarcely anything besides the four great arches over the tribune can be said to be his. His remains were interred in St. Peter's, and the solemnity was honoured by the presence of the papal court, and all the professors of the fine arts in Rome and its neighbourhood.

Besides the works above described, Bramante constructed a whimsical staircase, with the three orders of architecture, in the Vatican. The elegant circular temple in the cloister of San Pietro Monterio, though esteemed as one of his best performances, has many defects; for instance, the doorway cuts into two pilasters; the balustrade is a continued series of balusters without pedestals; and the ornament at the top of the cupola is clumsy and heavy. Out of the walls of Todi, Bramante built an insulated temple, encrusted on the exterior with white stone; the plan is that of a Greek cross, with a fine cupola in the centre; and the whole has an air of being the model of St. Peter's. In finishing the chapel within the basilica, he revived the use of the ancient stuccos. He made many designs of palaces and temples, both within and without the walls of Rome, and began the palace, which was afterwards finished by Raffaello, with columns of brick covered with plaster, then a new invention; but this edifice was destroyed to make room for the colonnade of St. Peter's; and the palace which he began for the Duchess Eleonora Gonzaga, wife of Francis Duke of Urban, was never completed, owing to the deaths of both duke and duchess.

BRANCHES, are the diagonal ribs of a Gothic vault, rising upwards from the tops of the pillars to the apex, and seeming to support the ceiling or vault.

BRANDRITH, or Brandrette, a fence round the mouth of a well.

BRASSES, sepulchral engravings on large or small brass plates, let into slabs in the pavement of our ancient churches, portraying the effigies of illustrious personages, with the accompaniments of buildings, &c. The greater part of the effigies are as large as life. The various colours for the dresses, armours, and coats of arms, in many instances, were laid on in enamel, the attitudes well drawn, and the lines both of dresses and architecture made out with precision and truth of imitation.

BREADTH, the greatest extension of a body at right angles to the length.

BREAK, a projecting part of the front of a building, carried up through one or more stories in a vertical surface. In its general acceptation, it implies only a part, which stands forward in a plane parallel to the other parts of the front behind the break; or a cylindric wall concentric with a receding one, and in this it comprehends not only the parallel projecting face, but the two flank parts which join the parallel walls. The break therefore forms, with the receding part or parts, two external and two internal angles. The term is, however, not restricted to this disposition of the planes, or cylindric faces of the building, it may also imply a bow, whether cylindric or canted. No break can be formed unless it have at least one internal angle, or, if the building adjoin on both sides, there will be at least two internal angles. Small breaks, or those projecting only a few inches, never add to the effect of the building.

A building may have either one, two, or several breaks in a front. When the disposition of the rooms naturally falls into the same plane on the inside of the front wall, no break should be admitted, because, in this case, it can only project a few inches. Breaks only fritter away the parts of a small building, and destroy the beauty and elegance which arises from the simplicity of its figure; but in large buildings they give the utmost splendour to the design, provided they have bold projections, and appear as distinct parts of the building, so that if the other connecting parts be supposed to be taken away, they would be so many insulated buildings, insisting each upon a simple rectangular plan. The greatest effect would, therefore, be produced by giving each part or break its separate roof, termination, or covering. For this reason, breaks should either be left lower, or carried higher than the main body, or the connecting part or parts of the building. When a break is carried higher than the connecting part or parts, it must have an entire roof, or uniform termination all round its four walls.

In the ancient architecture of Greece, the walls insisted upon simple rectangular plans, and therefore had no internal angles, and consequently no breaks. The Romans indulged in buildings consisting of greater variety of parts than the Greeks, and formed many of their principal edifices with breaks.

When the upper part of a front wall is intended to be one continued plane, with a break or breaks in the lower part or story, the superior continued wall may either be supported upon a row of columns arched above the intervals in long apartments, or with one arch, when the front horizontal dimension is small, and finished as above.

Breaks in cylindric walls destroy the harmony arising from the continuity of the figure, and should therefore be rejected in every round edifice.

Break-in, among carpenters, is to cut or break a hole in brickwork with the ripping chisel, for the purpose of inserting timber, as to receive plugs, or the end of a beam, or other piece of timber.

Break-Joint, in masonry or brick-work, is when two stones are placed contiguous to each other, with a third stone laid across the joint, so as to cover a part or the whole of the surface of both stones, in order to bind the work together.

BREAST of a Chimney. *See* Chimney.

Breast of a Window, the masonry or brick-work which forms the back of the recess and the parapet, for leaning upon, under the window-sill.

Breast Wall, a retaining wall at the foot of a slope.

BRESSUMMER, or Breast Summer, in building, a lintel-beam in the exterior walls, supported by wooden or iron posts, or by brick or stone pillars, for sustaining the superincumbent part of the wall. Bressummers are used in the construction of shops, where it it necessary to have the window as large as possible, and consequently the pillars as small as possible, in order to give light, and show articles for sale to advantage.

Where breast-summers are used for this purpose, the superincumbent mass should be strengthened by an arch of discharge or otherwise, for, if not so, they will be found of great injury to the building through the shrinkage of the timber. Where this precaution is not attended to, it almost invariably occurs that the brick-work above is fractured in its settlement, and in some cases to a very considerable extent.

Cast-iron beams are occasionally used for breast-summers, but although they have an advantage in not being liable to rot, and are naturally incombustible, yet they are by no means eligible for the purpose. Cast-iron should never be subjected to cross strain, as, although it may bear a certain weight with safety, the least addition or disturbance will cause it to break. In cases of fire, cast-iron is much less secure than wood, for it soon becomes red-hot, and in this state, upon the slightest contact with water, will snap asunder; whereas timbers, if of sufficient scantling, are seldom entirely consumed, usually only charred on their exposed surfaces.

Bressummers were a necessary part in the construction of old timber buildings, where it was requisite to have them not only for binding the building together, but for the support of every floor, and also of the roof. They were likewise placed at the bottom of the building as a foundation to the whole structure, and called *sills*. *See* Summer.

BRICK, an artificial kind of stone, composed in general of earth and sand, or coal cinders, or ashes, well mixed together, and tempered with water, then dried in the sun, and finally burned to a proper degree of hardness in a kiln, or in a heap or stack, denominated a *clamp*.

The antiquity of bricks seems to be coeval with the first edifices after the Deluge; the tower and city of Babel being built of them; as also most of the early structures of Egypt. The Greeks chiefly used three kinds of bricks: the first sort was called *Διδωρον*, *bricks of two palms;* the second Τετραδοονον, *of four palms;* the third *Πενταδορον*, *of five palms.* Besides these, they also had bricks of just half the above dimensions, used for making their work more solid, and for giving an agreeable diversity to its appearance.

The Romans began to build with brick towards the decline of the republic: according to Pliny, those most in use were a foot and a half long, and a foot broad; which agrees with the dimensions of several Roman bricks found in England, viz. seventeen inches in length, by eleven in breadth, of our measure. Sir Henry Walton speaks of some bricks at Venice, of which stately columns were built: they were first formed in a circular mould, and cut, prior to their being burned, into four or more sections; afterwards, in laying they were jointed so closely and exactly, that the pillars had the appearance of being composed of one entire piece.

For the purposes of building, bricks claim a decided superiority over stone, not only as being lighter, and more easily worked; but also because their porous texture facilitates their union with the mortar, and makes them less liable to attract or retain damp and moisture.

In England, the mould in which bricks are formed, is ten inches in length, by five in breadth; the bricks when burned are about nine inches long, four inches and a half broad, and two inches and a half thick. The degree of shrinkage, however, is various, according to the purity and temper of the clay, and the intensity of the heat to which it is exposed in the burning.

The earth selected for brick-making should be of the purest kind; though indeed bricks may be made of any kind of earth that is free from stones, and even of sea-ooze; but it is not every soil that will burn red, which is a property peculiar to earths containing ferruginous particles. In this country, bricks are chiefly made either of stiff clay, or of a hazelly-yellowish-coloured fat earth, commonly called *loam.* The former produces hard red bricks, incapable of rubbing or cutting; the latter is mostly found near London, and gives a neat gray-coloured brick, which yields freely to the axe and rubbing-stone, though equally durable with the harder red brick made in more distant parts. The earth, of whatever quality, should be dug in the autumn, and suffered to remain in a heap till the next spring, that it may be well penetrated by the air, and particularly by the winter's frosts, which by pulverizing the more tenacious particles, greatly assist the operations of mixing and tempering. Indeed, for the best bricks, two or three years will not be found too long to submit the earth to the action of the atmosphere, in order to render it free in the working. In making up this heap for the season, the soil and ashes or sand are to be laid in alternate layers, or strata; each stratum containing such a quantity as the stiffness of the soil may admit or require. For making such bricks as will stand the fiercest fires, Sturbridge clay and Windsor loam are esteemed the best.

In tempering the earth, much judgment is required as to the quantity of sand to be thrown into the mass, for too much renders the bricks heavy and brittle, and too little leaves them liable to shrink and crack in the burning. The London practice of mixing sea-coal ashes, and in the country of adding light sandy earth to the loam, not only makes it work easy and with greater expedition, but tends also to save fuel.

With reference to the proportion which should be observed in mixing the different ingredients, it is impossible to lay down any fixed rules, as such proportion must entirely depend upon the particular quality of the materials employed. The principal of these consist of clay, marl, and loam, with the admixture of sand, chalk, breeze, &c. We shall here give the particular uses to which the accessories are applied, but must leave it entirely to individual instances to determine in what manner each of them must be made use of. The clay of course is the principal matter, and forms the body of the brick, but before this can be made available for building, it has to be agglutinated together by means of sand vitrified by heat. Clay is composed for the most part of alumina and silica combined with a small quantity of lime, and occasionally of magnesia and alkali. Usually speaking, clay requires additional sand to be used as a flux, but it happens sometimes to contain sufficient in itself; when this is the case, no addition of course will be required. If the silica be in excess, it will on the contrary require the addition of some dry substance to hold the mass together, as otherwise the silica will fuse and run when under the action of great heat; for this purpose the chalk is used: if, however, too much be added, the bricks will become porous and friable. The heat, as above stated, is produced by means of the breeze, but the quantity of this also must be regulated according to the nature of the clay you have to use; if it contains a large quantity of sand, less breeze will be required, not only to prevent the silica from running, but also because silica contains a large portion of oxygen: should, however, the clay contain a free proportion of lime, more breeze will be required, for the reason that lime has but little oxygen in its composition. Thus it will be seen how impracticable it is to lay down any general rule in this case; the proportion of each ingredient to be added, can only be determined by careful observations in individual instances.

Every stony particle should be carefully cleared out of the earth, before the workman begins his operation of tempering; it should then be well trodden or beat, and frequently turned over, with the addition of as little water as possible, till the soil and ashes, or sand, are so completely incorporated as to form a paste of a tough viscous substance. If in this operation too much water be used, the paste will become almost as dry and brittle as the soil of which it is composed; but by a judicious management, as to the quantity of water, and the mode of administering it, the bricks become smooth, solid, and durable.

For the preparation or tempering of the soil, the workman is provided with a long hoe, in form like a mattock, a shovel, and a scoop. The hoe is for pulling down the soil from the great heap, which is then chopped backwards with the shovel, in order to turn it as often as may be necessary, and to incorporate the ashes, or sand, and soil, thoroughly together. The use of the scoop is for throwing water over the portion so pulled down with the hoe, to bring it to a more ductile state, and render it easier for tempering. When the mass is sufficiently mixed, it is removed in barrows to the pugmill. This mill consists principally of a strong barrel, firmly fixed on two transverse beams, having in its centre a vertical bar, kept in position by two shoulders attached to the sides of the barrel, and working on the transverse beams at their intersection as on a pivot. On the top of this bar is placed a horizontal beam, by means of perpendiculars suspended from which, the horse is attached. On that part of the bar which is within the barrel, is fixed several iron knives, by the revolution of which the masticated clay is forced through a hole in the bottom of the barrel, when it is cut off in pieces with a "cuck-hold," or concave shovel, and laid on one side. A quantity of sand is then thrown over it, and it is kept for use under a covering of sacking or matting, to preserve it from the sun and air.

The moulding-table is placed under a movable shed, and is strewed with dry sand. A boy, with the cuck-hold, cuts off as much as he can carry in his arms, from the prepared mass, and brings it to the table, where a girl receives it, and rolls out a lump rather larger than the mould will contain. The moulder receives this lump from the girl, throws it into his mould, previously dipped in dry sand, and with a flat smooth stick, about eight inches long, kept for the purpose in a pan of water, strikes off the overplus of the soil: he then turns the brick out of the mould upon a thin board, rather larger than the brick, upon which it is removed by a boy, and placed on a light barrow, having a lattice-work frame raised about three feet above the wheel, and about eighteen inches at the handles, forming an inclined plane. On this lattice-frame the new-made bricks are laid, and sand is thrown over them, to prevent their sticking to each other, as well as to preserve them in a certain degree from cracking in drying on the hacks. The hacks for drying, are each wide enough for two bricks to be placed edgeways across, with a passage between the heads, for the admission of air, to facilitate the circulation of which, the bricks are generally laid in a diagonal direction. The hacks are usually carried eight bricks high; the bottom bricks at the ends are commonly old ones.

In showery weather, the bricks on the hacks are to be carefully covered with wheat or rye straw, to keep them dry; unless sheds or roofs be erected over the hacks, as is done in some country places; but in London this is impracticable, from the very great extent of the grounds.

In fine weather the bricks will be dry enough for turning, in a few days; in doing which they are reset more open than at first; and in six or eight days more they will be ready for burning.

The best bricks, that is, those made of the best materials, and well tempered, as they are harder and more ponderous, so they require half as much more earth, and longer time for drying and burning, than the common sort, which are light, spongy, and full of cracks. The well drying of bricks before they are burned, prevents their cracking and crumbling in the kiln or clamp.

In the vicinity of London, bricks are commonly burned in clamps; farther in the country it is the custom to burn them in kilns. In building the clamps, the bricks are laid after the manner of arches in the kilns, with a vacancy between every two bricks, for the fire to play through; yet with this difference, that instead of arching, the vacuity for the fuel is spanned over, by making the layers project one over the other from each side, till they meet at top. The flue is about the width of a brick, carried up straight on both sides about three feet; it is then nearly filled with dry bavins, or wood, on which is laid a covering of sea-coal and cinders (or *breeze*, as they are called); the arch is then overspanned, and layers of breeze are strewed over the clamp, as well as between the rows of bricks.

When the clamp is about the width of six feet, another flue is made, in every respect similar to the first; this is repeated at every distance of six feet, throughout the whole clamp, which when completed, is surrounded with old bricks, if there be any on the grounds, if not, with some of the driest unbaked ones, that have been reserved for the purpose. On the top of all, a thick layer of breeze is laid. The wood is then kindled, which gives fire to the coal; and when all is consumed, which will be in about twenty or thirty days if the weather be tolerable, the bricks are concluded to be sufficiently burned. Should there be no immediate hurry for the bricks, the flues may be placed nine feet asunder, and the fuel left to burn slowly.

If the fire in the clamp burns well, the mouths of the flues are stopped with old bricks, plastered over with clay. The outside of the whole clamp is also plastered with clay, if the weather be precarious, or if the fire burn too furiously; and against any side particularly exposed to the rain, &c., screens are laid, made of reeds worked into frames about six feet high, and sufficiently wide to be moved about with ease.

This is the ordinary method of manufacturing common gray-stocks. But washed malms, or marls, are made with still greater attention. A circular recess is built, about four feet high, and from ten to twelve feet in diameter, paved at the bottom, with a horse-wheel placed in its centre, from which a beam extends to the outside, for the horse to turn it by. The earth is then raised to a level with the top of the recess, on which a platform is laid, for the horse to walk upon. This mill is always placed as near a well or spring as possible, and a pump is set up, to supply it with water. A harrow, made to fit the interior of the recess, thick-set with long iron teeth, and well loaded, is chained to the beam of the wheel, to which the horse is harnessed. Previously to putting the machine in motion, the soil, as prepared in the heap in the ordinary manner, is brought in barrows, and distributed regularly round the recess, with the addition of a sufficient quantity of water; the horse then moves on, and drags the harrow, which forces its way into the soil, admits the water into it, and by tearing and separating its particles, not only mixes the ingredients, but also affords an opportunity for stones and other heavy substances to fall to the bottom. Fresh soil and water continue to be added till the recess is full.

On one side of the recess, and as near to it as possible, a hollow square is prepared, about 18 inches or two feet deep. The soil being sufficiently harrowed and purified, and reduced to a kind of liquid paste, is ladled out of the recess, and by means of wooden troughs conveyed into this square pit; care being taken to leave the sediment behind, which is afterwards to be cleared out and thrown on the sides of the recess. The fluid soil diffuses itself over the hollow square, or pit, where it settles of an equal thickness, and remains till wanted for use, the superfluous water being either drained away or evaporated, by exposure to the atmosphere. When one of these square pits is full, another is made by its side, and so on progressively, till as much soil is prepared as is likely to be wanted for the season.

In the country bricks are always burned in kilns, whereby much waste is prevented, less fuel consumed, and the bricks are more expeditiously burned. A kiln is usually thirteen feet long, by ten feet six inches wide, about twelve feet in height, and will burn 20,000 bricks at a time. The walls are about one foot two inches thick, and incline inward towards the top, so that the area of the upper part is not more than 114 square feet. The bricks are set on flat arches, having holes left between them resembling lattice-work. The bricks being set in the kiln, and covered with pieces of broken bricks or tiles, some wood is put in and kindled, to dry them gradually; this is continued till the bricks are pretty dry, which is known by the smoke turning from a darkish to a transparent colour. The burning then takes place, and is effected by putting in brushwood, furze, heath, fagots, &c., but before these are put in, the mouths of the kiln are stopped with pieces of brick, called *shinlog*, piled one upon another, and closed over with wet brick earth. This shinlog is carried just high enough to leave room sufficient to thrust in a fagot at a time; the fire is then made up, and continued till the arches assume a whitish appearance, and the flames appear through the top of the kiln; upon which the fire is slackened, and the kiln cools by degrees. This process is continued, alternately heating and slackening, till the bricks are thoroughly burned, which is generally in the space of forty-eight hours.

The practice of steeping bricks in water after they have been once burned, and then burning them again, renders them more than doubly durable.—*Goldham.*

Many attempts have been made to introduce machinery in the practice of brickmaking, but with little success, as is evident from the old practice continuing so general in use.

The most usual varieties of bricks consist of *marls*, *stocks*, and *place-bricks*, but there is very little difference in the manufacture. *Marls* are prepared and tempered with the greatest care; but the construction of the clamp for burning them is similar to that for other bricks, though more caution is required not to overheat them, and to see that the fire burn equally and diffusively throughout the clamp or kiln. The finest marls, called *firsts*, are selected as cutting bricks, for arches of doorways, windows, and quoins; for which purpose they are rubbed to their proper dimensions and form. The next best, termed *seconds*, are used for principal fronts The cleanly pale yellow colour of marls, added to their smooth texture and superior durability, give them a pre-eminence above other sorts of bricks. *Gray-stocks* are somewhat like the seconds, but of an inferior quality. *Place-bricks*, sometimes called *peckings*, *sandal*, or *samel-bricks*, are such as, from being outside in a kiln or clamp, have not been thoroughly burned, and are consequently soft, of a more uneven texture, and a red colour. There are also *burrs*, or *clinker-bricks*, such as from being too violently acted upon by the fire, have vitrified in the kiln, and sometimes several are found run together.

Red-stocks are made in the country, and burned in kilns. They owe their colour to the nature of the clay of which they are formed, which is always used tolerably pure. The best sort are used as cutting bricks, and are called *red-rubbers*. In old buildings they are frequently to be seen, ground to a fine smooth surface, and set in putty, instead of mortar, as ornaments over arches, windows, doorways, &c. Though many very beautiful specimens of red brickwork are to be met with, yet these bricks can seldom be judiciously used for the front-walls of buildings. The colour is much too heavy, and in summer conveys an unpleasant idea of heat to the mind; to which may be added, that as in the fronts of most buildings of any consequence, more or less of stone-work is introduced, there is something harsh in the contrast between the red bricks and the cold colour of the stones; and even where no stone is employed, there is always some wood used, which being painted white, by no means lessens the objection. Gray-stocks match so much better with the colour both of stone and paint, that they have obtained a universal preference in London and its immediate vicinity.

At Hedgerly, a village near Windsor, red bricks, about one inch and a half thick, of a very firm texture, are made; they will stand the greatest violence of fire, and are called *Windsor bricks*, and sometimes *fire-bricks*.

Bricks for paving are of the same dimensions with Windsor bricks, viz., nine inches long, four inches and a half broad, and one inch and a half thick. Besides these, there are what are called *paving-tiles*, which are made of stronger clay, of a red colour. The largest are about twelve inches square, and one inch and a half thick; the next size, though called ten-inch tiles, are about nine inches square, and one inch and a quarter thick. *See* Tiles.

Besides the foregoing varieties, the following are worth notice, though some of them are not much in use: 1. The ordinary *Paris brick* is eight inches long, four inches broad, and two inches thick, French measure, which makes them rather larger than ours. 2. *Buttress*, or *plaster bricks*, made with a notch at one end, half the length of the brick; used for binding work built with great bricks. 3. *Capping bricks*, used for the purpose which their name denotes. 4. *Great bricks*, used in fence walls, are twelve inches long, six inches broad, and three thick. 5. *Cogging bricks*, for making the indented works under the capping of walls built with great bricks. 6. *Compass bricks*, of a circular form, for steyning wells. 7. *Concave*, or *hollow bricks*, made flat on one side, like an ordinary brick, and hollowed on the other side; used for drains and water-courses. 8. *Dutch*, or *Flemish bricks*, used in paving yards, stables, &c., also for lining soap-boilers, cisterns, and vaults. 9. *Feather-edged bricks*, made of the same size with the ordinary statute bricks, but thinner on one edge than on the other; they are used for pinning up brick panels in timber buildings.

Brick-Nogging, a wall constructed with a row of posts or quarters, disposed at three feet apart, and with brickwork, so as to fill up the intervals. This kind of walling is generally either the thickness or breadth of a brick, and the woodwork flush on both sides with the faces of the bricks. In brick-nogging, thin pieces of timber, reaching horizontally from post to post, are disposed so as to form the brickwork between every two posts or quarters, into several compartments in the height of the story; each piece being inserted between two courses of bricks, with its edges flush with the faces of the wall.

Brick and Stud. *See* Brick-Nogging.

Brick-Kiln, a building erected in the form of the frustum of a cone, for the purpose of burning bricks.

BRICKLAYER, a workman who builds with bricks. His business, in London, includes walling, tiling, and paving with bricks or tiles; some jobbing-masters also undertake plastering. Country bricklayers unite bricklaying, plastering, and not unfrequently masonry. The bricklayer's materials are bricks, tiles, mortar, laths, nails, and tile-pins; with which he is supplied while at work by a labourer, who likewise makes the mortar.

Bricklayers form a very numerous body of artisans in this country. A good workman can lay 1,500 bricks daily in walls. His wages in London are from five to six shillings a day. The immense demand for bricklayers caused by the extensive works connected with railways, and the great increase of building operations in the last few years, have enabled good workmen to command almost any amount of wages.

Bricklayers, in London, are, by a charter granted in 1568, a corporate company, consisting of a master, two wardens, twenty assistants, and seventy-eight on the livery.

BRICKLAYING, BRICKWORK, the art of building or erecting walls or edifices with bricks, cemented together with mortar, cement, &c. For the materials, &c., used in this business, see the articles Brick, Bricklayer, Mortar, Tiles, Cement, &c.

The first thing to be attended to, in bricklaying, is to dig trenches for the foundations, after which the ground must be tried with an iron crow, or rammer, to see that it is sound: if it appear to shake, it must be bored with a well-sinker's tool, in order to ascertain whether the shake be local or general. If the soil prove generally firm, the looser parts, if not very deep, may be dug up till a solid bed be got at, on which a pier or piers may be built, as hereafter described; if the ground be not very loose, it may be made good by ramming into it large stones, close packed together, or dry brick rubbish, of a breadth at the bottom proportioned to the intended insisting weight; but if the ground be very bad, it must be piled and planked, to ensure the safety of the structure.

In building upon an inclined plane, or rising ground, the foundation ought to rise with the inclination of the ground, in a series of level steps, which will ensure a firm bed for the courses, and prevent them from sliding, as they would be apt to do if built on inclined planes; and in wet seasons the moisture in the foundation would induce the inclined parts to descend towards the lowest parts, to the manifest danger of fracturing the walls, and destroying the building.

When the ground proves loose to a great depth in places over which it is intended to make windows, doors, or other apertures, while the sides on which the piers must stand are firm, it is a good practice to turn inverted arches under such intended windows, &c. Indeed, this is a necessary precaution in all cases where the depth of wall below the aperture will admit of it. For the small base of the piers will more easily penetrate the ground, than one continued base; and as the piers may be permitted to descend, in a certain degree, so long as they can be kept from spreading, they will carry the arch with them, compressing the ground, and forcing it to reaction against the sides of the inverted arch, which if closely jointed, so far from yielding, will, with the abutting piers, operate as a solid body. Whereas, if this expedient of inverted arches be not adopted, the low piece of wall under the aperture, not having a sufficient vertical dimension, will give way by the resistance of the ground upon its base, and not only fracture the brickwork between the apertures, but also the window-sills. Hence it is evident that these arches should be turned with the greatest exactness, and should be in height at least half their width. The parabolic curve will be found most effectual in resisting the reaction of the ground; it being the form most adapted to the laws of uniform pressure.

The bed of the piers ought to be of equal solidity throughout; for though the bottom of the trench may be firm enough, yet if there be any difference in substance, the settlement will be partial, the amount thereof varying according to the softness of the ground; consequently the piers on the softer ground will settle more than those on the firmer, and occasion a vertical fracture in the superstructure.

Should the solid parts of the trench be found under the intended apertures, and the softer parts where piers are to be built, the reverse of the above practice must be resorted to, viz.: build piers on the firm ground, and suspend arches, not inverted, between them; in performing which, attention must be paid to the insisting pier, whether it will cover the arch, or not; for if the middle of the pier rest over the middle of the summit of the arch, the narrower the pier is, the greater should be the curvature of the arch of its apex. When suspended arches are used, the intrados ought to be clear, that the arch may have its full effect. Here also, as before, the ground on which the piers are erected should be of equal firmness, lest the building be injured by an unequal settling, which is attended with much more mischievous consequences than where the ground, from being uniformly soft, permits the piers to descend equally, in which case the building is seldom or never damaged.

When it is necessary to ram foundations, the stone, being previously chopped or hammer-dressed, so as to have them as little taper as possible, should be laid of a breadth proportioned to the weight intended to be rested on them, and rammed closely together with a heavy rammer. In ordinary cases, the lower bed of stones may project about a foot on each side of the wall, on which another course may be laid, so as to bring the upper bed of stones upon a general level with that of the trench, projecting about eight inches on either side of the wall, or receding four inches on each side within the lower course. Care should be taken that the joints of every upper course fall as nearly as possible upon the middle of the stones in the course immediately beneath it; a principle also to be strictly adhered to in every kind of walling; for in all the modes, various as they are, of laying stones or bricks, the uniform object is to obtain the greatest lap one upon the other.

The directions for preparing a solid foundation, refer to the general practice amongst builders before the introduction of concrete. The now almost universal use of the latter, as a certain, convenient, and ready means of obtaining a secure foundation, has rendered it necessary to give a description of the mode in which this material is generally used.

The ground having been examined as described in the first part of this article, a sufficient depth must be excavated in the bottom of the trenches, to allow of throwing in a quantity of concrete, varying in breadth and depth, according to the size and character of the building to be erected, and the necessary width of the footings.

The concrete is composed of different materials, and proportions of those materials, as the qualities of sand, lime, &c., are most conveniently obtained in the locality of the building. The concrete used in and near London is generally composed of Thames ballast and fresh burned stone-lime, (ground to powder without slacking,) in the proportions of from one-fifth to one-ninth of lime to one of the ballast. These ingredients should be well blended together dry, and as small a quantity of water added as will bring them to the consistency of mortar; and then, after turning over the materials with the shovel once or twice, thrown as quickly as possible into the foundation, from a height of several feet. It sets very quickly, so that it is desirable that the mixture should be made at, or close to the height from which it is thrown, and then spread and brought to a level as expeditiously as possible. *See* Concrete.

Having premised thus much on foundations, we proceed to the operation of walling; the first object in which is the due preparation of the cementing material.

Mortar is most commonly used in modern brick buildings. It is composed of lime, gray or white, but gray or stone-lime is the better, mixed with river-sand, or road-sand, in the proportion of one of gray lime to two and a half of sand, and one of white or chalk-lime to two of sand.

In slacking the lime, no more water should be used than is barely sufficient to reduce it to powder; and it should be covered with a layer of sand, in order to prevent the gas, wherein is the virtue of the lime, from flying off. It is best to slack the lime in small quantities, about a bushel at a time, in order to secure its qualities in the mortar, which would evaporate were it to remain slacked any length of time before being used. *See* Mortar.

The mortar, when about to be used, should be beaten three or four times, and turned over with the beater, so as to incorporate the lime and sand, and break the knots that pass through the sieve: this not only renders the texture more uniform, but by admitting the air into the body and pores of the mortar, makes it much stronger. Should the mortar stand any length of time after this operation, without being used, it must be beaten again: it should be observed, that in these beatings very little water should be used; though in hot and dry weather the mortar may be kept considerably softer than in winter.

In dry weather, and for firm work, the best mortar must be used, and the bricks should be wetted, or dipped in water as they are laid; but in damp weather, the latter precaution will be unnecessary. The wetting of the bricks causes them to adhere to the mortar, which they will never do if laid dry, and covered with sand or dust, as they may be removed without the adhesion of a single particle of the mortar.

In laying the foundations of walls, the first courses are always laid broader than the wall intended to be carried up; these courses are called the *footings*, and the projections are called set-offs; there are generally two inches in each projection.

In working up the wall, not more than four or five feet of any part should be built at a time; for as all walls shrink immediately after building, the part which is first brought up will settle before the adjacent part is brought up to it; and the shrinking of the latter will consequently cause the two parts to separate. Unless it be to accommodate the carpenter, &c., no part of a wall should be carried higher than one scaffold, without having its contingent parts added to it. In carrying up any particular part, the ends should be regularly sloped off, so as to receive the bond of the adjoining parts, on the right and left.

In laying bricks, there are four kinds of Bond; viz., English-bond, Flemish-bond, Herring-bond, and Garden wall-bond. The two first are principally used in modern brickwork, the others only occasionally.

In *English-bond*, a row of bricks laid lengthwise on the length of the wall, is crossed by a row with its breadth in the said length, and so on alternately. The courses in which the lengths of the bricks are disposed through the length of the wall, are called *stretching courses*, and the bricks, *stretchers:* the courses in which the lengths of the bricks run in the thickness of the walls, are called *heading courses*, and the bricks, *headers*. The other sort of bond, called *Flemish-bond*, consists in placing a header and a stretcher alternately in the same course. *See* BOND, *English*, &c.

When new walls are to be built into old it is usual to cut a chase, or draw a brick at every other course in the old work, and *tooth* in the new work. When it is intended to add walls to buildings, these toothings are left.

The most difficult work for a bricklayer to execute is the groining or intersection of arches in vaults, where every brick has to be cut to a different bed. This and the arches called gauged arches, either circular or straight, require the neatest workmanship. Some straight arches are made roughly; that is, the bricks are inclined each way, parallel to each other, on the respective skewbacks, or shoulders of the arch, until the soffit-ends of the bricks touch, when the vacant space at top is filled with two bricks, forming a wedge: this arch, like other straight arches, is constructed on a camber slip, or piece of wood slightly curved on the upper side for centering.

In steining wells, a centre must be first made, consisting of a boarding, of inch or inch-and-a-half stuff, ledged within with three circular rings, upon which the bricks are laid, all headers. The gaps between the bricks towards the boarding are to be filled in with tile or pieces of brick. As the well-sinker excavates the ground, the centre with its load of bricks sinks, and another, similarly charged, is laid upon it, another upon that, and so on, till the well is completed; the centering remaining permanently fixed with the brickwork. This is the method generally adopted in London, at least where the soil is sandy and loose; where it is firm, centerings are not requisite. In the country, among many other methods, the following most prevails: rings of timber, without the exterior boarding, are used; upon the first ring, four or five feet of bricks are laid, then a second ring, and so on. But this is far inferior to the mode above described, as the sides of the brick-work are apt to bilge in sinking, particularly if great care be not taken in filling and ramming the sides uniformly, so as to keep the pressure regular and equal. In steining wells, and in the construction of cesspools, a rod of brick-work will require at least 4,760 bricks.

In winter, it is essential to preserve the unfinished wall, as much as possible, from the alternate effects of rain and frost, than which nothing is more destructive to a building; the rain by penetrating into the very heart of the bricks and mortar, and the frost by converting the water, so lodged, into ice, expanding its bulk, and bursting or crumbling the materials in which it is contained. The decay of buildings, commonly attributed to the effects of time, is, in reality, occasioned by this operation and counter-operation of the rain and frost, but as, in finished edifices, they have only a vertical surface to act upon, their effects are not rapidly extended. In an unfinished wall, there is a horizontal surface, by which both rain and frost find an easy access into the body of the work; care must therefore be taken to exclude them, by a sufficient covering, as soon as the frost or stormy weather sets in, either of straw, which is most usually employed, or of weather-boarding, placed in the form of a stone coping, so as to throw off the water equally on either side: but in the latter case, it is advisable to have a good body of straw under the wood, as no precaution can be too great, for the security and strength of the work.

A variety of pleasing cornices and ornaments may be formed in brickwork, by the disposition of the bricks, frequently without cutting them, or if cut, chamfering only may be used; but a great defect is frequently to be observed in these ornaments, particularly in the bilging of the arches over windows. This arises from mere carelessness in rubbing the bricks too much off, on the inside; whereas, if due care were taken to rub them exact to the gauge on the inside, that they bear upon the front edges, their geometrical bearings being united, they would all tend to one centre, and produce a well-proportioned and pleasing effect.

A rod of brickwork was taken from the original standard of $16\frac{1}{2}$ feet square, and consequently the supeficial rod contained 272.25 square feet, or $272\frac{1}{4}$ square feet; but as the quarter was found troublesome in calculation, 272 superficial feet was admitted as the standard for brickwork; the result is the same in practice, when it is considered that equal values will be found by annexing the proportional price per rod to each; and indeed, if the same price be appropriate to each, the difference would be so trifling as not to be worth the trouble of calculating. The standard thickness of a brick wall is $1\frac{1}{2}$ brick in length, therefore if 272 square feet be multiplied by $13\frac{1}{2}$ inches, the result is 306 cubic feet in the rod.

A rod of standard brickwork with mortar, will require 4,500 bricks at a medium, allowing for waste; this number will depend upon the closeness of the joints, and the size of the bricks. The mortar in a rod of brickwork will require $1\frac{1}{2}$ cwt. of chalk-lime, or one cwt. of stone-lime, and $2\frac{1}{2}$ loads of sand with stone-lime, or 2 loads with chalk-lime.

In walling, a foot of reduced brickwork will require 17 bricks. A foot superficial of marl facing laid in Flemish bond, will require 8 bricks; and a foot superficial of gauged arches, 10 bricks. In paving, a yard will require 82 paving-bricks, or 48 stock-bricks, or 144 Dutch clinkers laid on edge, or 36 bricks laid flat.

In tiling, 100 superficial feet make a square. A square will require, of plain tiles, 800 at a 6-inch gauge, 700 at a 7-inch gauge, or 600 at an 8-inch gauge. The distance of the laths will depend upon the pitch of the roof, and may require a 6, 7, or 8-inch gauge; thus, a kirb roof will require a gauge of $7\frac{1}{2}$ or 8 inches in the kirb part, and the upper part 6, $6\frac{1}{4}$, or 7 inches, the distance being less as the angle of elevation is less. A square of plain tiling will require a bundle of laths, more or less according to the pitch, two bushels of lime and one of sand, and a peck of tile-pins at least. The laths are sold in bundles, which generally consist of 3, 4, and 5-feet lengths; the 3-feet are 8 score, the 4-feet 6 score, and the 5-feet 5 score to the bundle. The nails used in lathing, are fourpenny. They are purchased by the long hundred, viz., six score to each hundred, and charged by the bricklayer by the short hundred, viz., five score to the hundred. The rates of charge by the hundred are as their names imply, viz., fourpenny, fourpence per hundred; sixpenny, sixpence per hundred. The number of nails required to a bundle of five-feet laths are 500, and to a bundle of six-feet laths 600. A square of pan-tiling will require 180 tiles, laid at a 10-inch gauge, and a bundle of laths. The bundle consists of 12 laths, 10 feet long.

In lime measure, 25 striked bushels, or 100 pecks, is a hundred of lime; 8 gallons, or $2{,}150\frac{2}{5}$ cubic inches, is a bushel of dry measure; and $268\frac{4}{5}$ cubic inches is a gallon.

In sand measure, 24 heaped bushels, or 30 striked bushels, is a load, and 24 cubic feet weigh a ton. In mortar measure, 27 cubic feet make a load, which contains half a hundred of lime, with a proportional quantity of sand; 1,134 cubic inches make a hod, which is 9 inches by 9, and 14 inches long; 2 hods of mortar make a bushel nearly.

A ton weight contains $23\frac{1}{2}$ cubic feet of sand, $17\frac{1}{3}$ of clay, or 18 of earth, or 330 bricks.

A cubic foot contains 95lb. of sand, 135lb. of clay, or 124lb. of common earth, or 125 bricks.

To measure trenches for foundations.—All kinds of excavations of earth are measured by the number of cubic yards which they contain; therefore, to find the number of cubic yards in a trench, find the solidity of the trench in cubic feet, which divide by 27, the number of cubic feet in a yard, and the quotient, if any, is the answer in cubic yards, and the remainder, if any, shows cubic feet.

Example.—The length of a trench is 62 feet, the vertical depth 2 feet 6 inches, and the breadth 2 feet 9 inches.

```
        62
         2½
       ----
       124
        31
       ----
       155
         2¾
       ----
       310
        77  6
        38  9
       -------
27 )   426  3 ( 15 yards 21 feet, the answer.
        27
       ----
       156
       135
       ----
        21
```

In the horizontal dimensions, if the trench is wider at the top than at the bottom, as is generally the case, and equal at the ends, take half the sum of the two dimensions for a mean breadth, and if the breadth of one end of the trench exceed that of the other, so as to have two mean breadths differing from each other, take half the sum of the two added together, as a mean breadth for the whole.

Or, take a mean dimension in the middle of the length, and the middle of the height, and proceed as in the above operation.

The footing of a wall is the projecting courses of brickwork under the wall, spread out to prevent it from sinking.

To measure the footing of a wall.—Multiply the length and the height of the course together, then multiply the product by the number of half bricks in the mean breadth: divide the last product by 3, and the quotient is the answer in reduced feet.

The number of half bricks in the mean breadth will be found by adding the number of half bricks in each course together, and dividing the sum by the number of courses; or take half the sum of the half bricks in the upper and lowermost courses; but if the number of courses is odd, this trouble may be saved by taking the number of half bricks in the middle course for the mean breadth.

Also, instead of measuring the height of the footing, it is usual to allow three inches to each course in height; or multiply the number of courses by 3, which gives the height in inches.

Example.—The footing of a wall is 62 feet in length, and consists of 3 courses, the middle course of which consists of $3\frac{1}{2}$ bricks; how many feet of reduced work are in the said footing?

```
      62  0
       0  9
     -------
      46  6
          7 number of half bricks in mean breadth.
 3 ) 325  6
     108 ft. 6 in. of reduced brickwork.
```

To find the number of rods contained in a piece of brickwork. Rule I.—If the wall be at the standard thickness, divide the area of the wall by 272, and the quotient, if any, will be the answer in rods, and the remainder, if any, in feet: but if the wall be less or more than a brick and a half in thickness, multiply the area of the wall by the number of half bricks, that is, the number of half lengths of a brick; divide the product by 3, and the wall will be reduced to the standard of $1\frac{1}{2}$ brick thick. Divide the quotient by 272, and this quotient will give the number of rods required.

Rule II.—Divide the number of cubic feet contained in the wall by 306, and the quotient, if any, will show the number of rods, and the remainder, if any, the number of cubic feet.

Rule III.—Multiply the number of cubic feet in the wall by 8; divide the product by 9, and the quotient will give the area of the wall at the standard: divide the standard area by 272, and this quotient, if any, will show the number of rods; the remainder, if any, is the reduced feet. The reason of this rule may be thus shown: $\frac{8}{9 \times 272} = \frac{1}{9 \times 34} = \frac{1}{306}$ which is a divisor of a rod, without any regard to the standard.

Example.—The length of a wall is sixty-two feet, the height fifteen feet, and the breadth equal to the length of two bricks and a half: how many rods of brickwork are contained in the wall?

Operation by Rule I.

```
         62
         15
       ----
        310
        62
       ----
        930
          5 number of half bricks.
   3 ) 4650
 272 ) 1550 ( 5 rods 190 feet, the answer.
       1360
       ----
        190
```

Operation by Rule II.

```
         62
         15
       ----
        310
        62
       ----
        930
          1  10  6
       ----------
         38   9  0
        775
        930
       ----------
 306 ) 1743   9  0 ( 5 rods 213 feet, the answer.
       1530
       ----
        213
```

Operation by Rule III.

```
         62
         15
       ----
        310
        62
       ----
        930
          1  10  6
       ----------
         38   9  0
        775
        930
       ----------
       1743   9
              8
       ----------
   9 ) 13950  0
 272 ) 1550 ( 5 rods 190 feet, the answer.
       1360
       ----
        190
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In the calculation of brickwork, where there are several walls of different thicknesses, it will be quite unnecessary to use the divisors 3 and 272, as will be hereafter shown.

In measuring walls within the districts to which the building act extends, it is customary to take the length of front walls within the building, and the length of party walls from the front to the rear faces of the building, in order to appropriate more easily the share of each proprietor; but in country houses, which stand insulated, and which have their adjoining faces of the same workmanship, either of the two pair of parallel walls may be taken the whole length of the external faces, and the dimensions of the other pair of parallel walls should be taken perpendicularly from the interior sides of the said walls, or the horizontal stretch of the interior side of either.

In measuring for workmanship only, it is customary to allow the length of each wall on the external side; or, if all the adjoining walls are of the same workmanship, to girt the whole on the outside; and consequently, if the building be a rectangle, the contents will by this means exceed the real quantity by four square pillars, each the height of the building, and in horizontal dimensions the thickness of each wall. This is a compensation for plumbing the angles; but this practice is unfair with regard to materials.

In measuring walls that are faced with bricks of a superior quality, the London surveyors measure the whole as if common work, and allow so much per rod for the facing, as the quality of the bricks and superior excellence of the work may deserve. The facing may be reckoned at two thirds of a brick.

In taking the dimensions of the brickwork in the different stories, the height of each part, as high as it goes of the same thickness, must be taken; and the contents of each part computed separately, the offsets being always below the joists, and consequently the wall the same thickness throughout, from the ceiling of one floor to the ceiling of another.

All apertures and recesses from any of the faces are to be deducted, but an allowance per foot lineal should be granted upon every right angle, whether external or internal, except that two external angles are formed by a brick in breadth, and then only one of them must be accounted for. This allowance is in consequence of plumbing the faces which constitute the said angles; but if the bricks are cut so as to form oblique angles, this allowance should be at least double.

It is customary, in almost every part of the country, in measuring for workmanship, to find the contents of the walls as if solid, without deducting the vacuities, so that upon this principle, if the apertures be ever so large, they must, at all events, be accounted as solid; and, in this instance, the proprietor would be greatly overcharged by the workman.

Again, in apertures of small breadth, the trouble in plumbing at the returns is equally the same at the same height as if ever so wide; but in case the voids are less than the lineal allowance, there would be a manifest loss to the master workman. It is much to be wished that such an allowance as above mentioned should be established, in order to do away the uncertainty of computing the quantity of walling, such as to be often above, and sometimes below the real value of workmanship.

Gauged arches are sometimes deducted and charged separately, and sometimes not; but it is the same whether they are deducted or not, as the extra price must be allowed in the former case, and the whole price allowed in the latter, which is much the more troublesome of the two. Gauged arches are at least five times the trouble of the best marl facing.

To measure the vacuity of a rectangular window.—Find the solidity that would fill the outside vacuity from the face of the wall to the reveal, or outside of the sash-frame; the solidity that would fill the vacuity from the outside of the sash-frame to the vertical plane of the extension of the back upwards; and the solidity that would fill the vacuity contained between the vertical plane of the back and the internal face of the wall; then add these three solidities together, and the sum will be the solidity that will fill the whole void; then add the allowances.

Or thus—Find the area of each of the three vacuities parallel to the face of the wall; multiply each area by each respective number of half bricks in the thickness of the wall, add the three products together; divide the sum by 3, and the quotient reduces the contents in superficial feet to the standard thickness.

In taking the dimensions of brickwork, inches are generally neglected.

Example.—Suppose the height of the outer vacuity, from the sill to the under side of the head, to be 10 feet, the breadth 4 feet 6 inches, and the thickness half a brick; the height of the middle vacuity from the sill to the under side of the wooden lintels, to be 10 feet 3 inches, the breadth 5 feet 2 inches, and the thickness also ½ a brick, and the inside vacuity, from the floor to the under side of the said lintels, 13 feet; the mean breadth, supposing the inside to splay, to be 5 feet 6 inches, and the depth of the recess 1½ brick: required the solidity that will fill the void.

Operation for the outside vacuity.

10	
4½	
40	
5	
45	

Operation for the middle vacuity.

10	3	0
5	2	0
1	8	6
51	3	0
52	11	6

Operation for the inside vacuity.

13	
5½	
65	
6	6
71	6
3	
214	6

	ft.	in.	sec.	
	45	0	0	
	52	11	6	
	214	6	0	
3)	312	5	6	
	104	1	10	the solid that will fill the vacuity.

To calculate the price of a rod of brickwork.—This will depend upon the quality of the bricks and the goodness of the workmanship; for in building foundations and party-walls, which are commonly done with place-bricks, the bricklayer may easily lay 1,500 bricks in a day: in garden-walls, barns, and common country houses, where greater nicety is required in jointing, he may lay about 1,000 per day; and in gray-stock, or marl fronts, done with great care, he will hardly exceed 500 in a day. The expense per rod will also depend upon the articles of living, and consequently upon the times. One example, however, will be sufficient; the prices of materials and labour may be had from a Price Book. In the following statement, the work is supposed to be a well-built gray-stock front, the rates of charge according to the present London prices for 1848.

	£.	s.	d.
To 4,500 gray-stock bricks, prime cost at 38s. per thousand....................	8	11	0
$1\frac{1}{2}$ cwt. lime, at 14s. per cwt............	1	1	0
2 loads sand, at 5s. per load............	0	10	0
$\frac{3}{4}$ of a day of a labourer to slack, chaff, &c. the mortar, 3s. 6d. per day............	0	2	$7\frac{1}{2}$
Bricklayer 5 days, 5s. 6d.	1	7	6
Labourer 5 days, 3s. 6d................	0	17	6
	£12	9	$7\frac{1}{2}$
Add $1\frac{1}{2}$ per cent for scaffolding, &c......	0	3	$4\frac{1}{2}$
Add 15 per cent profit on the prime cost.	1	17	6
	£14	10	6

In making the calculation of a wall where the bricks of the facing are of a superior quality to the backing, it is proper to observe, that the number of bricks in the facing of a rod of Flemish-bond work will vary from 1,500 to 2,000, according to the size of the bricks and closeness of the joints; this number of bricks must be deducted from the whole number that would constitute a rod; and each number of bricks must be valued according to their respective qualities.

The following example will sufficiently explain the application of the foregoing rules in the measurement of the front wall of a house.

Example.—Suppose the front wall of a house to be four stories high, and the length 26 feet; the footing to consist of place-bricks in four courses, which are respectively, 5, $4\frac{1}{2}$, 4, and $3\frac{1}{2}$ bricks in breadth; the basement part of the wall to be built with gray-stocks, 11 feet in height, and 3 bricks in thickness; the parlour part of the wall to be 11 feet in height, and $2\frac{1}{2}$ bricks in thickness; the one-pair-of-stairs, or principal floor, to be 13 feet in height and 2 bricks in thickness; the chamber floor to be 10 feet in height and $1\frac{1}{2}$ brick in thickness; the three upper stories to be of gray-stock work, faced with marls; in each of the basement and entrance stories are to be two windows and a door, and three windows in each of the upper stories: the whole of the windows, as well as the doors, to be 4 feet in width; the windows in the basement to be 6 feet in height, and not recessed in the inside below the sash-frame; those in the parlour-story to be $8\frac{1}{2}$ feet in height, recessed from the inside of the room below the sash-frame, which is to be placed two feet above the surface of the floor; those in the drawing-room story to descend to the bottom, and to be in height 10 feet. The upper windows to be 6 feet 9 inches in height, and $2\frac{1}{2}$ feet above the surface of the floor, the head of the basement door to be upon a level with the windows, and the jambs $8\frac{1}{2}$ feet high. The street-door to entrance, or parlour-story, to be semicircular, and the top of the arch upon a level with the soffits of the heads of the windows; the sash-frames to be all sunk within the jambs in 4 inch reveals; likewise the under sides of the wooden lintels above the level of the soffits of the brick heads, to be recessed 3 inches upward, and the door-frames 13 inches into the jambs, and also 3 inches into the head; all the windows and doors to have rubbed and gauged arches: the arches of the windows to be 11 inches broad, and in height equal to four courses of the wall. Their mean length, or horizontal dimension, to be $4\frac{1}{2}$ feet; the soffits to be the breadth of a brick, or $4\frac{1}{2}$ inches, and the length is consequently four feet, the breadth of the windows: the arch of the door to be 9 inches broad on the face, and as much on the soffit: how much will the whole amount to, supposing the rod of place-bricks to be £12 15s., the rod of gray-stock work to be £14 10s., the extra facing of best marl stocks to be sixpence per foot superficial, the extra price of the rubbed and gauged arches 3s. per foot, and the lineal foot of angles in apertures to be a penny per foot: likewise, what will be the price of a rod, supposing the apertures not deducted, and what will be the rate if they are deducted, without making any other extra charge whatever; so that the profit of the master bricklayer shall be the same in either case?

The dimensions are generally taken with two five-feet rods, and entered in a book, ruled perpendicularly for the purpose. In brickwork it will be convenient to have three columns contiguous to each other on the left hand; the first vertical column to contain the dimensions, and to be only bounded by one vertical line on the right-hand side of the column: the dimensions of the same surface to be written one under the other, putting the like denominations in vertical rows; the number of times any work is repeated is put on the left of the upper dimension, and separated from it by a curve; the number of half bricks are to be written in the adjoining right-hand column, ruled on both sides, and in a horizontal line with either dimension.

It would answer little purpose to show the work arising by squaring the dimensions. It may be proper to observe, in order to avoid numerous repetitions of division, that the dimensions of the surfaces, in length and breadth, must be multiplied together, and the product multiplied by the number of times, if more than once repeated, and this last product again by the number of half bricks in the thickness of the work: but if the outline of the surface of the work be circular, or any figure whatever, the quantity of surface must be found by the rules for measuring that figure, and repeated the number of times, and this product by the number of half bricks in the thickness of the work, as before. These products may be found by beginning with any of the multipliers, and using any one of the remaining ones in each succeeding product until their number is exhausted; the result is to be placed in a third adjoining column on the right, in a horizontal row with either of the dimensions. The dimensions, the number of half bricks, and contents of every two surfaces, are to be separated from each other by a horizontal line. The numbers in the third column are the contents of the work reduced to a wall, half a brick thick; and consequently, any number of contents of the same species of work may be added together, and reduced to the standard by dividing the sum by 3; and if rods are required, the quotient must be divided by 272, which will save immense labour.

The following is a specimen of the Dimension Book: The lineal measures are as in the preceding description, and are supposed to be taken in order, as they succeed each other, beginning with the basement part of the building, whether of the same kind or not, in order to prevent frequent returning to the same place.

Where the same dimension is often repeated in different parts of the building, it would be unnecessary to insert the number of times they occur in every part; it is sufficient to make a memorandum of the number to be found in each place, on the waste, and then the number of times it is repeated in the whole may be inserted in the Dimension Book at last.

In each of the different stories, the same order, if possible, is repeated, that mistakes of overlooking any of the articles may be prevented.

Every other part will be sufficiently evident by inspection, and by attending to the general description in the example, except the semicircular head of doorway, the dimensions of which are set down in the same manner as the others, and the squaring is found by the rules for measuring a circle. Now the multiplier for the area of a circle reduced to duodecimals is 9 in. 5 sec.; the dimensions are 4 feet by 2; these multiplied together give 8; this product again multiplied by 9 in. 5 sec. gives 6 ft. 3 m. 4 sec., and this repeated by 2, the number of half bricks on the exterior part of the aperture, gives 12 ft. 6 m. as the seconds are always unnoticed.

Dimension Book, with the Contents.

26 0 1 0	8½	221 0	Footing of wall with place-bricks
26 0 11 0	6	1716 0	Part of the wall opposite basement, of gray-stock brick-work
2(6 0 4 0	1	48 0	Exterior part of the apertures of the two windows
2(6 3 4 8	5	291 8	Interior part of ditto
4(18 3		73 0	External and internal quoins of windows
8 6 4 0	2	68 0	Exterior part of the aperture of doorway
8 9 4 8	4	163 4	Interior part of ditto
2(25 9		51 6	Quoins of doorway
26 0 11 0	5	1430 0	Part of the wall opposite parlour, or entrance, story
2(8 6 4 0	1	68 0	External parts of apertures of windows
2(8 9 4 8	1	81 8	Middle parts of ditto
2(10 9 4 8	3	301 0	Internal parts of ditto
4(28 0		112 0	Quoins of windows
8 6 4 0	2	68 0	External part of aperture of street-door, excluding the circular head
8 6 4 6	3	114 9	Interior part of aperture of street-door, excluding the circular head
4 0 2 0	2	12 6	Exterior part of aperture of semicircular head of street-door
4 6 2 3	3	23 10	Interior part of ditto
2(25 6		51 0	Straight quoins of doorway
26 0 13 0	4	1352 0	Part of the wall opposite the one pair, or principal story
3(10 0 4 0	1	120 0	Exterior part of the aperture of windows
3(10 3 4 8	3	430 6	Interior part of ditto
6(30 6		183 0	Quoins of windows
26 0 10 0	3	780 0	Part of the wall opposite attic story
3(6 9 4 0	1	81 0	Exterior parts of apertures
3(7 0 4 8	1	98 0	Middle parts of ditto
3(9 6 4 8		133 0	Interior parts of ditto
6(20 9		124 6	Quoins of windows

Sundry Extras.

11(4 6 0 8	33 0	Rubbed and gauged faces of arches in all the windows
4 0 2 0	5 6	Rubbed and gauged arch of doorway
11(4 0 0 4	14 8	Soffits in ditto
34 0 26 0	884 0	Marl facing, including apertures
2(8 6 4 0	68 0	Deduction of parlour windows from marl facing
3(10 0 4 0	120 0	Deduction of the one-pair windows from marl facing
3(6 9 4 0	81 0	Deduction of attic windows from marl facings
8 6 4 0	34 0	Deduction of the area of doorway from marl facing, excluding the semicircle
4 0 2 0	6 3	Deduction of the semicircular head of doorway from marl facing

The dimensions are most frequently wrought upon the waste, or upon the right-hand side of the leaf of the Dimension Book, which is very convenient, as the work may be inspected should any mistake be apprehended.

The arranging of the several kinds of work into columns, so as that each column may contain the same kind throughout, is called an abstract. This arrangement saves much trouble in the calculation, reduces the whole into a very small compass in homogeneous kinds, and prevents the confusion which would otherwise arise from the multitude of parts in a complex building.

The following is an abstract of the whole: The contents are placed in vertical columns, which are in number equal to the number of kinds of work, every number of the same kind being arranged in the same column. The order of each kind or species of work is the same as they occur in the Dimension Book; for example, 221 footing of walls, with place-bricks, first occurs; this is entered in the first column of the abstract: 1716, basement wall of gray-stock brick-work next occurs; these bricks and work being of a different quality, are entered in the second column of the abstract: 48, the exterior part of the apertures next occurs; this is the same kind of work as the last, but as the former is a measure of both solids and voids, and this is only a part of the measure of the voids, the 48 is placed in an adjoining column. The next number is 291 .. 8; this is a deduction of the same kind, and is therefore inserted in the abstract below the 48: the next that occurs is 73 feet of quoins lineal measure; this, being different from the preceding, is entered in a fourth column. The next that occur in the Dimension Book, are 68 and 163 .. 4, external and internal parts of the aperture of doorway; being voids of the same kind as the preceding, they are successively entered in the third column, below the 291 .. 8. The next that occurs is 51 .. 6, quoins of doorway, and is entered in the fourth column. The next that occurs is 1430 .. 0, the part of the wall opposite parlour, or entrance-story; now, though this is gray-stock work, faced with marles, it is taken only as a gray-stock wall, and is therefore entered in the second column; the difference of price for the superior quality of bricks and work being afterwards made up by affixing an extra price to the superficial contents of this part of the wall, and thus for all that follows. The whole being inserted, each column is added together, and in the quality of the brick-work the sum of the voids is taken from the whole; the remainder is divided by 3, which gives the superficial contents in feet of the surface of a wall reduced to 1½ brick in thickness; the deductions being negative quantities, no further notice is taken of them; the sums of the other columns being positive, the price is affixed to each common measure, whether a foot or a rod, &c., and the value of each quantity is found by this common measure; then the quantities, with the prices of their common measures and values, are inserted in a bill; the whole being reduced into a sum, gives the amount of the whole money for the wall.

Abstract.

Footing of wall of place-bricks.	The whole of the walling reduced to ½ a brick thick, taken as gray-stock work without regard to the facing.		Quoins of apertures by the lineal foot.
	Contents of the wall.	Deductions.	
3)221 0	1716 0	48 0	
73 8	1430 0	291 8	73 0
	1352 0	68 0	51 6
	780 0	163 4	112 0
		68 0	51 0
	5278 0	81 8	183 0
	2103 3	301 0	124 6
		68 0	
	3)3174 9	114 9	595 0
		12 6	
	272)1058(3 R.	23 10	
	816	120 0	
		430 6	
	242	81 0	
		98 0	
		133 0	
		2103 3	

Rubbed and gauged arches.	Marl facing in superficial feet.	
	Contents.	Deductions.
ft. in.	ft. in.	ft. in.
37 1	884 0	68 0
16 6	309 3	120 0
		81 0
53 7	57 9	34 0
		6 3
		309 3

The next thing to be done is to affix the price of the common measure to each of the above species of work, and from this, to calculate the quantity of each; then insert the several sums in a bill, as follows:

Bill.

Rods.	Feet.		£.	s.	d.
0	73⅜*	Superficial of place-brick work reduced to the standard at £12. 15s. per rod	3	8	5¼
3	242	Superficial of gray-stock work reduced to the standard at £14. 10s. per rod	56	8	0
0	595	Feet lineal of quoins in apertures at 1d per foot	2	9	7
0	53½	Superficial of rubbed and gauged work at 3s. per foot	8	0	6
0	574¾	Superficial of marl facing at 6d per foot	14	7	4½
			£84	13	10¾

* ⅜ not noticed in the calculation.

In the foregoing admeasurement, the quoins are valued by the foot lineal, in addition, and the method of making out the contents is different from that commonly used; but though the allowance is strictly just, and the practice shorter and less liable to mistake than that in common use; that there should be nothing wanting to gratify those who may still favour the customary method, the admeasurement is here repeated in the usual way. The mark thus — signifies a deduction.

	Dimen.	Contents.	Th.	Names.
	ft. in. 26 0 1 0	ft. in. 26 0	brick 4½	Footing.
	26 0 11 0	286 0	3	Walling
2	6 0 4 0	— 48 0	½	Windows
2	6 3 4 8	— 58 4	2½	Ditto
	8 6 4 0	— 34 0	1	Doorway
	8 9 4 8	— 40 10	2	Ditto
	26 0 11 0	286 0	2½	Walling
2	8 6 4 0	— 68 0	½	Windows
2	8 9 4 8	— 81 8	½	Ditto
2	10 9 4 8	—100 4	1½	Ditto
	8 6 4 0	— 34 0	1	Ditto ⌓
	8 6 4 6	— 38 3	1½	Ditto ⌓
	4 0 2 0	— 6 3	1	Ditto
	4 6 2 3	— 7 11	1½	Ditto
	26 0 13 0	338 0	2	Walling
3	10 0 4 0	—120 0	½	Windows
3	10 3 4 8	—143 6	1½	Ditto
	26 0 10 0	260 0	1½	Walling
3	6 9 4 0	— 81 0	½	Windows
3	7 0 4 8	— 98 0	½	Ditto
3	9 6 4 8	—133 0	½	Ditto

The dimensions are frequently squared upon the waste on the margin of the Dimension Book; the following is a specimen:

First.	Second.
4 8	8 9
6 3	4 8
28 0	35 0
1 2	2 11
	2 11
29 2	40 10
2	
58 4	

Third.	Fourth.
8 9	4 8
4 8	8 9
5 10 0	3 6 0
35 0	37 4
40 10 0	40 10 0

The operations are wrought in various ways: as in the first and second, by aliquot parts; the third and fourth by duodecimals. These various modes serve to confirm each other. The third and fourth are the same dimension, but the factors are inverted in respect of each other.

4	4 6
2	2 3
0 8	1 1 6
9 5	9 0
0 3 4	10 1 6
6 0	0 9 5
6 3 4	4 2 7 6
	7 7 1 6
	7 11 4 1 6

The mark thus ⌓ signifies a semicircle. The method of finding the semicircular area is shown in the two examples above; first by multiplying the dimensions together, and multiplying the product by 9 inches and 5 seconds, as above, or by calling the feet inches, as in the first operation, and multiplying by 9 feet 5 inches.

The above contents are abstracted by inserting each area in a separate column, according to the number of half bricks it is thick.

In the following abstract, the several parts of each column are collected: the sum or amount is multiplied by the number of half bricks, and the product divided by 3; then the positive quantities are added together, and the negative ones added together, their difference is the real quantity in reduced feet, by dividing which by 272, the answer will be obtained in rods,

Wall, including Apertures.					Deductions from Wall.				
4½ bricks.	3 bricks.	2½ bricks.	2 bricks.	1½ brick.	2½ bricks.	2 bricks.	1½ brick.	1 brick.	½ brick.
Footing of place bricks.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
	286 0	286 0	338 0	260 0	58 4	40 10	100 4	34 0	48 0
ft. in.	6	5	4	450 8	5	4	38 3	34 0	68 0
26 0				476 8			7 11	6 3	81 8
8½	3)1716 0	3)1430 0	3)1352 0	572 0	3)291 8	3)163 4	143 6		120 0
							97 2	74 3	81 0
208 0	572 0	476 8	450 8	1759 4	97 2	54 5	54 5	2	98 0
13 0				700 11			49 6		133 0
							209 10	3)148 6	
3)221 0				272)1058 5(3 rds.					629 8
				816			700 11	49 6	1
73 8									
				242 feet.					3) 629 8
									209 10

Instead of dividing by 3, as in the above abstract, it would be easier to add the products of the half brickwork, both for the walling and for the deductions, and subtract the deductions from the walling; divide the difference by 3, and the quotient by 272, should it be found necessary.

Wall, including Apertures.					Deductions from Wall.				
4½ bricks.	3 bricks.	2½ bricks.	2 bricks.	1½ brick.	2½ bricks.	2 bricks.	1½ brick.	1 brick.	½ brick.
ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
26 0	286 0	286 0	338 0	260 0	58 4	10 10	100 4	34 0	48 0
8½	6	5	4	3	5	4	38 3	34 0	68 0
							7 11	6 3	81 8
208 0	1716 0	1430 0	1352 0	780 0	291 8	163 4	143 6		120 0
13 0				1352 0				74 3	81 0
				1430 0			290 0	2	98 0
221 0				1716 0			3		133 0
								148 6	
				5278 0			870 0		629 8
				2103 2			291 8		1
							163 4		
				3) 3174 10			148 6		629 8
							629 8		
				272) 1058 3(3 rods 242 feet					
				816			2103 2		
				242					

The other parts of the above abstracts are as in the preceding, and are, therefore, not again repeated.

A wall common to two houses, the properties of different persons, is termed a *party wall;* but if a building stands insulated, the walls which join the entrance to the rear front are called *flank walls.* Chimneys are generally carried up, either in party walls, flank walls, or partition walls, and sometimes in all of them; but never, or very seldom, in the front or rear walls. When the walls which contain the chimneys are thin, it becomes necessary to form a projection of sufficient breadth and depth, for the reception of the flues, or as many of them as can be collected into one stack. This projection is generally a rectangular prism, showing three vertical sides, and is termed *the chimney-breast*, or *breast of the chimney.*

The method of measuring the solid contents of every part of a building, is to reduce all the parts into rectangular prisms, and then find the solid contents of each prism. It frequently happens that walls consist of a cluster of prisms, which may be differently divided, in order to separate them. All apertures or cavities of any consequence, ought to be deducted from the measure, whether the proprietor or the contractor find the materials; but as every return or termination requires more trouble than a continued wall, an allowance ought to be made in lineal measure, upon every foot of angles, or terminations, as before mentioned, for the trouble of plumbing, levelling, and straighting. It is true, that a great length of wall requires several intermediate plumbings, but then, as they are only regulated upon the face, the trouble is small in comparison to what is required in a vertical termination, or a deflection of the wall from its course, by another return wall at an angle with it; and as these plumbings may be made at regular distances, the parts of the wall may be said to be uniformly built, and the same in all equal lengths of walls, and the time proportional to the quantity under the same circumstances of height and thickness, and therefore the area or solidity is a fair ratio of the price: and farther it is evident, that the greater the number of apertures or vacuities, in the same length of wall, the more trouble will they occasion the workmen, since more time is required to form the sides of the apertures, or the boundaries of the vacuities. In this case, therefore, the time of completing a wall of given dimensions, even with the same quality of work, depends upon the number of quoins that are to be built, and consequently cannot be determined by the solidity of the wall, but jointly by this measure and the lineal quantity of angles; for the solidity is not as the time, when the number of quoins are increased, and consequently the price not as the time; but the price may be made up by the increase of the angles.

It is likewise evident, that in building quoins, while the workmen continue at the same rate of work, the lineal quantity is in the same ratio as the time, and therefore this lineal measure is a fair representation of the value of the work. In carrying up a wall of the same horizontal length, where there are no vacuities, the quantity of work performed by the same number of bricklayers is equal in equal times, but the work requires an additional number of labourers as the height increases, to supply the materials: in this case also, the quantity of surface is a fair representation of the value of the work, in respect of the bricklayers, but an additional sum must be added as the work proceeds, and this increase would be the terms of an arithmetical progression; for suppose the materials at the foot of the scaffold, and the scaffolding erected at regular heights; now it is evident, that whatever time the labourer requires to mount the first scaffold, he would require a time double, triple, quadruple, the first, &c., to mount the second, third, fourth scaffold, &c.: the sum of all these times is the whole time. There should also be a uniform increase of price for the use of scaffolding, as well as for an additional number of labourers, as the work is carried upwards. From the aggregate of these circumstances, it is evident, that the value of the labour, with respect to the bricklayers, may be fairly estimated by the quantity of surface, of equal thickness, but an increase of price must be allowed for labourers and scaffolding.

To measure and value party walls, flank walls, and partition walls with flues.—Find the cubical contents of the whole, or each part of the wall, in feet, according to its figure, or the figures into which it may be resolved; deduct the vacuities, multiply the remainder by 8, and divide the product by 9, and the work will be reduced to the standard; then take the lineal measure of all the quoins, whether external or internal, the proper rate being affixed to each common measure, and it will give the value of the whole.

In measuring walls containing chimneys, it is not customary to deduct the flues; but this practice with regard to the materials, is unjust, though perhaps, by taking the labour and materials together, the overcharge, with respect to the quantity of bricks and mortar, may, in some degree, compensate for the loss of time; on the other hand, should the proprietor find the materials, it is not customary to allow for the trouble of forming the flues, which is therefore a loss to the contractor, or to the workman who engages to execute his part by measure or task-work.

With regard to the allowance for the lineal measure of quoins, we regret to observe, that the practice is not general, and, so far as we know, has only as yet taken place in outside and inside splays, and the angles of groins: we admit that every innovation, not founded upon reason, ought to be resisted; but as we are convinced of the justice of this mode, we have here ventured to introduce this as a general practice, which ought to be followed in every case, whether the quoins be vertical, or horizontal, or curved; and an appropriate price should be affixed to each species of quoins, whether external or internal, right-angled or oblique, curves or right lines, as the trouble is greater in external than in internal angles, greater in oblique than in right angles, greater in curved quoins than in straight ones, and still greater in groins, where the angles are continually varying, than in curves where the angles are the same throughout.

If the brick-work of the footing of a wall project equally on each side, and if the bricks be of the same kind as the wall above, take the height of the wall from the bottom of the footing, as high as it goes of the same thickness; multiply that by the length and the thickness, and reserve this solidity; then multiply the length of the wall, the height of the footing, and its projection with the addition of half a brick, will give the solidity of the footing; add these two solidities together, and the sum will be the solidity of the wall, from which deduct the vacuities, and the remainder will be the quantity of solid work.

If the breast of a chimney project from the surface of the wall, and be parallel thereto, the best method is to take the horizontal and vertical dimension of the face, multiply these together, and the product by the thickness taken in the thinnest part, taking no notice of the breast of the chimney; then find the solidity of the breast itself; add these solidities together, and the sum will give the solidity of the wall, including the vacuities, which must be deducted for the real solidity; after taking the dimensions for the quantity of brick-work, the lineal quantity of angles should be taken, and entered in the Dimension Book.

Nothing more is necessary to be said of the shaft, than to take its dimension in height, and horizontally in breadth and thickness, in order to ascertain the solidity; and then take the lineal quantity of angles, and enter them all in the Dimension Book.

If a chimney is placed in the angle, with the face of the breast intersecting the two sides of the wall, the breast of the chimney must be considered as a triangular prism; to find the solidity, therefore, multiply the area of the base by the height of the surface of the front or breast, and the product is the solidity.

To take the dimensions: from the intersections of the front of the breast into the two adjacent walls, draw two lines on the floor parallel to each adjacent wall, then will the triangle on the floor, included between the front and these lines, be equal to the triangular base of the chimney. In order to obtain the area of the triangular base, the dimensions may be taken in three various ways, almost equally easy; but as convenient a method is to take the extent of the base, which is the horizontal dimension of the breast, and multiply that by half the perpendicular; or, multiply the whole perpendicular by half the base, for the area of the surface on which the prism stands; but as fractions arise by the halving of odd numbers, it would be better in such cases to multiply the whole perpendicular by the whole base, and half the product will give the area of the prismatic base, which is that of the chimney-breast.

Sometimes the front of the chimney-breast does not intersect the walls, but is projected out from each adjacent wall by two returning vertical planes of equal breadth, each at a right angle with the adjacent wall: in this case the triangular prism is measured as before; but as the part between the prism and the wall is frequently constructed with burrs, an inferior kind of brick, this part will then consist of two rectangular prisms, and there is nothing more to do than to measure them as such; then deducting the vacuity of the fire-place from the triangular prism, the remainder will be the true solidity of this prism. In the former case, when the plane of the breast intersects the two sides of the room, a lineal allowance per foot ought to be made for the inside splays, and in the latter case, where the plane of the breast does not intersect the adjacent walls, there will be two outside splays, and two internal right angles; in this case, there must be an allowance for outside splays, and the internal right angles, per foot, running each according to its respective qualities: and in both cases it would only be fair to allow for the vertical extent of the angles of the fire-place. It is not here meant that these allowances should be made according to the present prices, which are adapted so as to include hinderances at a hazard, without any foundation to common reason, but that the price per rod should be reduced in an adequate degree, and each kind valued by its common measure, in proportion to the time it requires to perform a given portion.

A row of plain tiles laid edge to edge, with their broad surfaces parallel to the termination of a wall, so as to project over the wall at right angles to the vertical surface, is called *single plain tile creasing*, and if two rows are laid one above the other, the one row breaking the joints of the other, then these two rows are called *double plain tile creasing;* over the plain tile creasing a row of bricks are on edge, with their length in the thickness of the wall, called a *barge course*, or *cope*.

In gables which terminate with plain tile creasing, coped with brick, in order to form the sloping bed for the *tile creasing*, the bricks must be cut, which is a considerable trouble; the sloping of the bricks thus, is called *cut splay*. Plain tile creasing and cut splay are charged by the foot run, and sometimes the latter by the foot superficial.

A brick wall made in panels between quarters, is called brick-nogging. This kind of work is generally measured by the yard square, with the quarters and nogging pieces included in the measure; but the apertures should be deducted, and the lineal measure of the angles allowed.

Pointing is the filling up of the joints of the bricks on the face, after the wall is built, with mortar, so as to be regular. Pointing is of two kinds. In either, the mortar in the joints is well raked out, and filled again with blue mortar: in the one kind, the courses are simply marked with the edge of a trowel; in this state it is called *flat joint pointing*. If, in addition to flat joint pointing, plaster be inserted in the joint with a regular projection, and neatly pared to a parallel breadth, this state is called *tuck pointing*, or *tuck-joint pointing*, formerly *tuck and patt*.

Pointing is measured by the foot superficial, including in the price, mortar, labour, and scaffolding.

Rubbed and gauged work is set either in putty or mortar, and is measured either by the foot run, or by the foot superficial, according to the construction.

The circular parts of drains may be either reduced to the standard, or to the cubic foot, and the number of rods taken if required. The mean dimension of the arch will be found by taking the half sum of the exterior and interior circumferences; but perhaps it might be proper to make the price of the common measure, whether it be a foot, or a yard, or a rod, greater, as the diameter is less; but as the reciprocal ratio would increase the price in small diameters too much, perhaps prices at certain diameters would be a sufficient regulation.

Circular walls are measured in the same way, by finding a mean girt, which is to be multiplied by the height and thickness; but all work should be valued in proportion to the time required to perform a given portion of it, but in equal portions of straight and curved walls of the same kind of workmanship, the curved portion will require a greater price than the straight portion.

In measuring canted bows, the sides are measured as continued straight walls; but the angles on the exterior side of the building, whether they are external or internal, are allowed for in addition, and paid for under the denomination of *run of bird's-mouth;* all angles within the building, if oblique, from whatever cause they are formed, whether by straight or circular bows, or the splays of windows, are allowed for, under the denomination of *run of cut splay*. These allowances are certainly what ought in justice to be, and this is fulfilling, in part, what has been so much insisted upon; but allowances should extend to right angles also: if the bricks be made to the splay, then the charge need not be greater than when the angles are right.

8

Brick cornices are charged by the foot run, but as there are many kinds, and these executed with more or less difficulty, the price will depend on this, and also upon the value of the materials.

Garden walls are measured the same as other walls, but if they are interrupted with piers, the thin part may be measured as in common walling, and the piers by themselves, and the additional allowance for the right angles, at per foot run, should be granted. The coping is measured by itself, according to its kind.

The common measure for tiling, is a square of 10 feet, each side containing an area of 100 superficial feet. Not only the price of new work is valued by this measure, but also stripping and re-tiling of old roofs; but if any quantity of new tiles are used, they are charged separately, and the superficial quantity of old tiles that would fill the places of the new, are computed, and deducted from the old. In plain tiling, as the rafters are generally made three-quarters of the breadth of the building, the surface of the roof is exactly equal to the area, and a half more, of the length and breadth of the building, or the space contained between the sides of the covering and ends. This being kept in view, will save much trouble in calculation.

Paving is laid either with bricks or tiles, and is measured by the yard square. The price per yard will depend on whether the bricks are laid flat or on edge, or whether laid with bricks or tiles, or of what size tiles, or whether any of these be laid in sand or in mortar.

The mensuration of groins and vaults will be shown under their respective heads.

That this work may be generally useful, we shall here subjoin the customs of several other parts of the United Kingdom, as well as the foregoing, which are calculated for London and its neighbourhood, or work done in the country by London masters.

In most counties, brick walls are measured by the yard, without reducing the thickness of the work to the standard, and fixing a price per yard according to the thickness.

In Cumberland, walls are mostly measured by the yard, and rated according to the thickness of the work: they have also a standard thickness of 18 inches, and their rod or rood is 49 square yards; these are also used by masons in the country, but neither the standard nor the rod are frequently used; apertures are always included for workmanship. In measuring the breasts of chimneys, they take the horizontal girt from wall to wall, to this they add the number of withs, or divisions between the flues, reckoning each with 3 inches, for the whole breadth; the height of the story, or as high as the work goes on uniformly, is the other dimension of the face, and the thickness is reckoned 9-inch work. In measuring a chimney-shaft, they girt it all round, then add the number of withs for the breadth, as before, and if there is only one row of flues, they reckon the thickness a 9-inch wall.

In Scotland, the brickwork of outside walls is generally measured by the rood of 36 square feet, and this measure is almost, if not quite, general. In Glasgow, the standard thickness is 14 inches, or 1½ brick, the same as London; and walls of less thickness are generally measured by the yard, and the rate of price is according to the thickness of the work. Chimney shafts, or stalks as they are there called, are girt about for their horizontal dimension, and the altitude of the shaft, together with half its thickness, is the other dimension of the face; and the thickness is reckoned a brick and a half. In measuring the breasts of chimneys, they take the breadth of the face, and one return for the length, and the other dimension of the face is the height as far as the work goes of a uniform quality and thickness; the thickness is what the breast really projects. Vacuities for doors and windows are not deducted from outside work.

In Ireland, the common measure is a perch of 21 square feet, being 21 feet long, and 1 foot high; the standard thickness is 9 inches only. The custom there, as also in most country places in Great Britain, was to include the openings. A 4-inch wall is reckoned two-thirds of a 9-inch wall; and a 3-inch wall, half a 9-inch wall. In the centering of sewer vaulting, half the arch is allowed; and in groin vaulting, the whole arches are done at so much per piece, according to their kind; splayed jambs, cant quoins, &c., by the running foot.

For further information on measuring, the reader is referred to a valuable little work, called "The Student's Guide to the Practice of Measuring and Valuing Artificers' Works," published by *Weale, London.*

Materials in bricklaying are charged as follows:—

Fine bricks, red rubbers, best marl stocks for cutters, second best, pickings, common bricks, place bricks, paving bricks, kiln-burnt bricks, and Dutch clinkers, by the thousand.

Red rubbers, kiln-burnt bricks, and fire-bricks, are also sold by the hundred.

Foot-tiles and ten-inch tiles, either by the hundred or thousand.

Sunk foot-tiles, and ten-inch tiles, with five holes, by the piece.

Pantiles, plain tiles, and nine-inch tiles, by the thousand.

Oven-tiles, Welch oven-tiles, Welch fire-lumps, fire-bricks, and chimney-pots, are sold by the piece.

Sand, clay, and loam, by the load: lime sometimes by the hundredweight.

Dutch terras, Parker's Roman cement, and lime, by the bushel.

Pantile laths, oak laths, double and single, for slating, are sold by the bundle or load.

Hair and mortar by the load.

Mortar, lime, and hair fine stuff, Parker's cement, and blue pointing mortar, are sold by the hod. Hair is sometimes sold by the bushel.

Hip hooks and T nails by the piece.

In the former edition of this work was inserted a number of tables, showing the prices and quantities of materials; but as there are now published several useful *price-books*, in which this kind of information is given, it has been considered better to refer to them than occupy so large a portion of our limited space as the tables would necessarily occupy.

BRIDGE, a structure of wood, stone, brick, iron, or other material, raised over a river, pond, lake, or any intervening space, for the purpose of affording a convenient mode of passage for men or animals. The extreme supports of a bridge are called the *butments*, or *abutments*. *See* ABUTMENT. If composed of more than one opening, the intermediate supporters are called *piers:* the protecting walls or fences on each side are called *parapets.*

When the bridge is intended for both foot-passengers and carriages, the sides are generally raised, and sometimes paved with flag-stones, and are called *banquettes*, or *foot-paths;* the middle part, being reserved for carriages, is the *road*, or *carriage-way.*

In this place we propose to give a slight historical sketch of the rise, progress, and present state of bridge-building, exemplified in descriptions of the most celebrated edifices of the kind in various parts of the world. Under the respective heads of STONE BRIDGE, TIMBER BRIDGE, IRON BRIDGE, SUSPENSION BRIDGE, &c., will be found the required information on each of these several branches of this important subject; and some account will be given of the theory under STONE BRIDGE.

The origin of bridges, there can be no doubt, takes its date very far back in the annals of the human race, though we have no documents by which to trace their progressive improvement, from the trunk of a tree, rudely thrown by accident or choice over a stream, to the convenient and stupendous edifices of more modern times.

It is probable that the first bridges were composed of lintels of wood or stone, stretching from bank to bank; or if the breadth of the river or valley to be passed were considerable, resting on piers or posts fixed in the bed of the river. In a strong current, the frequent piers or posts required for the support of lintels, would, by contracting the water-way, increase it to a torrent, obstructive of navigation, and ruinous to the piers themselves. In constructing bridges therefore over rapid rivers, it would be found essential to their stability, that the openings between the supporters should be as wide as possible, and every facility given to the free passage of the water; and as this could be effected only by the use of stone arches or wood trusses, there can be no doubt that these inventions were perfected before bridges of importance had become common.

There are still remaining bridges of great antiquity built by the Romans, but we are not acquainted with the earliest history of so useful a contrivance. It is by many supposed that the Greeks very soon adopted the use of *arches*, but at any rate they do not appear to have applied them to other purposes than for covering apertures in their buildings. *See* ARCH, ARCHITECTURE. Nor had they a bridge over the Cephisus, which crossed the high-road between Athens and Eleusis, till the Emperor Adrian erected one. In the Old Testament there is no mention of a bridge, and perhaps the bridge of Semiramis, at Babylon, may be considered the oldest on record.

The Chinese lay claim to a high antiquity for their skill in bridge-building by means of arches. Several of these structures are of great magnitude, built of stone, and turned on arches in the usual manner; others are constructed with stones from five to ten feet in length, so cut as each to form the segment of an arc, which consequently has no key-stone; ribs of wood being fitted to the convexity of the arch, and bolted through the stones by iron bars, fastened in the solid parts of the bridge.

The suspension-bridges of South America are of a very extraordinary character, and from the lightness of their materials, their oscillation, and the great height at which they are sometimes suspended, present to the startled traveller objects at once alarming and picturesque, and well calculated to try the strongest nerve. *See* SUSPENSION-BRIDGE.

The Roman bridges are described by Bergier, as possessing all the requisites met with in a modern bridge; they consisted of piers, arches, butments, carriage-ways, and raised banquettes or footpaths separated from the road by a railing, and sometimes furnished with a cover to shelter passengers from the weather. Their solidity and proportion prove they must have been constructed on sound principles.

The superintendence and care of bridges was always an important object with the Romans; it was at first committed to the priests, who thence obtained the name of *pontifices;* afterwards it was given to the censors and curators of roads; and at last the emperors took it into their own hands. In the middle ages, the building of bridges was esteemed to be an act of religion; and about the close of the twelfth century, St. Benezet founded a regular order of hospitallers, under the denomination of *pontifices*, or bridge-builders, whose province it was to erect bridges, appoint ferries, and entertain travellers in hospitals built on the banks of rivers.

Of the bridges of antiquity, that built by Trajan across the Danube, near the town of Warhel, in Hungary, is allowed to have been the most magnificent. It was destroyed by Adrian, but some of the piers may still be seen.

The remains of a bridge bearing as strong marks of ruined magnificence as any of antiquity, are to be met with at the bottom of a hill, on which the town of Narni is seated, on the road between Loretto and Rome. This bridge was built by Augustus, to join two mountains, between which flows the river Nera, and to enable the inhabitants of Narni to pass on a level from one mountain to the other. It was of an extraordinary height, and its whole length, 850 palms (637½ feet). It consisted of four large unequal arches.

The next considerable Roman work of this kind is the *Pont du Garde*, about three leagues from Nismes; which serves the double purpose of a bridge over the Gardon, and an aqueduct for supplying the people of Nismes with water. The bridge, which consists of six arches, is about 465 feet in length, and supports a second series of 11 arches, which are continued beyond the extremities of the bridge, and form a junction with the slope of the mountains on either side; it is about 780 feet long. Over these is a third series of 35 arches, much smaller than those below, 850 feet in length, supporting a canal on a level with the two mountains, along which the water is conveyed to Nismes by a continued aqueduct. This extraordinary edifice is built with very large stones, held together by iron cramps without cement. The whole height is 190 feet above the lower river.

The bridge of *St. Esprit*, near Lyons, is of Roman origin, and has long been deemed one of the finest and boldest of the ancient bridges of France. Its whole length is upwards of 800 yards; it is very crooked, bends in several places, and makes many unequal angles, particularly in those parts where the river has the strongest current. The arches run from 15 to 20 fathoms in width. The feet or bottoms of the piers consist, in their lower parts, of several courses of footings jutting out like steps; and are each protected by two pedestals, projecting from them. Between the large arches are smaller apertures, like windows, reaching nearly to the tops of the pedestals, about the middle of the pier. This mode of construction was adopted with a view to break gradually the mighty force of the Rhone: the several courses of steps, jutting out from the piers, oppose and break the stream by portions, and prevent it from operating with its whole force upon the fabric at once; and when the flood rises so high as to cover the steps and pedestals, the small arches, or windows, allow the water to pass freely, which otherwise would have choked in the upper part of the great arches, and endangered by their being forced up.

The city of Valenza de Alcantara, in Spain, is celebrated for its ancient bridge over the Tajo, or Tagus, about 25 miles from Madrid, built in the time of the Emperor Trajan; and, as appears from an inscription over one of its arches, by the people of Lusitania, who were assessed to defray the expense. It is 200 feet above the water, and though consisting of only six arches, is 670 feet in length, and 28 in breadth. At the entrance of the bridge is a small chapel dug in the rock by the pagans, who dedicated it to Trajan; but when the Christians obtained possession, they consecrated it to St. Julian.

Near the old town of Brioude, in the Lower Auvergne, or department of the Upper Loire, is a stupendous stone bridge, of one arch, the largest with which we are acquainted. It is attributed to the Romans, and stretches over the whole stream of the Allier. The extremities of the arch rest on a natural rock, which occasions the spring on one side to be lower than on the other; it is formed of squared stones in two ranks; the rest of the fabric is of rubble-work. The span of the arch is 181 feet; its greatest height, from the level of the water to its intrados, 68 feet 8 inches; and the breadth of the bridge, 13 feet.

The bridge of Avignon was begun in the year 1176, and finished in 1188, probably under the direction of St. Benezet and the fraternity of hospitallers, over whom he presided; it consisted of 18 arches, and was about 1,000 yards in length. The road-way was so narrow, that two carriages could not pass each other in any part; this had caused it to be deserted by all but foot-passengers long before its destruction, which happened in 1699, by one of those violent inundations common to the Rhone. Many of the ruinous-decayed arches still remain.

The city of Venice has nearly 500 handsome bridges of one arch, and various sizes, over the canals, &c.; most of them are of white stone, similar to that with which the streets are paved, without any balusters or fence on either side. Of these the principal is the Rialto, esteemed, when erected, a masterpiece of art. It was begun in 1588, and finished in 1591, after a design of Michael Angelo, and consists of one bold flat arch, nearly 100 feet wide, and only 23 in height from the level of the water. Its breadth, which is 43 feet, is divided into three narrow streets, by two rows of shops: the middle street is the widest, and in the centre there is an arched aperture, by which the three streets communicate with each other. At each end of the bridge is an ascent of 56 steps, and the prospect from its summit is both lively and magnificent. The foundation extends 90 feet, and rests upon 12,000 elm piles; the whole exterior of the bridge, as well as of the shops, is of marble. The building cost the Republic 250,000 ducats.

The most stupendous and magnificent work ever executed in the department we are now speaking of, is the aqueduct bridge of Alcantara, near the city of Lisbon. It was begun in the reign of John V. king of Portugal, in the year 1713, and was finished on the sixth of August, 1732, under the superintendence of Brigadier Mansel de Maya. The aqueduct commences at a spring near Ribeira de Caranque, about three leagues and a half from Lisbon, to which city the water is conveyed for the supply of the inhabitants. The aqueduct passes subterraneously through the hills, receiving in its course the waters of several springs, and stretches across many valleys on the tops of magnificent ranges of arches, of which that crossing the vale of Alcantara is the principal. When the water emerges from its subterraneous passage, it is received in two channels on the tops of these arches, each about 12 inches deep; it generally flows at about the depth of seven inches, yielding an abundant supply for the city and its environs. The interior height of this building is 13 feet, and between the streams is a paved walk or foot-path. The subterraneous passages are continued of the same height and width throughout the whole extent of the works, and are lighted and ventilated by openings to the surface of the hills through which they pass. Over each of these openings are turrets or square towers, with strong latticed windows, to prevent mischievous persons from throwing stones, &c., into the aqueduct. These turrets are 16 in number, each 16 feet square, and rising 23 feet six inches above the roof of the aqueduct; the number of windows is 79, each three feet seven inches long, by 13 inches wide, railed with iron and latticed with bars. Beneath every second turret is an arched doorway into the aqueduct. The water-channel under the grand arch is about 24 feet in width, and seven feet in depth; but this channel is dry, except in very rainy seasons. There is, indeed, a small stream constantly running through the vale of Alcantara, but it is conveyed by a very narrow channel under the pavement beneath the grand arch, and then continues its course through the valley in a stream between two and three feet wide, till it falls into the Tagus, about two miles below. This remarkable structure consists of 35 arches, of various dimensions. The eighth is the grand arch, which is 108 feet five inches in the span, and 227 feet in height: the other arches vary from 21 feet ten inches, to 72 feet in width. The total length of the piers and arches is 2,464 feet. The expense of erecting this work, and keeping it in repair, has hitherto been defrayed by the trifling rate of one rey on every pound of meat sold in the markets of Lisbon.

In France, besides the Roman structures already noticed, there are many bridges of more recent date, remarkable both for their size and the boldness of their construction: among these may be mentioned the bridge of Neuilly, built between the years 1768 and 1780, by M. Perronet. It crosses the Seine, on a line with the grand avenue of the Champs Elysées, in the front of the Tuilleries; it is level on the top, and consists of five equal arches, 120 feet French (128 feet English) in the span, with a rise of 30 French feet (32 feet English). The piers are 14 feet thick, and the bridge itself 48 feet broad. The arches, which are elliptic, are composed of 11 arcs of circles, of different diameters: the upper portion of the arch was formed with a circle of 160 feet radius, which, by its settlement during the building and after removing the centres, became flattened to an arc of a circle of 259 feet radius, differing so little from a platband, that the rise of the curve in a length of 33 feet, amounts to no more than six inches nine lines.

At Mantes is a bridge of three arches, likewise over the Seine. It was begun in 1757, by M. Hupeau, and finished by M. Perroet. The centre arch is 120 feet French (128 feet English) in the span; the side arches are each 12 feet less. The piers are 25½ feet wide, and the abutments 29 feet thick.

In the year 1771, M. Regemortes constructed a flat bridge over the river Allier, at Moulins, consisting of 13 semi-elliptical arches, of 64 feet span each, and 24 feet high.

Over the river Oise, on the great road from Paris into Flanders, is the bridge of St. Maxence, 41 feet wide, built by M. Perronet. The arches, three in number, each describe the segment of a circle, whose radius is 118 feet, leaving a water-way of 77 feet. The piers are singularly constructed; each being composed of four cylindrical pillars, nine feet in diameter, leaving between them three spaces or intercolumniations, which are arched over; those on the outsides are closed with a thin walling, and the middle one is left open.

The last foreign bridge we shall notice, is that of Orleans, over the Loire, built by M. Hupeau, between the years 1750 and 1760. It comprises nine oval arches, described from three centres, which spring at 12 inches above low water. The middle arch is 106 feet in span, with a rise of 30 feet; the extreme arches at either end, are each 98 feet wide, and 26 feet high; the intermediate arches increase gradually in dimensions as they approach the centre. The four middle piers are 19 feet wide; the others, 18 feet each; and the abutments 23½ feet thick; making the whole length of the bridge 1,100 feet.

We come now to speak of bridges in our own country, beginning with those of the greatest antiquity. The Gothic triangular bridge at Croyland, Lincolnshire, is supposed to be the most ancient structure remaining entire in the kingdom. It was erected about the year 860, but for what purpose, it is difficult, if not altogether impossible to determine; it is, however, obvious that utility was not the motive of the builder; though it may be allowed to claim the qualities of boldness of design and singularity of construction, as powerfully as any bridge in Europe. It is formed by three semi-arches, whose bases stand in the circumference of a circle, equidistant from each other, and uniting at the top. This curious *triune* formation has led many persons to imagine, that the architect intended thereby to suggest an idea of the Holy Trinity: nor is this improbable, considering the age in which it was built. The ascent on either side of the semi-arches is by steps paved with small stones, and so steep that foot-passengers only can go over the bridge. Horsemen and carriages frequently go under it, as the river is in that place but shallow. Although this structure has been built for so many centuries, the arches are still sound and free from fissures, and the building in general exhibits very trifling marks of decay.

The bridge of Burton-upon-Trent is 1,545 feet in length. It consists of 34 arches, all of free-stone, and is strong and lofty. It was erected in the 12th century, by Bernard, abbot of Burton.

Near Old Aberdeen is a celebrated Gothic bridge, over the river Don.

The centre arch of the bridge at York is 82½ feet wide, and 27 feet high.

At Winston, Yorkshire, is a bridge of a single arch, 108 feet nine inches in width, built of rubble stone, for the small cost of £500. It was designed by Sir Thomas Robinson, and built by John Johnson, a common mason, of Walsingham, in the year 1762.

At Kelso, is an elegant stone bridge over the Tweed, built by Mr. Rennie. It is quite level at the top, having five elliptical arches, each of 72 feet span; every pier has a circular projection, on which stand two Doric pilasters, supporting a simple block cornice. This bridge cost about £13,000 exclusive of the new roads at each end, which cost about £3,000 more.

Mr. Rennie also constructed the aqueduct bridge over the river Lune, at Lancaster, which is considered as one of the most magnificent works of the kind extant. At the place where it is built, the water is deep and the bottom bad: the foundations are therefore laid 20 feet below the surface of the water, on a flooring of timber resting on piles. The arches are five in number, of 70 feet span each, and rise about 39 feet above the surface of the water. It has a handsome cornice, and every part is finished in the best manner The total height from the surface of the river, to that of the canal, is 57 feet; and the canal admits barges of 60 tons burden to navigate upon it. The foundation alone of this building cost £15,000, and the superstructure more than double that sum, although the stone was obtained from a quarry less than a mile and a half from the spot.

The bridge over the Pease, or Peaths, between Dunbar and Berwick-upon-Tweed, is rather an uncommon structure. It crosses a deep ravine, and consists of four semicircular arches. The arch on the east side of the ravine is 54 feet wide; the second 55 feet; the third 52 feet; and the fourth, or western arch, 48 feet. From the bottom of the ravine to the surface of the road, the height is 124 feet. It was designed and built by the late Mr. D. Henderson, of Edinburgh.

The bridges of Edinburgh are built, not over water, but over dry land. They are distinguished by the name of *North Bridge* and *South Bridge*, and afford an easy communication between the New Town and the royalty and suburbs on either side of it. The North Bridge, which forms the main communication between the Old and New Towns, was projected in the year 1763; but the contract for building was not signed till the 21st of August, 1765. The architect was Mr. William Mylne, who agreed with the town-council of Edinburgh to finish the work for £10,140, and to uphold it for ten years. It was also to be finished before Martinmas, 1769; but on the 8th of August that year, when the work was nearly completed, the vaults and side walls on the south fell down. This misfortune was occasioned by the foundation having been laid upon the rubbish of the houses which had long before been built on the north side of the High-street; and which had been thrown out into the hollow to the northward; of this rubbish there was a depth of no less than eight feet between the foundation of the bridge and the solid earth. Besides this deficiency in the foundation, an immense load of earth, which had been laid over the vaults and arches, in order to raise the bridge to a proper level, had, no doubt, contributed to produce the catastrophe above-mentioned. The bridge was repaired by pulling down some parts of the side walls, and afterwards rebuilding them; strengthening them in others with chain bars; removing the quantity of earth laid upon the vaults, and supplying its place with hollow arches, &c. The whole was supported at the south end by very strong buttresses and counterforts on each side; but on the north it has only a single support. The whole length of the bridge, from High-street, in the Old Town, to Princes-street, in the New Town, is 1,125 feet; the total length of the piers and arches, is 310 feet. The width of the three great arches, is 72 feet each; of the piers, $13\frac{1}{2}$ feet; and of the small arches, each 20 feet. The height of the great arches, from the base to the top of the parapet, is 68 feet; the breadth of the bridge, within the wall over the arches, is 40 feet; and the breadth at each end, 50 feet. The South Bridge is in a line with the North Bridge, so as to make but one street, crossing the High-street almost at right angles. It consists of twenty-two arches of different sizes; but only one of them is visible, viz. the large one over the Cow-gate; and even this is small in comparison with those of the North Bridge, being no more than 30 feet wide, and 31 feet high. On the south, it terminates at the University on one hand, and the Royal Infirmary on the other.

The aqueduct bridge at Glasgow, over the river Kelvin, which conducts the great canal from the Forth to the Clyde, is the work of that great engineer, Mr. Smeaton. Its length between the abutments, or land-piers, is 245 feet; the arches, which are four in number, are each 50 feet in span, rising 15 feet 3 inches, from 15¼ feet above the footing of the piers; the three piers are each fifteen feet thick, and 54 feet high, exclusive of the footing. The extrados is a straight surface for the canal. This bridge is constructed upon true mechanical principles, and the parapet is recessed opposite to the arches in order to resist the pressure of the water in the canal. The land-piers are also ingeniously contrived to be concave outwardly, so as to spread out at the base.

The bridge at Perth was erected between the years 1766 and 1771, according to a plan by Smeaton, under the patronage of the late Earl of Kinnoul. It consists of ten arches, one of which is a land arch. The clear water-way is $589\frac{3}{4}$ feet; the extent of all the arches, $730\frac{3}{4}$ feet; and the wing-walls 176 feet: so that the total length of the bridge is $906\frac{3}{4}$ feet. The expense of building amounted to £26,446 12s. 3d., and was defrayed by public subscription. Blenheim bridge consists of three arches, the chief of which is $101\frac{1}{2}$ feet in the span.

But the most extraordinary bridge in Great Britain, is that over the Taff, near Llantrissent, in Glamorganshire, called by the Welch *Pont-y-ty-Pridd.* It is the work of William Edwards, an uneducated mason of the country, who engaged, in 1746, to erect a new bridge at this place, which for elegance of design, and neatness of execution, surpasses any thing of the kind throughout the Principality. The description and history of the progress of this bridge, we shall borrow from Mr. Malkin's *Tour in South Wales:* "It consisted of three arches, elegantly light in their construction. The hewn stones were excellently well dressed and closely jointed. It was admired by all who saw it. But this river runs through a very deep vale, that is more than usually woody, and crowded about with mountains. It is also to be considered, that many other rivers, of no mean capacity, as the Crue, the Bargoed Taff, and the Cunno, besides almost numberless brooks, that run through long, deep, and well-wooded vales or glens, fall into the Taff, in its progress. The descents into these vales from the mountains being in general very steep, the waters, in long and heavy rains, collect into these rivers with great rapidity and force, raising floods, that in their description would appear absolutely incredible to the inhabitants of open and flat countries, where the rivers are neither so precipitate in their courses, nor have hills on each side to swell them with their torrents. Such a flood unfortunately occurred soon after the completion of this undertaking, which tore up the largest trees by the roots, and carried them down the river to the bridge, where the arches were not sufficiently wide to admit of their passage: here therefore they were detained. Brush-wood, weeds, hay, straw, and whatever lay in the way of the flood, came down, and collected about the branches of the trees, that stuck fast in the arches, and choked the free current of the water. In consequence of this obstruction, a thick and strong dam was formed, and the aggregate of so many collected streams being unable to get any farther, the waters rose to a prodigious height, and by the force of their pressure carried the bridge entirely away! Edwards had given security for the stability of his bridge during the space of seven years; it had stood only about two years and a half; of course he was obliged to erect another, and he proceeded on his duty with all possible speed. The second bridge was of one arch, for the purpose of admitting freely under it whatever incumbrances the floods might bring down. The span or chord of this arch was 140 feet; its altitude 35 feet; the segment of a circle, whose diameter was 170 feet. The arch was finished, but the parapets were not yet erected, when such was the pressure of the unavoidably ponderous work over the haunches, that it sprang in the middle, and the key-stones were forced out! This was a severe blow to a man, who had hitherto met with nothing but misfortune in an enterprise which was to establish or ruin him in his profession. William Edwards, however, possessed a courage which did not easily forsake him; he engaged in it a third time, and by means of cylindrical holes through the haunches, so reduced their weight, that there was no longer any danger to be apprehended. The second bridge fell in 1751; the third, which has stood ever since, was completed in 1755." The breadth of this bridge is about 11 feet in the widest part; but in order to strengthen it horizontally, it is contracted towards the centre by seven off-sets, so that the road-way is there one foot nine inches narrower than at the extremities. It consists of a single arch, 140 feet in width, forming the segment of a circle of 175 feet; its height is 35 feet. This arch is between 40 and 50 feet wider than that of the celebrated Rialto, at Venice, and its additional altitude only in proportion. In each haunch are three cylindrical openings running quite through, from side to side, like circular windows: the diameter of the lowest is nine feet; of the middle one, six feet; and of the uppermost, three feet.

Besides the bridges already mentioned, there are other neat and elegant structures in various parts of Great

Britain and Ireland. In the latter kingdom, we cannot refrain from noticing the bridge over the Liffey, above Dublin, called *Sarah*, or *Island Bridge*, built in the year 1792, by Mr. Alexander Stevens, a mason of Edinburgh. It consists of a single elliptical arch, 106 feet wide, rising only 22 feet: and is consequently six feet wider than the Rialto, at Venice, and one foot less in altitude. The city of Dublin has likewise five other bridges over the Liffey, of which the two following are particularly worth notice: Arran, or Queen's Bridge, originally erected in the year 1684, but being destroyed by a flood in 1763, was rebuilt of hewn stone, and finished in 1768. It is built in a handsome light style, and consists of three arches, with paved *banquettes* for foot-passengers, on each side of the carriage-way, guarded with stone balusters. The other is Essex Bridge, first built in 1681, taken down in 1753, and rebuilt after the model of Westminster Bridge. It has five arches, the buttresses between which support semicircular niches, projecting from the parapet; between these niches are balustrades, which are continued to the ends of the bridge. The foot-ways are flagged, and the whole is constructed of hewn stone, in very fine taste.

We come now to those magnificent examples of bridge architecture, equalling any that the Romans have left, and surpassing all others in the world—the bridges of London. Each of these noble structures may be considered almost perfect in its kind, and as affording a specimen of the application in its grandest form, of the peculiar material of which it is constructed.

Four of these fine bridges are built of stone—namely, London Bridge, Blackfriars Bridge, Waterloo Bridge, and Westminster Bridge. They will be fully described under Stone Bridge. Southwark Bridge, built of iron, under Iron Bridge. And the beautiful new bridge lately completed at Hungerford, by Brunel, the celebrated engineer, under Suspension Bridge.

Among *Bridges of Wood*, (for the principles and methods of constructing which, see Timber Bridge,) the first that attracts our notice is the bridge of Cæsar across the Rhine. It consisted of a double row of piles, leaning to the course of the stream, and joined together at the distance of two feet from each other. Forty feet lower down the river, was another double row of piles, leaning against the stream, and towards the former row. Between the double piles, which were well rammed into the bed of the river, long beams, two feet thick, were placed, and held fast at each end by two braces. These beams being joined by transverse pieces, the whole was surmounted with hurdles. To preserve this structure from injury by the force of the water, the supporters were guarded with piles as buttresses; and above the bridge, other piles were placed, to stop the progress of trees or timber, which by accident might fall into the river, or be designedly floated down by an enemy, to destroy the work.

The bridge over the Cismone, a river falling from the mountains which separate Italy from Germany, is described by Palladio as an interesting object to the builder and architect. The river where this bridge is erected is 100 feet wide; and because the current is very rapid, and great quantities of timber are floated down it by the mountaineers, the bridge was constructed of a single span. The width is divided into six equal parts, and at the end of each part, except at the banks, which are strengthened with pilasters of stone, are placed the beams that form the breadth of the bridge. On these, leaving a little space at their ends, other beams are placed lengthwise, constituting the sides. The king-posts are disposed on either side, over both beams, connected with the projecting ends of those forming the breadth, by means of iron bolts and pins.

At Wittengen, in Switzerland, is a very curious bridge, the contrivance of Ulrick Grubenhamm, an uneducated carpenter of Tuffen, in the canton of Appenzel, celebrated for several works of the same nature. It consists of two wooden arches parallel to each other, with the roadway hanging between them. The span is 230 feet, and rises only five feet. The arches approach the catenarian shape, and are built of seven courses of solid oak logs, in lengths of 12 or 14 feet, and 16 inches and upwards in thickness. By picking these logs of a natural shape suited to the intended curve, the wood is nowhere trimmed across the grain. The logs being laid one upon the other, with their abutting joints carefully alternated, have the appearance of a wooden wall: instead of being pinned together, they are surrounded with straps of iron, at every distance of five feet, and fastened by bolts and keys. The abutments are the natural rock. The roadway intersects these arches at about the middle of their height, and is supported by cross joists, resting on a long horizontal beam, connected with the arches on either side by uprights bolted into them. Three of the spaces between these uprights have struts or braces, giving the upper work a sort of trussing in that part. The whole is covered with a roof, projecting over the arches on each side of the roadway, to defend the timbers from the injuries of the weather. This bridge is of more than sufficient strength to bear any load that can be laid upon it, though the attempt to truss the ends demonstrates that the builder was ignorant of true architectural principles.

In 1754, Grubenhamm erected another bridge, upon a plan nearly similar to the foregoing, at Schaffhausen, where the river (the Rhine) is nearly 390 feet wide. The current is very rapid at this spot, and had destroyed several stone bridges, when Grubenhamm offered to throw a wooden bridge across, of a single span; but the magistrates were alarmed at the proposition, on account of the breadth of the river, and would scarcely listen to it: at last they consented that he should build a bridge, provided he would divide it into two spans, and use the middle pier of the late stone bridge as a support at their junction. Grubenhamm complied with the wish of the magistrates so far as to divide his bridge into two unequal parts, the span of the one being 172 feet, and of the other, 193, both appearing to rest upon the old pier, though he contrived to leave it doubtful whether they really did so or not. This structure cost £8,000 sterling, and travellers inform us, that though it sustained the most heavily laden waggons in perfect security, yet the weight of a single foot-passenger caused it to tremble under him. It was destroyed by the French, when they evacuated Schaffhausen, in April, 1799.

Among wooden-bridges, the Schuylkill bridges at Philadelphia, in America, are very remarkable.

Wooden-bridges, unsupported by posts or pillars, and sustained only by butments at the ends, have obtained the denomination of *Pendent* or *Hanging Bridges*, by some also called *Philosophical Bridges*, of which Palladio has described three modes of erecting; such is the bridge over the Cismone, already described. Doctor Wallis has likewise given the design of a timber bridge, 70 feet long, without any pillars, which may be useful where supports cannot be conveniently erected; and Doctor Plott assures us, that formerly there was a large bridge over the castle ditch at Tutbury, in Staffordshire, made of short timbers, none of them above a yard in length, yet not supported from beneath, either by pillars or arches. The Spaniards use bridges of this kind for crossing the torrents of Peru, over which it would be difficult, not to say impossible, to throw more solid structures, either of wood or stone. Some of these hanging-bridges are sufficiently strong and broad for loaded mules to pass along them with safety. In China, these flying bridges are constructed of an almost incredible magnitude; the *Philosophical Transactions* contain the figure of one, consisting of a single arch, 400 cubits long, and 500 in height.

A great change in modern bridge-building has been effected by the introduction of iron, and the use of chain or suspension-bridges. The invention of Iron Bridges is said to be exclusively English, but Duhalde gives the merit of it to the Chinese; be that as it may, there is no country where there has been so extensive an application of the discovery, or in which has been erected so many fine bridges of iron as in Great Britain. The first was set up at Colebrook Dale, Shropshire, in the year 1797, and was speedily succeeded by numerous others in all parts of the United Kingdom; for a description of which we must refer to IRON BRIDGE.

Draw Bridges are of wood or iron, sometimes of both, with stone abutments. They are placed over navigable canals and rivers, or used in fortified places for the purpose of shutting out the enemy, and are of varied construction. Some are fastened at one end by hinges, so that the other end may be raised or lowered at pleasure. The most common method of doing this is by a kind of balance, called *plyers*, in which case the bridge when drawn up stands erect, to preclude a passage across a moat, &c. Others are so constructed as to be drawn back, or thrust forward, as occasion may require. On small canals, &c., draw-bridges consist of one leaf only; but on larger navigations, wet-docks, &c., they are of two pieces, meeting in the middle, and forming an arch, which are raised or lowered by means of balance frames, movable on the tops of uprights suited in height to the magnitude of the bridge; such as that at Bristol, over the Frome. Such bridges, however, having been found inconvenient from their tackling catching the yards and rigging of vessels passing through them, a kind of bridge, diverse from all the preceding, has been invented, called a *Swivel Bridge:* these, on small rivers, are only of one frame, or leaf, and turn on a centre, or series of balls or rollers; but when made on a wider scale, they consist of two parts, one on each side of the channel, and meeting in the centre. The most complete of this kind are those constructed at the West-India and London Docks; the latter spans 40 feet, and is 15 feet wide in the road-way. It consists of cast-iron ribs, about 1½ inch thick, turning on a number of concentric rollers, which move between two circular cast-iron rings, very nicely turned: each leaf has a flap, which lets down by a screw, and abuts upon the stone-work on either side, forming the whole bridge, when shut, into an arch capable of bearing any weight that can possibly pass over it. The whole apparatus weighs 85 tons; but it moves with so much ease, that it can be opened and shut in less than three minutes.

Suspension Bridges have only lately been introduced into this country, though known to the Chinese from a very early period. The iron-chain bridge of Yunnan is supposed to have been erected about A. D. 65, in the reign of the emperor Mingus, and is described as very similar in principle to the Hammersmith Suspension Bridge near London. In Kircher's *China Illustrata*, it is stated, that the chord-line is of the length of 200 cubits. In the *Asiatic Researches*, Turner gives a very interesting account of the singular bridges erected by the natives of Bootan. These bridges are of varied construction, but admirably adapted to the circumstances for which they are intended. Over the widest river in Bootan, there is an iron bridge, consisting of a number of iron chains, which support a matted platform; and two chains are stretched above, parallel to the sides, to support a matted border, which is absolutely necessary for the safety of the passenger, who is certainly not quite at his ease till he has landed from this swinging, unsteady footing. At another place, a bridge for foot-passengers is formed by two parallel chains, round which creepers are loosely twisted, from which planks are suspended, the end of one plank resting upon the other without being confined.

In the rude suspension bridge of South America, with its ropes of twisted bark, and its platform of cross pieces of wood interwoven in them, or the platform attached immediately to the sustaining ropes, the form assumed, the catenarian curve, is the same as in the more perfect structures of modern times—and one traces easily the transition from the simple but effective contrivance of the untutored Indian, to the master-pieces of the genius of a Telford. *See* SUSPENSION BRIDGE.

Bridges of Boats are made of boats, either of copper, tin, or wood, fastened across the stream by means of anchors or stakes, and laid over with planks. The earliest instance upon record of this kind of bridge, was that laid by Darius Hystaspes over the Ister, or Danube, in his Scythian expedition, 508 years before the Christian era. The same monarch also crossed the Thracian Bosphorus with 700,000 men by means of a bridge of boats; the strait being five stadia, or 1,008 yards in width. Modern armies carry with them tin or copper boats, called *pontoons*, to be ready on any emergency: several of them, placed side by side, across the river, till they reach the opposite shore, with planks laid upon them, form a plane for the soldiers to march on. At Beaucaire, Rouen, and Seville, are very fine stationary bridges of boats, which rise and fall with the tide: that at Rouen is nearly 300 yards long, and paved with stone, so that laden carriages and horses, as well as foot-passengers, go over it in safety. In the absence of pontoons, military bridges have been made of blown bladders, hollow casks, sheaves of rushes, &c., covered over with planks.

When bridges of this kind do not extend over the whole breadth of the river, but are contrived to float from one side to the other, they are termed *Flying* or *Floating Bridges.* A bridge of this description is generally composed of several boats connected with each other by a flooring of planks, and surrounded by a railing. This stage or raft is furnished with one or more masts, according to its dimensions, to which is fastened a strong cable, supported at proper distances by boats, and extending to an anchor, in the middle of the water, where it is made secure. The bridge thus becomes movable, like a pendulum, from one side of the river to the other, with the assistance only of a rudder. Such bridges were formerly sometimes constructed of two stories, for the more expeditious passage of a great number of men.

Another kind of flying bridge is formed of two platforms, laid one upon the other, and by means of cords and pullies the uppermost is made to run out beyond the lower platform, till its farther extremity rests against the place it was designed to reach. In the *Histoire de l'Académie Royale des Sciences*, for the year 1713, page 104, is a description of a floating bridge, which lays itself on the opposite side of a river.

Under this head we have now to describe one of the most useful and ingenious constructions of modern science and engineering skill—the steam Floating Bridge invented by Mr. J. M. Rendel, the eminent civil engineer. The first bridge on this principle was erected by Mr. Rendel across the estuary of the Dart at Dartmouth, about the year 1832, and a similar one was established about two years after, across the Hamoaze, between Torpoint and Devonport.

A very full description of the latter, accompanied by elaborate drawings, has been furnished to the Institution of Civil Engineers by Mr. Rendel himself, and from the first volume of the "Transactions" of the Institution, we have extracted the following brief sketch.

The medium width of the river at the site of the bridge may be taken at about 2,350 feet, the strength of the current after heavy land floods is very great, and the site so much exposed, that it is not uncommon for the ships lying in the vicinity of the bridge to drag their moorings. The bridge is a large flat-bottomed vessel, of a width nearly equal to its length. The vessel is divided in the direction of its length into three parts—the middle one being appropriated to the machinery—each of the side divisions to carriages, &c. These side divisions or decks are raised about 2 feet above the line of flotation, and by means of movable platforms, an easy communication is afforded with the shore on embarking or landing. The bridge is guided by two chains, which passing through it over cast-iron wheels, are laid across the river and fastened to the opposite shores, forming as it were a road along which the vessel travels backwards and forwards.

The moving power employed is two small steam-engines turning a shaft, on each end of which is a large iron wheel whereon the guide-chains rest. The peripheries of these wheels are cast with sockets fitted to the links of the chains, so that when the bridge is put in motion by the steam-engines, it is moved in the reverse direction of, and with the same velocity as the wheels. The ends of the chains have balance-weights attached to them, which rise or fall as the tension of the chains becomes more or less.

A similar bridge has been established at Portsmouth, and plies between that place and Gosport.

Under this article we may also mention *Portable Bridges*, which are easily taken to pieces, and as readily put together again. M. Couplet speaks of a bridge of this kind, 200 feet long, carried by 40 men.

Writers on architecture have bestowed considerable attention on the subject of bridge-building, which is justly esteemed as one of the most noble and striking specimens of human art. The earliest of these is Alberti, a native of Florence, who flourished about the middle of the 15th century; he has given several judicious precepts, which, with little alteration, were afterwards laid down by Palladio, Serlio, and Scamozzi. The best of these rules are likewise given by Goldman and Baukhurst, as well as by Hawkesmoor, in his *History of London Bridge*.—M. Gautier has written a large volume on bridges, ancient and modern. M. Belidor has treated on this subject, in his *Architecture Hydraulique;* as has M. Parent, in his *Essais et Recherchés Mathematiques*, vol. iii.—De la Hire, too, has touched on it, in his *Traité de Mechanique*.—Perronet has given the result of his experience in a magnificent work, which has acquired him great credit in France.—Bosset has given an excellent treatise on bridge-building, in the *Mémoires de l'Académie*.—Regemortes published, in 1771, an account of the bridge built by him over the Allier, at Moulins.—In 1760, Mr. Riou published a work entitled, *Short Principles for the Architecture of Bridges;* and Mr. Semple has given some excellent practical remarks in his *Treatise on Building in Water*, published in 1776. Other writers on the construction and principles of arches and bridges, are Muller, Labelye, Atwood, Emerson, and Dr. Hutton.

When a bridge is constructed of stone, and arched over, it requires, in the act of building, to be supported upon a mould, called a *centre;* the construction of which is shown under the article CENTRE.

BRIDGE BOARD *See* NOTCH BOARD.

BRIDGE OVER: when there are any number of parallel timbers, and another piece fixed transversely over them, then the transverse piece is said to *bridge over* the other parallel pieces. In framed roofing, the common rafters bridge over the purlins; likewise in framed flooring, the upper joists, to which the boarding is fixed, bridge over the beams or binding joists, and are therefore called *bridging joists.*

BRIDGE STONE, a stone laid from the pavement to the entrance-door of a house, over a sunk area, not supported by an arch.

BRIDGED GUTTERS, those made with boards, supported below with bearers, and covered above with lead.

BRIDGING FLOORS, those in which bridging joists are used. *See* NAKED FLOORING.

BRIDGING JOISTS, those which are sustained by transverse beams below, called *binding-joists;* also those on which the boarding for walking upon is nailed or fixed. *See* NAKED FLOORING.

BRIDGINGS, or BRIDGING PIECES. *See* STRAINING PIECES, and STRUTTING PIECES.

BRING UP, a term used by workmen for carrying up the walls to a certain height: they say, "bring up that part;" but the term *carry up* is more frequently used.

BROACH, an old English term for a spire, still in use in the north of England. The term is specifically applied to spires which spring directly from the eaves of the tower or other substructure, without the intervention of a parapet. This kind of spire is confined more especially to the earlier styles of Gothic architecture; in the later ones, the parapet is seldom dispensed with.

BROAD-STONE, the same as FREE-STONE.

BRONZE; a compound of copper and other metals, especially zinc. It is used for cannon, medals, &c.

BRONZE also denotes any piece of sculpture made of bronze metal, as statues, busts, &c., whether in imitation of the antique, or representing a modern prototype. The method of casting bronzes is described under CASTING.

BROWN, a dusky colour inclining to redness. Of this there are various shades, distinguished by different appellations, as *Spanish brown*, *sad brown*, *tawny brown*, *London brown*, and *clove brown*. *Spanish brown* is a dark dull red, of a horseflesh colour, of great use to painters, being generally used in house-painting, for priming the timber work, or first coating. The best is that of a deep colour, and free from stones. It is the best and brightest when burnt in the fire till it is red-hot. The various browns used in drawing are BISTRE, COLOGNE EARTH, and UMBER.

BRUNELLESCHI, PHILIP, the son of a notary, born at Florence in 1377, was at first designed for the bar; but not liking that profession, he was apprenticed to a goldsmith. His genius, however, turned him to the study of sculpture, geometry, and architecture. The first model by which he formed his taste in architecture was the church of St. John, at Florence, a building of good style, and much inclining to the antique; he afterwards went to Rome, to study the ancient monuments there, the best of which he measured and took drawings from; and he is said to have first distinguished the three ancient orders.

When the Florentines first thought of raising a dome upon the church of St. Mary del Fiore, they invited all the principal architects of Europe to a consultation, at which Brunelleschi proposed a double cupola, with a space between the inner and outer vaults, sufficient to admit of staircases and passages to the top. This idea was deemed so preposterous, that he was actually turned out of the assembly, for having presumed to insult the good sense and judgment of so many experienced artists, who had never heard of such a thing, and held it to be impracticable. Undaunted by this treatment, Brunelleschi persisted in maintaining the practicability of his scheme, and demonstrated it by drawings and models: but the clamour excited by his brother artists ran so high for a time, that he was looked upon as a downright madman! At length, however, the violence of prejudice began to subside, and when it was seen that the rest of the architects produced nothing eligible for the purpose, the deputies, who had the management of the building, sent for Brunelleschi, listened candidly to what he had to propose, examined his drawings and models, and finally set him to work, under certain restrictions: they also appointed him an assistant, but his complete ignorance soon manifested itself, and he was dismissed. Brunelleschi being thus left at liberty, the citizens saw with admiration a magnificent cupola arise over their church, which Michael Angelo himself pronounced to be a masterpiece of science. This cupola is octangular, 154 cubits (Flemish) in height, on which rises a lantern of thirty-eight cubits, surmounted with a ball of four cubits, and a cross of eight cubits; making a total of 202 cubits. a height never before attempted on such a plan. Brunelleschi died before the lantern was quite finished, but he left a model, and recommended on his death-bed, that it should be loaded with the heaviest marble. The portico that was to have surrounded the tambour still remains unfinished. The peculiarity of this celebrated cupola is, that it has no counterforts.

Brunelleschi built the abbey for the regular canons at Fiesole, under the direction and patronage of Cosmo de Medicis; it is a convenient cheerful edifice, and the ornaments are in a chaste style. He also constructed several military works. A great part of the church of St. Laurence, at Florence, was built by Brunelleschi, but he died before it was completed, and his successors committed so many blunders in finishing it, that the original design is very much mutilated. The palace of Pitti, at Florence, was likewise begun from his designs; and so completely did the tide of public favour turn in his behalf, that his fellow-citizens elected him to the office of magistrate. But it was after his death that his talents were most appreciated, and his merit fully acknowledged as the reviver of pure architecture. He died in 1444, aged 67, honoured and esteemed by all who knew him, and was buried in St. Mary's cathedral.

BUCCULA, in antiquity, denotes the *umbo*, or prominent part of a shield.

BUDGET, a kind of pocket used by bricklayers, for holding nails when they lath for tiling.

BUFFET, a cabinet or cupboard for plate, glasses, or china-ware. In former times, these were frequently made very ornamental, in the form of niches, and left open in the front in order to show the furniture. The buffet is now rarely seen, except in old-fashioned houses; in modern establishments it has been superseded by the sideboard.

BUILDER, a person who contracts to build, or rear up edifices.

BUILDING, in general, is a mass formed by the junction of materials. When a building is stationary, and erected for dwelling in, or for some useful purpose or ornament, it is called an *edifice.* Those who intend to build, should make choice of an architect who is known to be a man of ability and of tried experience and integrity. The proprietor should then explain as clearly as possible his ideas and intentions respecting the proposed building, to enable the architect to furnish the requisite plans and estimates. These should be carefully examined and gone into, so that the proprietor be perfectly satisfied that his wishes are understood, and the cost of carrying them into effect brought within the extent of his means or inclinations. The whole management ought then to be committed to the architect, with full liberty in the choice of masters for the execution of the respective departments. The architect should then proceed to make out a specification, and contract for each individual branch concerned in the business, and put them into the hands of respectable tradesmen; if the estimates appear to be reasonable, the contracts should be signed. There are many kinds of work for which, however, from novelty in execution, it would be impossible to anticipate a price: but if the work consist of similar repetitions or parts. the value of one part being known, by taking an account of the time, that of the others will follow, and then the estimated expense of the whole may be ascertained. There are many proprietors whose ideas are never fixed, and no sooner is work done than it is undone: in such a case, the work should be done by measure and value, affixing a regular price to every corresponding article; and an account should be taken of the work pulled down. In whatever way the work be valued, there should be a person employed, stationary in the building, called *a clerk of the works*, whose business it is to give directions for fixing, and to superintend all parts of the execution; to keep the workmen's time, to give in weekly reports, and to examine the work, should it happen to be prepared out of the building.

The drawings necessary in the construction of an edifice are, plans of the several stories, elevations of the façades, a transverse and a longitudinal section at least, horizontal and vertical sections of all the difficult parts, and a detail of all the mouldings and ornaments at large. These ought to be committed to the care of the clerk of the works. It is not very easy for an architect to furnish all the detail before a building is to be estimated; but if time would permit this to be done, the contractors would be able to undertake the work at the lowest rate, and this would in a great measure supersede the necessity of the addition, which is too generally found necessary to cover the uncertainty of estimating large works.

With regard to building in general, it must be obvious, that to the taste, judgment, and science of the architect, must be left the selection of the character and style of the building to be erected; no certain rules can be given to form the general contour of an edifice, but the middle part ought to have some commanding feature, and the general outline of the whole should approach to a pyramidal form. Large edifices are susceptible of great splendour, by an agreeable variety of parts; but the beauty of a small building consists in the simplicity and symmetry of its surfaces.

The regularly repeated columns, entablatures, and other ornaments which may adorn a circular building, create the most pleasing feelings, and in a straight building also, the uniformity and succession of parts are usually delightful to the observer, hence the gratifying sensation arising from long ranges of colonnades, as in the Grecian temples and the aisles of churches: but the preceding observation, with respect to the entablature, does not apply in a straight building. The entablatures may either be broken or continued, according to the use of the columns; the outline of the building being still preserved in either case: for when the repetitions are fac-similes of each other, the eye will judge of the figure of the building the same, whether the entablature be continued or interrupted, which is not the case in rotund edifices. When columns are placed so remote from each other, as not to be capable of supporting an entablature, or not sufficiently near to excite the idea, the entablatures may be broken, as in the triumphal arches at Rome, where the columns are introduced to support the ornaments of triumph. In the peribolus of the Grecian temples, the broken entablatures are not only beautiful, but the repetition of the order itself is useful in reinforcing the strength of the enclosure, and thus performing the office of buttresses to the walls. Much of the agreeable sensation in viewing our venerable antique-modern churches, arises from the uniform succession of the buttresses and their ornaments.

For farther particulars, with regard to the exterior of a building, we must refer the reader to the term BREAK.

With regard to situation, a building should be placed in a salubrious and mild atmosphere, free from noxious exhalations, within the reach of the rays of the sun, so as to make it cheerful, and to have a plentiful supply of water and coal, as likewise of all other necessaries of life: it should be surrounded with an agreeable variety of woods and walks, and ought to have an easy access to the highway. The situation should be commanding, but not so high as to expose the building to the fury of heavy winds.

With regard to the plan of a building, the disposition of the apartments must be agreeable to the intention of the design, and in general the rooms ought to be all entered by one common passage; for farther particulars on this head, see APARTMENT, CHIMNEY, PASSAGE, ROOF, ROOM, and STAIRCASE.

The modern method of placing a bedchamber and dressing-room together, each with its separate door to the common passage, and likewise with a door common to each other, is very convenient. The mode of uniting, when necessary, two or more rooms by means of folding-doors, is a very great improvement, particularly in small houses. The hall, or entrance, should at least have one chimney, and if connected with the staircase or a lofty saloon, the heat will be of essential service in warming the whole house. Double doors are useful in preserving a uniform temperature.

Besides double external doors, for the exclusion of cold winds, double windows should be used for winter apartments.

The proper distribution of rooms must be regulated by the course of the sun, in order to avoid the extremes of the summer's heat and winter's cold. Bedchambers are properly situated towards the east, in order to regulate the time of rising. Every house ought to have two sitting-rooms, to accommodate the extreme seasons of the year; that for the summer ought to be disposed in the north, and that for the winter in the south. Drawing-rooms and dining-parlours are best situated in the west, as they are generally used in the afternoon, that the declining sun may throw an agreeable shade upon objects; these matters, however, frequently depend upon other circumstances of convenience.

The drawing-rooms should be so disposed, as to be easily converted into one room, by throwing open the folding-doors. In country mansions, the kitchen should be as near the dining-room as convenient, but so disposed with regard to the passage of communication, as to prevent the effluvia from escaping to other principal parts of the house. The offices connected with the kitchen should be generally placed towards the north; but in town-houses this cannot always be done, and therefore regard must be had to circumstances. The larder, however, must always be placed beyond the influence of the heat of the kitchen. Galleries for paintings, and museums, that require a steady light, should have a northern aspect.

Windows ought to be made vertically one above the other, and not too near the angles of the building; and in large edifices, where the walls are thick, their jambs ought to be splayed or beveled, for a more full distribution of light. Lofty windows, descending to the floor, or nearly so, with a projecting balcony in front of the building, defended by a railing of cast-iron, are both healthy and agreeable. Sky-lights, in cold climates like ours, are productive of many inconveniences, as they admit of cold air, damps, rain, and snow, and thereby waste the heat generated in the house. They ought therefore never to be admitted, except for stairs and halls; but when this admission is necessary, their apertures should be of sufficient dimensions, not to hinder the passage of the sun's rays.

The plans of buildings may be of various forms; the circle is the most capacious of all figures, under the same perimeter, and a building erected upon a circular plan, is also the most strong, durable, and beautiful of all others; but its compartments are not convenient in dwelling-houses, on account of a waste of room occasioned by the disposition of angular furniture; so that the loss in this respect more than counterbalances the quantity of area gained by the property of its figure. Circular buildings are also the most expensive, and, on account of the impossibility of dividing them into compartments without distortion, they are unfit for the purpose of private edifices: on this account they were employed by the ancients only in their temples and amphitheatres, which had no need of compartition. In modern mansions, entire cylindric or polygonal buildings are seldom or never used, except in parts which form single apartments upon a floor, as in towers or bows. Though very beautiful forms of edifices may be reared upon rectilineal plans, a judicious arrangement of apartments formed both of plane and curved surfaces will make a most agreeable variety.

Of all buildings upon plans of equilateral and equi-angular polygons, the triangle contains the least area, and on account of the acuteness of its angles, rectangular furniture cannot be disposed on its area without very considerable waste; the employment of this figure, therefore, occasions not only a loss of surface from its property, but a loss also in placing of furniture: it may, however, be observed, in buildings erected upon equilateral and equi-angular polygons, the greater the number of sides the plan has, the less loss of area will be sustained on account of the property of the figure; but those with obtuse angles will still have the same objections on account of the furniture. Various figures may be adopted occasionally, for the sake of variety, when the loss of room is not an object; but for general use, the rectangular disposition of an edifice is the most convenient, as it will compart *ad infinitum* into rectangular figures, which is the best form of furniture for general use.

The accessories of a building are ornaments borrowed from sculpture and painting; but wherever they are introduced, they ought to be in character, and to indicate in some measure its destination. Figures representing animals are of a higher class than those of foliage or vegetables: the former were generally employed by the Greeks, particularly in the principal parts of their edifices, though sometimes the small parts were covered with foliage, in which the honeysuckle was most predominant. The Romans, whose taste was inferior to that of the Greeks, indulged in both. It is to the remains of the edifices of these two nations, that the architect must have recourse for the embellishments of the fabric.

Of all the ornaments applicable to buildings, columns are the most splendid and dignified, and no invention has yet been able to supplant the three Grecian orders, though a lapse of more than two thousand years has past. Pilasters are not only very beautiful, but when wrought in with the work, they reinforce the strength of the walls, and consequently the whole fabric; but they have neither the dignity nor the graceful appearance of columns.

The materials used in the construction of edifices are of various kinds, as timber, earth, mortar, chalk, stone, marble, iron, &c.; every place adopts, in the general construction of its buildings, those materials which are its own native productions, or those of other places which can be procured by an easy carriage.

The chief writers on building, whose works have been transmitted to our hands, are Vitruvius, Alberti, Serlio, Scammozzi, Vignola, Palladio, Baldus, Barbarus, Blondel, Catanei, Demoniosius, Friard, Goldman, Perrault, Rivius, Gulielmus, Langley, Ware, and some living authors. *See* Architecture and House.

Building, in masonry, is the art of joining stones together, with or without cement, so as to form the whole or part of an edifice. Building also signifies the mass of body formed by the junction of stone with regular surfaces. In this sense it is the same with masonry, or a piece of masonry. Masonry always implies building; but building does not always imply masonry. *See* Masonry.

BUILDING ACT, the act passed in the year 1844, known as 7 & 8 Vict. cap. 84, for regulating the construction and the use of buildings in the metropolis and its neighbourhood, within certain limits defined by the act.

As this act is usually appended to Price Books, &c., we have thought it unnecessary to occupy space by giving it here at length.

BUILDING OF BEAMS, the joining of two, or several pieces of timber together in one thickness, and of several pieces in one length, by means of bolts, so as to form a beam of given dimensions, which it would be impossible to obtain from a single piece of timber. Beams thus built, are stronger than such as are scarfed, provided their joints be judiciously strapped across on the exterior sides; and their construction does not require so much waste of timber. Not only beams, but ribs for vaulted roofs, may be built so as to be stronger, and require less timber in their fabrication, than those which are scarfed; and if due attention be paid to their curves, no trussing will be necessary. The practice of building a compound timber, so as to form one mass, or piece, which would perform the function of a single piece, will be found under the article Rib. Other particulars, with regard to the lengthening of beams, will be found under Scarfing.

BULKER, a term used in Lincolnshire for a beam or rafter.

BULLEN-NAILS, those with round heads and short shanks, tinned and lacquered: there are about three sizes of them, which are used in the hangings of rooms.

BULWARK, in ancient fortification, is nearly the same with bastion in the modern. *See* Rampart and Torus.

BUNDLE PILLAR, in Gothic architecture, a column consisting of a number of small pillars around its circumference.

BUSCHETTO, a distinguished Grecian architect, born in the isle of Dulichio, and employed, in 1016, by the republic of Pisa, in erecting their cathedral church. This has been reckoned one of the most sumptuous edifices in Italy. He died at Pisa, where he had a monument erected to his memory, with an inscription, intimating his superior knowledge of the mechanical powers. He had many disciples, and is regarded as the founder of modern architectural science in Italy.

BUST, or Busto, in sculpture, that portion of the human figure, which comprehends the head, neck, breast, and shoulders. The Italians also apply this term to a greater portion of the human figure, as low as the hips, with or without the head and arms, as in the busts of many illustrious ancient Romans. The word is probably derived from the Latin *bustum.* These pieces of sculpture are generally placed upon a pedestal or console.

BUT-HINGES, those employed in hanging closures, as doors, shutters, casements, &c., placed on the edges with the knuckle projecting on the side on which the closure is to open, and the other edges stopping against a small piece of wood left on the thickness of the closure, so as to keep the arris entire. It is customary to sink the thickness of the hinges flush with the surface of the edge of the closure, and the tail part one-half into the jamb. There are several kinds of but-hinges, such as, *stop but-hinges*, which only permit the closure to open to a right angle, or perhaps little more, without breaking the hinge; *rising but-hinges*, which turn upon a screw, employed in doors, and cause the door to rise in the act of opening, so as to clear a carpet in the apartment. *Slip-off but-hinges*, are those employed where a door or window-blind requires to be taken off occasionally.

BUTMENT. *See* Abutment and Stone Bridge.

Butment Cheeks, the two solid parts on each side of a mortise: the thickness of each of the cheeks should be equal to that of the mortise, when there is no circumstance which may require them to be of a different thickness.

BUTT-END of a piece of timber, the largest end next to the root.

BUTT-JOINT, in hand-railing, a joint at right angles to the curve of the rail. *See* Hand-Railing.

BUTTERY, the store-room for provisions. Its situation is generally north.

BUTTING-JOINT, that which is formed by the surfaces of two pieces of wood, of which the one surface is perpendicular to the fibres, and the other in their direction, or making an oblique angle with them;—as the joint which the struts and braces in carpentry make with the truss-posts.

BUTTON, a small piece or wood or metal, made to turn round a centre, for fastening a door, or any other kind of closure. The centre in commonly a nail, which should be made round where it is to turn, and the head made smooth.

Button of a Lock, a round head for moving the bolt.

BUTTRESS, an erection serving to support a wall or other building, which is either too high otherwise to maintain its position, or is pressed against from the other side by an adventitious force.

Buttresses are so frequent in Gothic architecture as to become a marked and principal feature in buildings of that style; they are placed around the exterior sides of the edifice, usually one between every two windows, and one or two at each of the angles of the building. In the earlier erections, each angle was supported by two buttresses, disposed so as to leave their sides parallel to the planes of the walls; but in later examples, for the sake of giving a lighter appearance to the building, as well as for economizing materials, only one buttress was used, situate in such a manner as to receive the direct drift of the vaulting, having its sides parallel to the vertical diagonal plane which bisects the angle formed by the two planes of the adjoining faces of the building. The use of these projections is not so much to support the weight of the walls, as to resist the outward thrust of the roof, more especially when vaulted.

There are two kinds of buttresses used in Gothic buildings; those that are formed of vertical planes, and attached to the walls, are called *pillared buttresses;* those which rise from the pillared buttresses upon the sides of the aisles, with an arch-formed intrados, and sloping extrados or top, are called *flying buttresses*, *arc boutants*, or *arch buttresses.*

In few instances perhaps have the mediæval architects shown greater constructive skill than in the erection of buttresses, as is more especially evidenced in their larger structures, such as cathedrals, where by means of them the active force of the vaulting, which would otherwise overthrow the walls, is borne down harmless outside the building into the earth. By the arc-boutants the drift is carried over the aisles to the upper part of the main buttresses, where, by the gravity of the super-imposed pinnacles, the direction of the force is changed, so that from an horizontal thrust, it becomes or at least approaches to a vertical pressure, which again is carried through the mass of the buttress to the ground at its base. No material is thrown away, all is pressed into active service, what does not answer a useful end is removed, and nothing added merely for ornament; an instance of the latter has been shown in the case of the surmounting pinnacle; which, although by a superficial observer it might be considered as mere ornament, is in reality of the utmost importance in the construction; as an example of the previous statement, may be produced the buttresses at Westminster Hall, from which a considerable portion near the ground and adjoining the walls, being of no service, has been entirely cut away.

Pillared buttresses are enriched with pinnacles, niches, statues, and other ornaments. Flying buttresses are often perforated, particularly in the later examples, in which the perforations assume the form of polyfoils, flambeaux, and other beautiful devices. A rich specimen is to be found in Henry the Seventh's chapel at Westminster, where the buttresses are of a wonderfully light and gorgeous appearance; the main buttresses also in this instance are of a very elaborate description.

BYZANTINE ARCHITECTURE, a style of architecture bordering on the Romanesque, which prevailed in Greece and its dependencies during the early ages of Christianity.

This style may be said to have commenced with the establishment of the Eastern empire, when Constantine transferred the seat of government from Rome to Byzantium, from the name of which city it also derives its distinguishing appellation. Some writers indeed have gone so far as to state that the first Christian emperor removed from the ancient city for the sole purpose of obtaining greater freedom in the establishment of his new religion; solicitous for its purity, that it might remain unpolluted by any mixture with the ancient rites, distinct from paganism even in its architecture. Hope, to whom we are indebted for much information on the subject, states this as his opinion, and says that Constantine, having evaded the restraints which his new creed was subject to at Rome by his removal to Byzantium, set himself diligently to work to establish it on a firm basis: one great object which presented itself to his notice, was the erection of appropriate places of worship, which were much needed, the number of Christians exceeding that of pagans, and there being no previous edifices either of a civil or religious character, which could be conveniently adapted to the purpose. Architects, therefore, were left entirely to their own resources, unless indeed they were willing to copy that class of edifices adopted in the old metropolis; but this does not seem to have been their object, they desired rather to form an entirely new style of building; there were besides no existing edifices of any note, whose materials might tempt their removal to the new structures, and so, to a certain extent, determine their construction, as had been the case at Rome. Under such circumstances originated the peculiar style of architecture which has been since denominated Byzantine.

We have before noticed that the Christians had already outnumbered their heathen adversaries in this city, and as their religion was daily acquiring more and more proselytes, the want of churches must have been daily more apparent; it would be reasonable to suppose, therefore, that a vast number must have been at once erected, and such indeed seems to have been the case, for we are told that no less than eighteen hundred were endowed between the reigns of Constantine and Justinian, a period of little more than two hundred years. Few of these, however, remain: many of the oldest of them were destroyed by earthquakes and fires, principally in the reign of Zeno; and all that survived that period, in the sedition of A. D. 532. This outbreak happened in the time of Justinian, who set zealously to work to repair the losses which had been sustained, and vied with his illustrious predecessor in the erection and restoration of Christian churches.

It must not be supposed that this style of building was all this time confined to its original locality; it had spread rapidly throughout the Eastern empire; where the Eastern churches extended, there also did its architecture extend, from the city of the chief bishop through the whole patriarchate under his jurisdiction. It is remarkable, however, how rarely it found its way into Western Christendom; the first instance of its appearance in that quarter, was the church of S. Nazareo e Celso, at Ravenna, in the year A. D. 440. This church was erected by Galla Placidia, daughter of Theodosius, afterwards married to Constantius Cæsar, and mother of Valentinian; she was regent of the Western empire for some time during the minority of her son, and seems to have been a zealous promoter of the Christian religion; the erection of many churches is attributed to her, amongst which are three or four in this same city of Ravenna. The next we hear of Byzantine architecture in Italy is A. D. 547, at Ravenna again, in the church of S. Vitale, which was erected by Julianus, the treasurer, under the direction of Justinian. The reign of this prince is remarkable for the number of buildings of all kinds erected; bridges, aqueducts, roads, fortresses, and a variety of works of public utility were undertaken throughout the provinces, but the number of churches erected surpassed that of all other structures; new ones were constructed, and old ones re-edified, of which last a great number, as already stated, had been destroyed in the insurrection which occurred in this reign. Of all the restorations which this emperor effected, the most remarkable is that of S. Sophia, at Constantinople; this church he entirely rebuilt, preserving, however, as it would appear, the original plan.

In this same reign the Ostrogoths were driven out of Italy by Narses, one of Justinian's generals, and the Western empire again brought under the rule of one sovereign, which circumstance led to a further introduction westward of Byzantine architecture. Its progress, however, seems to have been more limited than might have been expected, for, with the exception of some of the principal cities where the viceroys held their court, we see but few instances of its adoption. We have already alluded to Ravenna, which was the seat of the principal exarchate, and have now only to refer to the cases of Ancona and Venice, in the former of which is found the church of S. Ciriaco, and in the latter that of S. Mark, though the existence of this style in the latter city is perhaps attributable rather to the mercantile intercourse of the Venetians with the East, than to the authority of the emperor over the western shores of the Adriatic. We have now quoted all the principal examples of this style that have been discovered in the West, at least on the one side the Alps; we make this reservation, for Hope, quoting Fleury, says that the style crossed the Alps, and is to be seen in the old city of Atlas, on the Mediterranean, in the church of S. Cesarius, an erection of the sixth century; he further states that it eventually reached as far north as Paris. Be this as it may, however, putting all the examples together, it is certain that they number much lower than would naturally be expected; a fact not easily to be accounted for, were it not for one circumstance, the rivalry that existed between the eastern and western churches. As early as the second century, a serious division arose between them respecting the time of celebrating Easter, which proceeded to such an extent, that Victor, bishop of Rome, separated his opponents from his communion. The Roman church, owing to its connection with the metropolis of the empire, as well as from other causes, had obtained an early distinction, which, in process of time, became invidious from the pertinacity with which it was claimed, and the encroachments which it gave rise to under individual bishops. When, however, Constantine removed his court to Byzantium, the see of Constantinople rose suddenly to dignity and power, and showed itself a formidable rival to that of Rome, and a serious hindrance to its usurpations; thus originated a determined jealousy between the two churches, which was manifested by the constant differences which occurred between them, of which there were no less than four in little more than a century and a half, one of twenty-five years' duration, and which led eventually to the final separation in the eleventh century. It is to this rivalry we attribute the paucity of examples in this style of architecture to be met with in the Western empire; an opinion confirmed by Mr. Gally Knight, who, alluding to the subject of our article, says, "This plan became a favourite in the East, and was adhered to in those parts with the greater tenacity, in consequence of the schism which subsequently took place between the pope of Rome and the patriarch of Constantinople. There was to be a difference in every thing. The Greeks insisted upon the square form of their own inventions; whilst all the nations which continued to acknowledge the supremacy of the pope, continued to employ the long form, which was persevered in at Rome." A reviewer of the work from which this extract is made, remarks, "Mr. Knight's observations with regard to the antagonism of the eastern and the western churches, are entirely correct. Except when favoured by peculiar political relations, it is remarkable how little influence was exerted in Italy by Byzantine art. Ravenna and Venice are almost the only localities where we may trace any decided imitation of the type of Constantinople."

There is one passage in this extract which we would desire to qualify, for although Byzantine architecture, as a style, does not seem to have been employed to any extent in the West, still it cannot be said that it possessed no influence in that quarter. That many of its features were imitated in succeeding styles cannot be doubted; its principal characteristics are evident in most of the Lombardic churches, and in the other styles which prevailed in Western Christendom. The Greek church was seldom copied entire; but its different parts were adopted in buildings otherwise of a different character; for instance, in some cases the Greek dome appears in conjunction with the Latin cross; in others, the Greek plan alone is imitated; in others again, both appear together; so that were it not for some peculiarity of arrangement or detail, it would be difficult to decide to which style the building might belong. This kind of influence was exerted not only in Italy, but throughout the whole of Western Europe.

In A. D. 586, the Lombards made their appearance in Italy, and from that time dates the downfall of the previous styles of art, and the introduction of that mode which is entitled, after their designation, Lombardic; not that this may be strictly said to be a new style, but rather a modification of those already existing; still its characteristics are so marked as readily to distinguish it from its predecessors. After this period we see little more of Byzantine architecture beyond the locality where it first originated; in the East it seems to have held out until the invasion of the Ottomans.

The distinguishing characteristic of Byzantine architecture is the dome, a feature which distinguishes it at once from all preceding styles, and no less surely, though perhaps less readily, from its successors; in the one case by its mere presence, in the other by its peculiar form. The adaptation of the sphere throughout the building, may be said to be the mark of the style, for it is used not only in the case of the principal dome, but in a modified form as the covering of the building in every part where it can possibly be applied, as instanced in the conchs over the apsides or extremities of the aisles. We might perhaps speak more generally, and lay down the circle as the standard figure of construction, for it appears every where, in plan, in section, and in elevation, or, as Hope says, "Arches rising over arches, and cupolas over cupolas, we may say, that all which in the temples of Athens had been straight, and angular, and square, in the churches of Constantinople became curved and rounded, concave within and convex without." The plan of the buildings was generally that of a cross inscribed in a square, having each of the arms of an equal length, and not greatly prolonged. At the angles of the square formed at the intersection of the cross were situate four piers, supporting as many arches, whose spandrils converged so as to unite in the form of a circle towards their summit, which again supported the crowning dome. The four arms of the cross terminated in apsides of semicircular plan, and were likewise covered with semi-cupolas, closing over the arches which supported the central dome. The principal entrance was preceded by a porch, and this again by an atrium or open quadrangle, which is seldom omitted in the Eastern churches. The church of S. Sophia is said to have had four distinct nartheces besides the atrium. The domes in this style are generally flat or depressed, of a vertical section less than a semicircle, that of S. Sophia is noted as having been remarkably low; the materials of their construction were always of a light description, frequently hollow jars of a somewhat cylindrical form, fitting one in the other, and made of earthenware or some light substance. The thrust of the dome was most usually resisted by pendentives or brackets springing from the angles of walls, which were square, and carried up to support the base of the dome; but this method was not universally adopted, for in the Church of S. Vitale at Ravenna, the dome is supported by a series of small arches; in this case, however, the plan of the walls is not square, but octagon.

The minor points of distinction are to be found in the details, of which the following are the most remarkable. The heads of apertures are for the most part of a semicircular form, sometimes however of a larger, sometimes of a lesser segment; not unfrequently at a late period, stilted arches are used, that is, semicircular arches having the lower extremities continued downwards perpendicularly;—this method seems to have been adopted for the sake of preserving the same level when arches of different spans were employed. Besides these forms, pointed arches are occasionally met with, also apertures having triangular or pedimental heads. Another peculiarity is the frequent employment of a series of successive arches. The only remaining distinction which we shall notice has reference to the capitals of the columns, which are square, tapering blocks of the form of truncated pyramids having the apex downwards; they are little better than plain blocks, their only ornamentation consisting of foliation in low relief, or a sort of basket-work which is peculiar to this style of architecture. Nothing further need be said respecting its characteristics, the dome of itself is almost a sufficient feature to stamp the character of the type.

The origin of this mode of building is variously attributed by various writers; some will have it that it is but a modification of the Basilican style, with the addition of the dome, which necessitated the shortening of the oblong of the Basilica; but this, which is considered as merely an addition, is the principal feature both in construction and design. It is true, the plan of the Basilica was an oblong, and that of the Byzantine buildings a square, but surely it does not follow that the latter should have been borrowed from the former; as a matter of fact it may be so, but there is no prima facie evidence in favour of such an opinion, from the mere similarity of plan. Others attribute its origin to the baptisteries, or to the sepulchral chapels built by Constantine, such as that of S. Costanza, the burial-place of Constantia, his daughter, or the Holy Sepulchre at Jerusalem, and it must be confessed that these offer a greater resemblance to the Greek churches than do the Basilicas: others again are of opinion that this was entirely a new style without any previous model, owing its origin to the skill and conception of the Byzantine architects. The question remains, how are these differences to be settled? Not, we presume, by following any one opinion to the exclusion of the others, but by granting a moderate credit to all. We believe that they all speak truly, but that no one of them speaks the whole truth; it is probable that Byzantine architecture owes its origin to each and all of the above sources,—to one perhaps more than another, but not to one to the exclusion of another. We would say that it owed its existence not a little to the two first causes, but more especially to the last, for as Mr. Knight, in describing the church of S. Vitale, says, "The chief architectural novelty in this building, is the dome. No vaulting of any kind had ever been hitherto employed in the roofs of churches, much less that most skilful and admired of all vaulting, the cupola, or dome; a mode of covering buildings perfectly well understood by the Romans, but discontinued as art declined, and, for the first time, reproduced by the Greek architects of Constantinople, in the instance of S. Sophia."

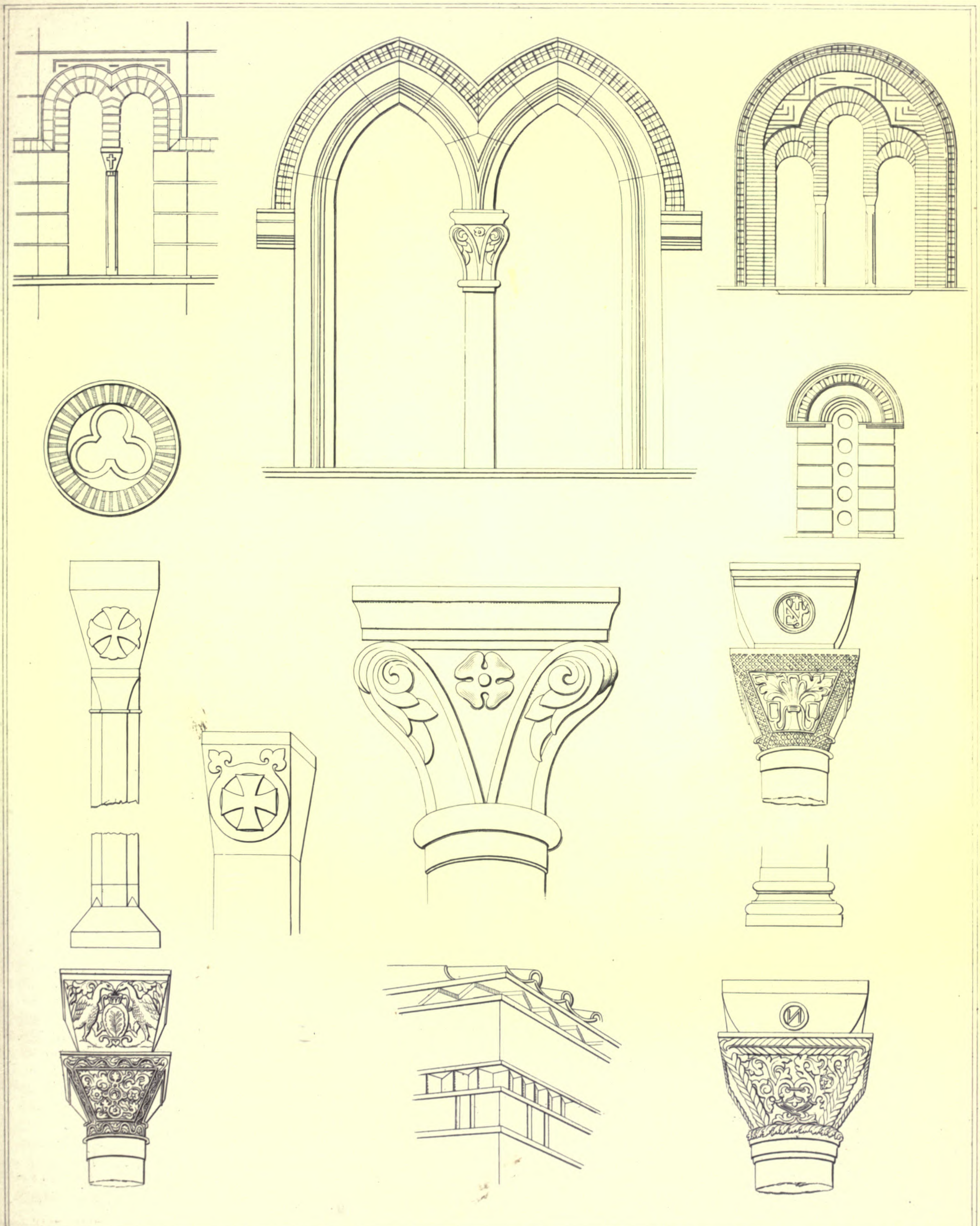
With the insufficient materials we have to work upon, it would be futile to attempt a detailed classification of the examples belonging to this style. It is to be regretted that our knowledge on the subject is so scanty, but we trust that some of our travellers will take an interest in those hitherto neglected remains of Christian art. That there is a scarcity of examples, we can hardly suppose; we believe that Asia Minor would afford ample materials for a proper investigation. The only writer we know of who has essayed an arrangement of known examples, and their division into classes, is M. Couchaud in his book on the Eglises Byzantines en Grèce. It is true he seems to include some examples under this style which other authors do not suppose to belong to it, but he has given considerable attention to the subject, and his opinions cannot but be worth consideration. He commences by dividing the buildings into three classes, to each of which he assigns a particular period. The first period is comprised between the fourth and sixth centuries, the second between the sixth and eleventh, and the third between the eleventh and the invasion by the Ottomans. We cannot do better than follow his own description as closely as possible.

Few of the churches of the first period, says he, are now extant; but we learn from the historian Eusebius that they were in plan either round or octagon, and were surmounted by a dome. Of this description was the church erected by Constantine at Antioch, which was of the latter class, and that erected by his mother Helena, in Syria, of the circular form. The churches of S. Marcellin and S. Constance at Rome, as well as that of S. Vitale at Ravenna, afford further examples of the historian's description. The plans in both cases, whether circular or octagonal, terminated of a square form, and upon the plans thus produced were erected the façades; the most ancient of which are simple parallelopipeds, terminated at their summit by a cornice of stone or marble, and sometimes of bricks, so placed as to form salient and re-entering angles. Pediments showing the slope of the roof do not appear in the façades, for the use of timber had already been discarded by the Greeks in the formation of their roofs, which were now either flat or spherical. One or more gates gave admittance into the church, and these were generally adorned with deep mouldings; the lintels were relieved by an arch of discharge. We have said that all the churches of this period were surmounted by domes; these were pierced at their lower extremity by a multitude of apertures which lighted the interior of the cupola. According to Eusebius and S. Paul of Seleucia, the domes were covered with lead and occasionally gilded, but all those which are still to be found in Greece are covered with tiles of terra cotta. The lateral façades differ little from the principal one; they are each of them provided with an entrance. The apsides, generally three in number, symbolizing the three Persons of the Holy Trinity, were of a simple plan, which was more frequently circular than polygonal: their sides were pierced with one or more apertures or windows. In the interior of the church the nave was always preceded by a porch or vestibule. A gallery for the female portion of the congregation was carried along the nave as far as the sanctuary, and was lighted by windows situated over the principal façade, and sometimes by others in the side façades. The principal difference between the styles of the two empires, is shown in the length of the nave, which in the Greek churches is much shorter than in the basilicas of the west. In the centre of the church were four piers supporting the dome, which was erected on a square plan, the angles being filled up by very ingenious contrivances technically termed pendentives. The extremities of the nave were covered by two hemispherical cupolas.

Such are the principal features of the edifices which were erected from the time of Constantine to the middle of the sixth century.

An enumeration of the peculiarities of the second period will help to give us an idea of the progress made by Justinian in the Christian architecture of this era.

The first edifice which presents itself to our notice is the smaller church of S. Sophia at Constantinople, converted into a mosque after the invasion of the Ottomans. The plan of the exterior is that of a square surrounding an octagon, the form of that of S. Vitale at Ravenna. In the interior the galleries for females were carried round the first story, and the nave covered, as in the preceding period, with a dome. From this let us pass on to the larger church of the same name, a building erected by Justinian to replace one which had not long previously been destroyed by fire. In plan this is similar to the smaller church, with the exception that the octagon is slightly prolonged. The interior galleries are similar to those already described, but the dome is more rich and beautiful than in all previous examples, and pierced with a larger number of apertures. The effect produced by this building was great, as is evidenced by the influence which it obtained throughout the Eastern empire. At a later time, the form of the interior was repeated in the exterior; this combination, which was first applied to the nave



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and transepts, at last became so general, that externally you could scarcely discover a straight line towards the summit of the building. The churches of "the Almighty," and of the monastery at Constantinople, which still preserve the roof of this period, offer remarkable examples of this combination of vaulting; and the method, which was employed in a great number of instances, is still to be seen in most of the isles of the Archipelago. In this period the domes were increased in number, and at last were carried even over the porch; the side façades follow the same form as the principal one, and the rear end of the edifice terminates in a polygonal apsis, pierced with windows of two or three compartments. In the interior decoration mosaics took the place of the marble slabs previously employed, which were retained only in the surbasements. The nave was simplified; square piers were substituted for columns, which gradually disappeared, and the pendentives were modified and somewhat varied. The vaults were divided by horizontal rings, and decorated with paintings; the centre of the cupola being occupied by a colossal head of Christ, surrounded by angels. The domes belonging to the latter portion of this period differed from the preceding, inasmuch as the windows encroached upon the spherical part, whereas before they had been confined to the base. This second period, as may readily be seen, added greatly to the embellishment of Byzantine architecture, and eventually considerably modified its character.

In the third period, the systems of Italy and Greece were united; the division indeed owes its origin, in a great measure, to the Roman basilica, as is manifested by the gable ends of the wall showing the inclination of the roof. Athens furnishes a number of examples, in which the influence of Western type is particularly noticeable. The galleries for females were now dispensed with, and a portion of the area of the church set apart for their service in the transepts. The influence of this new mode, however, was more especially shown in the profusion and richness of the ornaments employed in the details of the buildings.

Paintings in fresco took the place of mosaics, and were multiplied to such an extent, that at last the very marble which previously adorned the surbasement, was imitated by this means.

Semicircular vaults covered the whole length of the church; the windows were closed up with slabs of stone or marble, pierced with small circular apertures to admit light; and the doors began to be of more elaborate workmanship; the interior arrangement remained the same as before. This last period, which has been said to end with the invasion of the Turks, may be considered as continuing for some time longer, during which the arts remained stationary in Greece, up to the period of the last war of independence.

It now only remains to give some description of a few of the churches which have been alluded to in a previous part of this article: we cannot do better than commence with that of S. Sophia, which forms a fair type of the whole style. The following extract is taken from the *Encyclopedia Metropolitana*:—

"The cathedral of S. Sophia, at Constantinople, which had been built by Constantine, having been twice destroyed by fire, was rebuilt finally by Justinian, about A. D. 532. His architect, Anthemius, gave the design, and the emperor every day superintended the wotk, which was completed in about six years from the time of laying the foundation; the magnificence of the edifice so well satisfied the emperor, that he is said to have glorified himself with the reflection that in it he had exceeded Solomon himself.

"The plan of the interior is that of a Greek cross, the four arms of which are of equal length; the central part is a square, the sides of which are each about 115 feet long. At each angle of the square a massive pier of travertine stone has been carried to the height of 86 feet from the pavement, and four semicircular arches stretch across the intervals over the sides of the square, and rest upon the piers. The interior angles between the four piers in the central square are filled up, from the springing points of the four arches, in a concave form, to a horizontal plane passing through their vertices, which are at 143 feet above the pavement; so that, at the level of the vertices, the interior edge of the part filled up becomes a circle, the diameter of which is equal to the side of the central square. Upon this circle, as a base, is raised the principal dome, the form of which is that of a segment of a sphere, which is said to be equal in height to one-sixth of the diameter of the base. On both the eastern and western sides of the square, in the centre of the church, is a semicircular recess, the diameter of which is nearly equal to the side of the square; it is carried up to the same height as the piers, and terminates in a half-dome, or quadrant of a sphere, its base resting upon the hemicylindrical wall of the recess, and its vertical side coinciding with the arch raised between the piers on the face of the building; the flat side of each recess and dome being open towards the interior of the church. These quadrantal domes were intended to resist the lateral thrust of the arches raised on the northern and southern sides of the church, but they were found insufficient, for the arches pushed away the half-dome on the eastern side twice, and it could only be made to stand by constructing the great dome of pumice stone and very light bricks obtained from Rhodes, by filling up the arches with others of smaller dimensions, and by carrying an enormous arch-buttress from a massive wall beyond the building to the foot of the dome.

"At the extremities of the semicircular recesses, in a line running east and west through the centre of the church, are smaller recesses, the plan of one of which terminates in a semicircle, and of the other in a right line; these recesses are built to the height of the springing of the four principal arches, and are crowned by quadrantal domes, which, as well as the recesses, are open towards the interior. In each of the two principal hemicylindrical recesses between the great piers, and the other recesses just mentioned, are formed two other cylindrical recesses, open towards the interior, and covered by quadrantal domes. All the recesses and domes are perforated by rows of small windows to obtain light.

"On both the northern and southern sides of the square, in the interior of the church, is a grand vestibule forming a square on the plan; the roof of each consists of three hemicylindrical vaults extending from north to south, and of another vault of the same kind crossing the former at right angles through the middle, and forming, by their intersections, three groined arches; these vaults are supported by massive pillars, which have bases, but no plinths; the upper part of their capitals resemble the volutes of the Ionic order, but the lower part seems to be a barbarous imitation of the Corinthian base. Above these vestibules are galleries exactly similar to them, and, probably, appropriated to women during the performance of divine service. The whole church is surrounded by cloisters, and enclosed by four walls, forming one great rectangle on the plan. The exterior does not correspond with the internal grandeur of the edifice, being surrounded by clumsy buttresses. The entrance is by a portico as long as the church, and about 36 feet wide; this is ornamented with pilasters, and communicates with the interior by five doorways of marble, sculptured with figures in bas-relief. Contiguous to this vestibule, and parallel to it, is another, which has nine doorways of bronze.

"After twenty years, the Eastern dome was thrown down by an earthquake, but it was immediately restored by the persevering industry of Justinian; and it now remains, after a lapse of thirteen centuries, a stately monument to his fame."

The next description, that of S. Vitale, Ravenna, is given by Mr. Gwilt, in his Encyclopædia of Architecture.

"The exterior walls are formed in a regular octagon, whose diameter is 128 feet. Within this octagon is another concentric one, 54 feet in diameter, from the eight piers whereof—55 feet in height—a hemispherical vault is gathered over, and over this is a timber conical roof. The peculiarity exhibited in the construction of the cupola is, that the spandrils are filled in with earthen vases, and that round the exterior of its base, semicircular-headed windows are introduced, each of which is subdivided into two apertures of similar forms. Between every two piers hemicylindrical recesses are formed, each covered by a semidome, whose vertex is 48 feet from the pavement, and each of them contains two windows, subdivided into three spaces by two columns of the Corinthian order, supporting semicircular-headed arches. Between the piers and the external walls are two corridors, which surround the whole building, in two stories, one above the other, each covered by hemicylindrical vaulting. The upper corridor, above the vault, is covered with a sloping or lean-to roof."

Mr. Hope adds the following particulars:—"S. Vitale," says he, "built under Justinian in 534, announces itself at first sight as a work of Greek architects, and a kindred production with S. Sophia, and the others of Constantinople. Its form, round without, though octagonal within; its two tiers of arcades supported on pillars; its larger arcades or apsides, containing lesser arches or pillars; its square capitals, partly of basket-work, and its coating of Mosaic, at once complete the resemblance and establish the relationship."

The next descriptions, of S. Ciriaco, at Ancona, and S. Mark's, Venice, are taken from Mr. Gally Knight's beautiful work on the Ecclesiastical Architecture of Italy.

"Ancona was one of the towns of Italy which remained longest in the hands of the emperors of the East. Muratori informs us, that in the year 1174 Ancona was governed by an officer appointed by the Emperor Comnenus, and he adds, that the Emperor Frederick saw with impatience that remnant of Oriental power in the heart of the Western Empire. These circumstances will sufficiently account for the plan and style of S. Ciriaco, which, constructed under the domination of the Greeks, is Greek in all its parts.

"No certain record of the date of this building has been preserved, but from an inscription still extant, it appears that the bodies of SS. Ciriaco, Marcellino, and Liberio, were deposited in the crypt of this church in the year 1097. Almost invariably, when the bodies of saints were translated, a new church was prepared for their reception, and the translation usually took place when the building was sufficiently advanced for the performance of divine service, but before the work was entirely completed. We further find, that Bernard, Bishop of Ancona, consecrated a high-altar in 1128, and that in 1189, Bishop Beraldus added a chapel, and encrusted the walls of the interior of the church with marble. From all these circumstances, it may be inferred, that this cathedral was begun about the middle of the eleventh century, and completed in the course of the twelfth. It is highly probable that the Saracens, who landed at Ancona in 983, and committed extensive devastations, maltreated the cathedral, which was then in existence, and made it necessary to provide another in peaceable times.

"The cathedral was originally dedicated to S. Lawrence, and retained that name till so late as the fourteenth century, but finally the local favourite obtained the ascendant. The body of S. Ciriaco was originally imported from the East by the empress Galla Placidia in the fifth century, and by her deposited in the cathedral which then existed at Ancona.

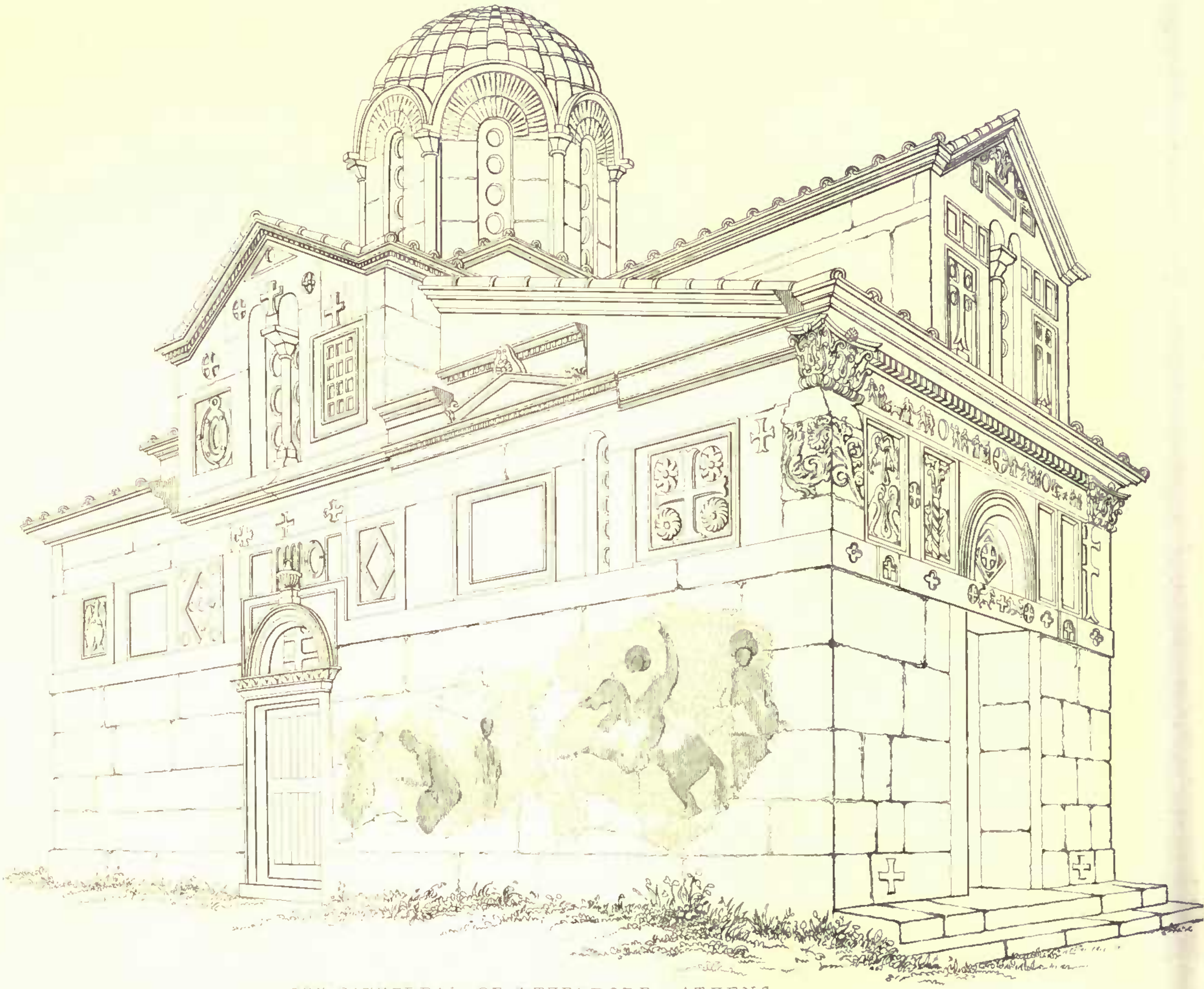
"S. Ciriaco is on a large scale. The plan exactly represents the Greek cross, and was probably supplied by a Greek architect. The centre of the building is surmounted by the Eastern cupola. The building appears to have been erected without any deviation from the original design, and for the most part remains as it was at first constructed. The principal porch, which projects boldly, and is enriched with numerous mouldings, must have been a subsequent addition, as the courses of the stones of which it is composed, do not correspond with those of the church. In the interior, pillars supporting round arches, divide the nave from the aisles. The capitals of these pillars imitate the Corinthian, and exhibit no admixture of the Lombard imagery, which, at the time when the cathedral was built, prevailed in the north of Italy. The cupola is supported by piers and arches. The arches under the dome are pointed, but are evidently alterations. These pointed arches may have been introduced by the celebrated architect, Margaritone, who flourished in the second half of the thirteenth century. Margaritone was very much employed at Ancona, and to him the entire construction of S. Ciriaco is attributed erroneously by Vasari. Margaritone may have added the porch."

"The plan of S. Mark's, like that of S. Sophia, is a Greek cross, with the addition of spacious porticos. The centre of the building is covered with a dome, and over the centre of each of the arms of the cross, rises a smaller cupola. All the remaining parts of the building are covered with vaults, in constructing which, the Greeks had become expert, and which are much to be preferred to the wooden roofs of the old basilicas. Colonnades and round arches separate the nave from the aisles in each of the four compartments, and support galleries above. The capitals of the pillars imitate the Corinthian, and are free from the imagery which at that time abounded in the other churches of Italy. It is computed, that in the decoration of the building, without and within, above five hundred pillars are employed.

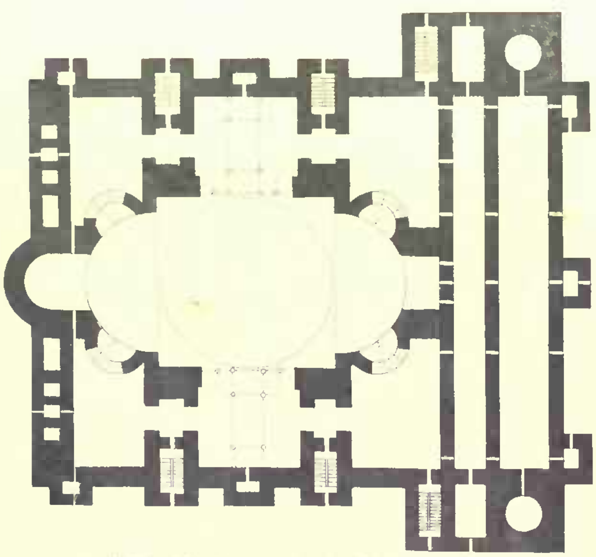
"The pillars are all of marble, and were chiefly brought from Greece and other parts of the Levant. Whilst S. Mark's was building, every vessel that cleared out of Venice for the East, was obliged to bring back pillars and marbles for the work in which the republic took so general an interest."

"The external appearance of S. Mark's is no less Byzantine than its interior, but less resembles S. Sophia from the increased numbers and elevation of its cupolas. Succeeding generations endeavour to outstrip their predecessors, and in the interval which had elapsed between the construction of S. Sophia and that of S. Mark's, the Greek architects had multiplied the feature which had obtained so much admiration, and had sought to give it additional importance, and surmounted the hemisphere of the dome with a second cupola of wood covered with lead. This change was imparted to the Venetian copy.

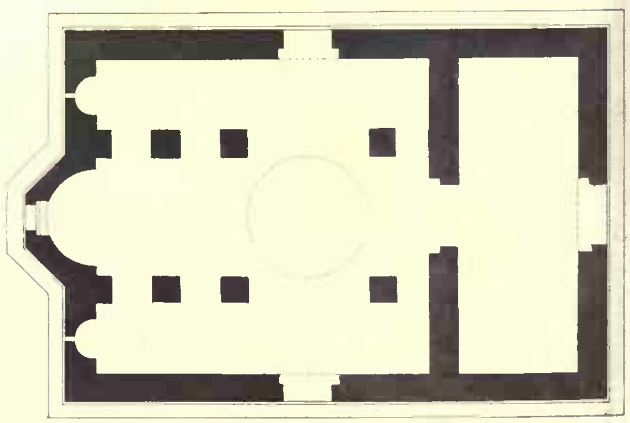
"Another Byzantine feature is conspicuous in the exterior of the building in the tiers of round arches by which the flank walls are relieved. With a singular contrast to the habits of their forefathers, who inflexibly adhered to the horizontal, the Greeks of the lower Empire turned



THE CATHEDRAL OF S THEODORE ATHENS



PLAN OF S SOPHIA CONSTANTINOPLE



PLAN OF S THEODORE

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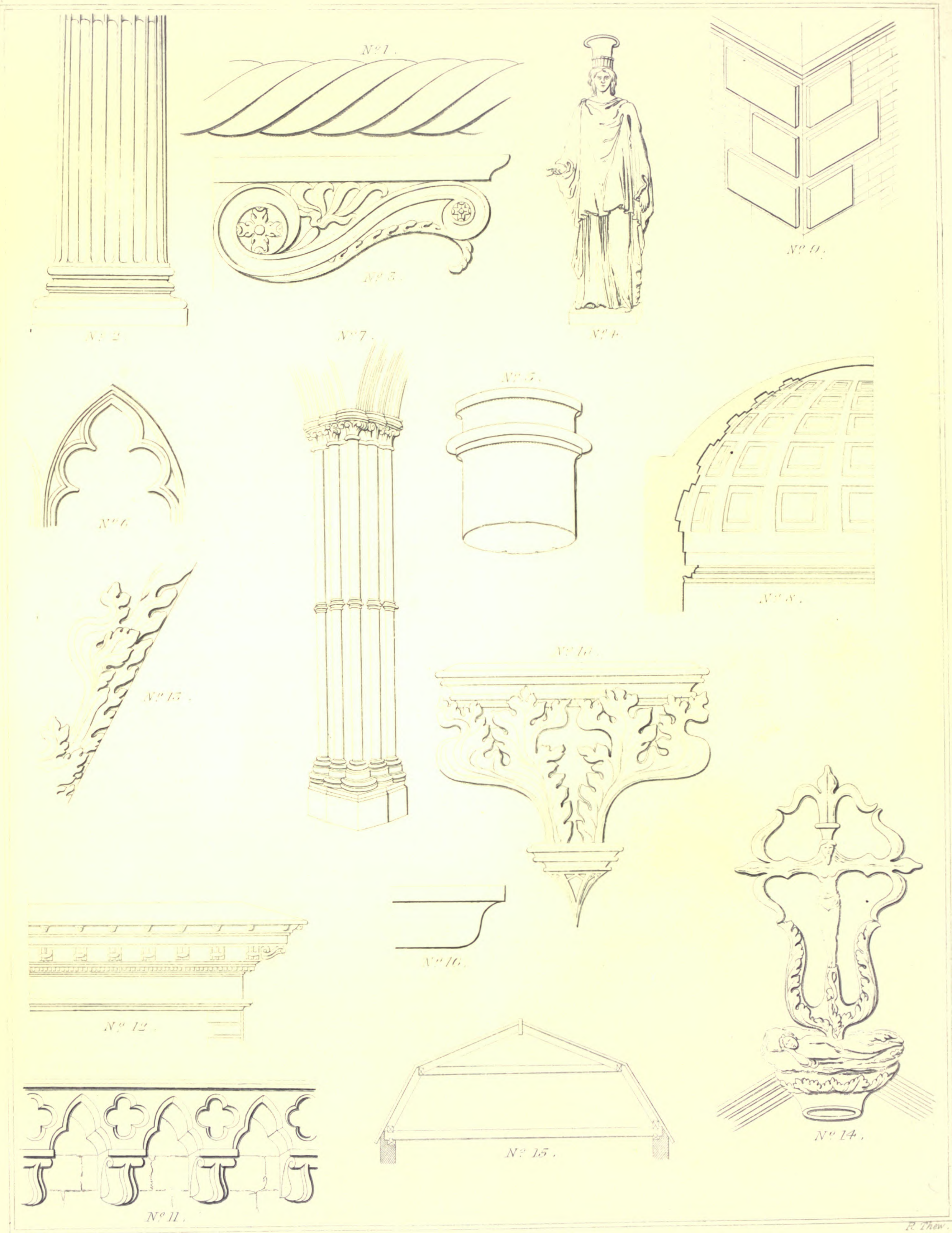

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No. 1. Cable moulding.
No. 2. Cabling.
No. 3. Cantaliver.
No. 4. Caryatic order.
No. 5. Cincture.
No. 6. Cinque foil.
No. 7. Clustered column.
No. 8. Coffer.
No. 9. Coin.
No. 10. Corbel.
No. 11. Corbel table.
No. 12. Cornice.
No. 13. Crocket.
No. 14. Cross.
No. 15. Curb roof.
No. 16. Cymatium.

every line into a curve, and introduced a semi-arch wherever they could, even in the shape of windows, which were often what in modern phraseology would be termed fan-lights. The front is on the same principle: a second tier of semicircular arches rises over the portico, which consists of no less than five semicircular entrances decorated with numerous pillars; the summit is crowned with spiral and pyramidal forms, partaking more of the character of the pointed style than of the round. Altogether, the exterior of S. Mark's is a strange mixture, but it is venerable and picturesque."

The last description which we shall give is that of S. Theodore, at Athens; it is extracted from M. Couchaud.

"Of all the churches which Athens possesses, S. Theodore is certainly the most complete, since it has three apsides, a dome and belfry; but the fresco painting in the interior has decayed. The altar-screen, the furniture, and the pulpit, have been replaced. It is constructed of a porous stone, separated by courses of brick; the only peculiarity which it offers is a frieze in terra cotta, running along the front façade, and the two side façades, which are pierced with doors of singular proportion, and having a horse-shoe-headed arch."

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CAABA, a part of the temple of Mecca, to which the Mahometans principally address themselves in prayer. It consists of a stone edifice, nearly square, and is said, by the followers of Mahomet, to have been first built by Abraham and his son Ishmael.

The word is Arabic, *caaba*, and *caabah;* a name which some have given to this building, on account of its height, which exceeded that of the other buildings in Mecca; but others, with more appearance of propriety, derive the name from its quadrangular form.

This edifice is so ancient, that its original use, and the name of its builder, are lost in a cloud of idle traditions; it is not improbable, however, that it was built by some of the immediate descendants of Ishmael. But, whatever was the original destination of the building, it does not seem to have been a temple, as the door was not placed in the middle of the structure; and for many ages there was no worship performed in it, though the pagan Arabs went in procession round it. It is most probable, however, that the Caaba was primarily designed for religious purposes; and it is certain, that it was held in the highest veneration long before the birth of Mahomet. Having undergone several reparations, it was, a few years after his birth, rebuilt, on the old foundation, by the tribe of Koreish, who had acquired possession of it, either by fraud or force. It was afterwards repaired by Abdallah Eben Zobeir, the calif of Mecca; and again rebuilt by Yussof, surnamed Al Hejâj, in the seventy-fourth year of the Hegira, with some alterations, in the form in which it now remains.

The length of the Caaba is twenty-four cubits, from north to south; its breadth, from east to west, twenty-three cubits; the door, which is on the east side, is raised four cubits from the ground, and the floor is on a level with the threshold of the door. The Caaba has a double roof, supported by three octangular pillars of aloes-wood. The outside of the building is covered with rich black damask, adorned with an embroidered band of gold, which is changed every year, and which is provided by the Turkish emperors. At some distance, the Caaba is surrounded, but not entirely, with a circular enclosure of pillars, joined at the bottom by a low balustrade, and towards the top by bars of silver. Without this enclosure, on the south, north, and west sides of the Caaba, are three buildings, which are the oratories, or places where three of the orthodox sects assemble to perform their devotions; and towards the south-east stands the edifice which covers the well Zemzem, the treasury, and the cupola of Al Abbas. All these buildings are enclosed, at a considerable distance, by a magnificent piazza, or square colonnade, covered with cupolas. From each angle of this piazza rises a minaret, with a double gallery, adorned with a gilded spire and crescent, as are the cupolas which cover the piazza. Between the pillars of both enclosures, hang a great number of lamps, which are constantly kept lighted by night.

CABLE, a moulding of a convex circular section, rising from the back or concave surface of a flute, so that its most prominent part may be in the same surface as the fillet, on each side of the flute; the surface of the flute being that of a concave cylinder, while that of the cable is the surface of a convex cylinder, with the axes of the cylinders parallel to each other. A cable represents a rope or staff laid in the flute; it is always shorter than the flute, and placed at the lower end of it.

Cable mouldings of a somewhat different character are made use of in Norman architecture; they represent cables or twisted ropes, laid in mouldings of a concave circular section, and having one half or greater portion of their bodies exposed, and projecting from their beds.

Cabled Flutes, such flutes as are filled with cables.

CABLING, the filling of flutes with cables, or the cables themselves so disposed. Cabling the flutes of columns was not in very frequent use in the works of antiquity. The flutes of the columns of the arch of Constantine are filled with cables to about one-third of the height of the shafts. Most of the columns in the ruins of Balbec, Palmyra, and Dioclesian's palace at Spalatra, have neither flutes nor cables. Cabling has sometimes been practised in modern times, without fluting, as in the church of Sapienza, at Rome. *See* Flutes.

CAGE, in carpentry, an outer work of timber, enclosing other works within it; as, the cage of a stair, is the wooden wall that encloses it.

CAISSON, in water-building, a large chest of strong timber, made water-tight, and used in large and rapid rivers for building the pier of a bridge. The bottom consists of a grating of timber, so contrived as to be detached from the sides when necessary. The ground under the intended pier is first levelled, and the caisson being launched and floated to a proper position, is sunk, and the pier built as high as the level of the water, or nearly so; then the sides are detached, and the bottom remains as a foundation for the pier.

The most considerable work that has come to our knowledge, where caissons have been used, is Westminster Bridge; of this, therefore, a particular account may be acceptable. Each of the caissons contained 150 loads of fir timber, and more tonnage than a man-of-war of 40 guns; their size was nearly 80 feet from point to point, and 30 feet in breadth; the sides, 10 feet in height, were formed of timbers, laid horizontally over each other, pinned with oak trunnels, and framed together at all corners, except the salient angles, where they were secured by proper iron work, which being unscrewed, would permit the sides of the caisson, had it been found necessary, to divide into two parts. These sides were planked across the timbers, inside and outside, with 3-inch planks, in a vertical position. The thickness of the sides was 18 inches at the bottom and 15 inches at the top; and in order to strengthen them the more, every angle, except the two points, had three oaken knee-timbers, properly bolted and secured. These sides, when finished, were fastened to the bottom, or grating, by twenty-eight pieces of timber on the outside, and eighteen within, called *straps*, about 8 inches broad and 3 inches thick, reaching and lapping over the tops of the sides; the lower parts of these straps were dovetailed to the outer kirb of the grating, and kept to their places by iron wedges. The purpose of these straps and wedges was, that when the pier was built up sufficiently high above low-water mark, to render the caisson no longer necessary for the masons to work in, the wedges being drawn up, gave liberty to clear the straps from the mortises, in consequence of which the sides rose by their own buoyancy, leaving the grating under the foundation of the pier.

The pressure of the water upon the sides of the caisson was resisted by means of a ground timber, or ribbon, 14 inches wide, and 7 inches thick, pinned upon the upper row of timbers of the grating; and the top of the sides was secured by a sufficient number of beams laid across, which also served to support a floor on which the labourers stood, to hoist the stones out of the lighters, and to lower them into the caisson.

The caisson was also provided with a sluice to admit the water. The method of working was as follows: a pit being dug and levelled in the proper situation for the pier, of the same shape as the caisson, and about 5 feet wider all round; the caisson was brought to its position, a few of the lower courses of the pier built in it, and sunk once or twice, to prove the level of the foundation; then, being finally fixed, the masons worked in the usual method of tide-work. About two hours before low-water, the sluice of the caisson, kept open till then, lest the water, flowing to the height of many more feet on the outside than on the inside, should float the caisson and all the stone-work out of its true place, was shut down, and the water pumped low enough, without waiting for the low ebb of the tide, for the masons to set and cramp the stone-work of the succeeding courses. Then when the tide had risen to a considerable height, the sluice was opened again, and the water admitted; and as the caisson was purposely built but 16 feet high, to save useless expense, the high tides flowed some feet above the sides, but without any damage or inconvenience to the works. In this manner the work proceeded till the pier rose to the surface of the caisson; when the sides were floated away, to serve at another pier. (Labelye's *Description of Westminster Bridge.*)

Caisson, signifies also the sunken panel in a vaulted ceiling, or in the soffit of a cornice.

CALATHUS, the work-basket of Minerva: also a hand-basket, made of light wood or rushes, used by the women for gathering flowers, after the example of Minerva. The figure of the calathus, as represented in ancient monuments, is narrow at the bottom, and widens upwards in its horizontal dimensions. Also a cup used in sacrifices.

CALCAREOUS CEMENTS. *See* Cements.

Calcareous Earth, a sort of earth which becomes friable by burning, and is afterwards reduced to a fine powder by mixing it with water; it also effervesces with acids. It is frequently to be met with in a friable or compact state, in the form of chalk. *See* Limestone and Gypsum.

CALENDARIO, Philip, a celebrated architect and sculptor, who flourished at Venice about the year 1354, and constructed those beautiful porticoes round the Palace of St. Mark, which established his fame.

CALIBRE, or Caliber, the greatest extent or diameter of a round body.

Calibre Compasses, or Callipers, a pair of compasses with bent legs, for taking the thickness of a convex or concave body in various parts.

CALIDUCTS, (from *calor*, heat, and *ducere*, to lead,) pipes or canals disposed along the walls of houses and apartments, used by the ancients for conveying heat to the remote parts of the house, from one common furnace.

CALLIMACHUS, a celebrated architect of antiquity, inventor of the Corinthian order.

CALOTTE, a concavity in form of a cup or niche, lathed and plastered, to diminish the height of a chapel, cabinet, or alcove, which would otherwise be too elevated for the breadth.

CAMAROSIS, (from *καμαροειν*, to *arch over*,) an elevation terminated with an arched or vaulted head.

CAMBER, an arch on the top of an aperture, or on the top of a beam; hence camber windows.

Camber Beams, those which are cut with an obtuse angle on the upper edge, forming a declivity each way from the middle of their length; they are used in truncated roofs, where, after being covered with boards, the boards are again covered with lead, in order to discharge the rain-water towards each edge of the flat, or platform.

Cambered beams are employed in a multitude of situations where great strength is required. All beams which are so situate as to be subject to cross-strain should be cambered. Instances of cross-strain occur in bressummers, which are loaded with a wall, and of course are most affected by the gravity of its materials where the bearing is greatest, which will be in their mid-length. A weight applied in this manner will have the effect of pressing the centre below the level of the ends of the beam, and thus fracturing the superincumbent wall; and besides this, will tend to snap and tear asunder the timber; and although, on account of its great scantling, such an event rarely, if ever, occurs, yet it strains the beam in the direction of its length, a test which timber should not be subjected to. Moreover, in all cases where beams of any great length are employed, the gravity of the timber itself will weigh them down midway, even where they are subjected to no additional weight, as in the case of the tie-beams of a truss. In all these instances the difficulty may be obviated by cambering the timber upwards. This method not only ensures that the beam shall be level after settlement, but entirely alters the nature and operation of the force; for whereas previously the beams were strained or extended, this tension, by the employment of a camber, is changed into a pressure, so that the tendency instead of being to tear the particles asunder, and thus weaken or break the timber, is rather to press them more closely together, and render the beam firmer and more compact.

Further, all timber is liable to shrinkage by the evaporation of the moisture which is always present in a greater or less degree, and thereby becomes of smaller dimensions than when first inserted in a building. This defect may be rectified as far as the length is concerned, by cambering to such a degree, that when the wood is completely dry, it may fall into a horizontal position, or nearly so. The extent to which the beam should be bent is a matter of nice calculation, and the regulation of it must be left to experience. In trusses the camber of the tie-beam should not be too great, as if so, it will tend to thrust out and derange the principals. When bressummers occur one above another, the higher ones should be cambered to a greater extent than those below, the camber increasing in direct proportion to the number of bressummers beneath it.

CAMERATED, arched.

CAMES, in glazing, small slender rods of cast lead, about 12 or 14 inches long, to be drawn through a vice, in order to make turned lead; each such bar is called a *came*.

CAMP CEILING, a ceiling formed by one or more planes, with inclinations rising at an internal obtuse angle from the sides of the apartment, and most frequently enclosing a level plane in the middle, in the manner of a coved ceiling. This kind of ceiling is chiefly used in garrets, where otherwise there would be a want of head-room.

CAMPANA, the body of the Corinthian capital, otherwise called the *vase* or *bell*, from its figure.

CAMPANILE, (from *campana*, a bell,) a bell-tower, chiefly in use among the Italians. It was sometimes a distinct and separate building of itself; but more commonly adjoining to the church, so as to make a part of the fabric, usually at the west end. Several of these towers are remarkable for being considerably out of the perpendicular, of which those of Pisa and Bologna are the most celebrated.

Campaniles were erected to a great height; that of Cremona, the highest in Italy, is 395 feet high; that of Florence, built by Giotto, 267 feet, of a square plan, the sides of which are 45 feet in length. The leaning tower of Pisa is 150 feet in height, and 13 feet out of the perpendicular.

CANAL OF THE IONIC VOLUTE, the spiral channel or sinking on the face, which begins at the eye, in a point, and expands in width until the whole number of revolutions are completed. In the volutes of the Ionic order of the temples of Minerva Polias and Erectheus, at Athens, are several canals, which begin and end in the manner above described.

CANAL is also used for a FLUTE.

CANAL OF THE LARMIER, the channel recessed upwards on the soffit, for preventing the rain-water from reaching the bed or lower part of the cornice. *See* BEAK.

CANARDIERE, or GUERITE, a small turret, sometimes of wood, and sometimes of stone; used as a sentry-box on the salient angles of works, as places of shelter for sentinels. They were formerly constructed on castles, and used for firing, or discharging anything unseen in unmolested security.

CANCELLI, latticed windows, or those made with cross-bars of wood or iron. Also balusters or rails, especially those which separate the chancel from the body of the church.

CANOPY, a magnificent covering suspended over an altar, throne, tribunal, pulpit, chair, or the like. *See* BALDACHIN. It also denotes the projecting head of Gothic niches or tabernacles.

CANT, a term used by carpenters, signifying to turn a piece of timber, which is brought in the wrong way for their work. Also, the external angle made by any two planes of a solid or building.

CANT MOULDING, a bevelled surface, or one that is neither perpendicular to the horizon nor to the vertical surface of the body or building. These mouldings are of very remote antiquity, and have an effect similar to the Grecian echinus. A cant moulding, instead of the echinus, is applied to the capital of the columns of the portico of Philip, king of Macedon, and in many other situations, both of Grecian and Roman edifices, as is exhibited in Stewart's *Ruins of Athens*, in the *Ionian Antiquities*, and in Adams's *Ruins of the Palace of Dioclesian, at Spalatra, in Dalmatia.* The mouldings of our first Saxon buildings were originally very simple, consisting only of surfaces perpendicular and parallel to the naked of the walls; though afterwards they were formed not only of squares, but of cants also. These simple forms continued in use for some time after the Conquest; and even when a great variety of curved forms came to be introduced, they were never entirely laid aside; we find them frequently employed in the windows of castellated buildings, and other parts.

CANTED COLUMN, a column of which the horizontal sections are polygons, consisting of straight sides instead of concave sides or flutes. Canted columns are not frequently to be met with in the works of the ancients, yet examples may be seen in the columns of the portico of Philip, king of Macedon, and of the temple of Cora. The cants of columns are difficult to execute with truth, so as to preserve the arrises in the proper contour of the column, and in a vertical plane passing through its axis; and when done, they want the beautiful contrast of light and shade, which is so conspicuous in the flutings of the Grecian Doric.

CANTING, the cutting away a part of an angular body at one of its angles, so that the section may be a parallelogram, the edges of which are parallel from the intersection of the adjoining planes.

CANTALIVERS, those blocks which are placed at regular distances, projecting at right angles from the surface of the wall, and supporting the upper members of a cornice, the eaves of a house, or balcony: they answer the same purpose as modillions, mutules, blocks, or brackets, although they are applied to more trivial purposes; modillions, mutules, &c., being employed in regular architecture. Cantalivers are frequently made of timber, or cast iron, and project to a great distance. Those used in the cornice of St. Paul's, Covent Garden, are of timber, and project one-fourth of the height of the column.

CANTHARUS, among ecclesiastical writers, a fountain or cistern in the middle of the atrium, before the ancient churches, wherein people washed their hands and faces before they entered.

CANTHARUS OF A FOUNTAIN, with the Romans, the part, or apparatus, out of which the water issued; it was of various fanciful forms, sometimes resembling a shell, at others, an animal vomiting the water from its mouth, and sometimes the stream issued through the eyes.

CANTHERS, or CANTERII, in ancient carpentry, the common rafters of a roof, or those placed in vertical planes at right angles to the ridge or eaves of the building.

CANTING STAIRS. *See* STAIRS.

CANTONED BUILDING, a building whose angles are adorned with columns, pilasters, rustic quoins, or anything that projects beyond the naked of the wall.

CANTONED COLUMNS. *See* COLUMNS.

CAP, the mouldings which form the head of a pier or pilaster.

CAP, in joinery, the uppermost part of an assemblage of principal or subordinate parts. The term is applied to the capital of a column, the cornice of a door, the capping or uppermost member of the surbase of a room, the hand-rail of a stair, when supported by an iron strap, &c.

CAPACITY, in geometry, the solid content of a body.

CAPITAL, (*capitello*, Italian; from the Latin, *caput*, the head) the assemblage of mouldings or ornaments above the shaft of a column, on which the entablature rests; in other words, the head of the column. Capitals are variously composed, some with simple mouldings, others with mouldings, foliage, and volutes.

The capitals used in the architecture of the Greeks, though with numberless minute variations of ornaments and proportions, arrange themselves into three general classes, and offer the most obvious distinctions between the orders.

In all the orders, the capital is divided from the shaft by some small member, as an astragal and fillet, or by one or three channels, which are always accounted a part of the shaft; so much of the column, therefore, as appears above this member, belongs to the capital.

The Doric capital consists of a neck, which is a continuation of the shaft, with its fluting, several fillets, varying from three to five in number, a bold projecting ovolo, and a massy abacus, of a square form, which covers the whole.

The Ionic capital consists of an ovolo above the astragal of the shaft; a band, or festoon, upon the ovolo, on the front and rear of the capital, with volutes on the right and left, suspended from the ends of each band, or festoon; and, lastly, a thin moulded abacus crowns the whole.

The Corinthian capital, which is more richly ornamented, consists of a vase, two rows of leaves attached to the vase, volutes, caulicoli, which spring between each two of the upper row of leaves, and, lastly, an abacus, which is not only moulded on all the four edges, but formed into a concavity from the two extremities of each of the said edges.

From this description of Grecian capitals, it will be seen that though the parts are generally so very unlike as to be incapable of comparison, yet they in variety maintain a general resemblance.

The variations to be found in different ancient examples of the same order, will be described under their respective heads.

With regard to the Tuscan capital, there are no authenticated remains of the order of which it is a part; and the precepts of Vitruvius on this head are so obscure, that modern compilers of systems of architecture have, of course, varied exceedingly in their designs; so that the order which passes under this name, must be regarded rather as a modern than an ancient invention. It is made to differ from the modern Doric by an air of poverty and rudeness, and by the suppression of the triglyphs, mutules, and other members.

The Composite appears never to have been admitted as a separate order by the ancients.

From the remains of Egyptian antiquities, we find that their architects had no certain rules; and it is rather singular, that though the buildings themselves were constructed with the greatest simplicity, their capitals are of infinite variety; many of them possessing richness of decoration, although devoid of the simple elegance which is the characteristic of the Grecian orders. The ornaments are, in general, accurate imitations of the natural productions of the country, such as the lotus, the reed, or the palm.

The temples of the ancient inhabitants of Hindostan, works of dateless antiquity, present many capitals of extraordinary form and composition. In some, we find represented the figures of elephants and horses, apparently crouching under the weight of the ceiling. Capitals, very similar in idea, are also found in the ruins of Persepolis, composed of horses and camels.

As Roman art degenerated with the decline of the empire, the capitals from the ancient edifices were used indiscriminately in the new structures; and this led, in later times, to the employment of a variety of capitals in the same edifice. The first alteration we find in the form of this member of the column, is in the erection of that style of architecture known as Byzantine, in which the capitals are in the shape of a truncated pyramid of four sides, placed in an inverted position, having the apex downwards; the surface is ornamented with foliations in low relief, or with a sort of basket-work, which is a distinguishing feature of the style to which it belongs. A nearer approach to their original is shown at a later period, in the style whose introduction is attributed to the Lombards; in this, which is merely a modification of the debased Roman, some of the capitals bear a great resemblance to the Corinthian, although far inferior to their original in simplicity and elegance; there are, however, other examples of a far different description, both in form and ornamentation; some ornamented with designs in low relief, others again of a grotesque character. If we include the Norman in this style, to which it certainly bears a close affinity, we shall have a great variety of forms, to be noted indeed rather for their variety and massive appearance, than for beauty of outline or decoration.

But of all capitals, those found in buildings in the modes commonly comprised under the term Gothic, hold a lofty pre-eminence, both for variety and tastefulness. What can be more chaste and elegant than the ornamentation of the early English? or what more graceful and natural than the foliage of the decorated capital? As to variety, it was the governing principle of decoration, there seldom being found many repetitions of one form in the same building. Nature was their model, by her alone were their designs limited, so long at least as their skill was sufficient to imitate her productions.

Capital, *Angular*. *See* Angular Capital.

Capital of a Baluster, one similar to those of the Tuscan or Doric orders.

Capital of a Lantern, the covering by which it is terminated, either in a bell-shape, the form of a cupola, that of a spire, or in any regular figure whatever.

Capital of a Triglyph, the projecting band which surmounts the plain vertical area, or face, and which is disposed in a plane parallel to the said face. The capital of the triglyph of the Grecian Doric projects but a very small distance, and is not returned on the flanks, except at the angular triglyphs, and this only upon each face of the building; but in the Roman Doric, the capital of the triglyph projects more than that of the Grecian, and is returned with the same projection on the flanks as in the face.

CAPITOL, a celebrated rock, or hill, at Rome, whereon stood many ancient edifices, with the house of Romulus, &c.

Among the many celebrated edifices that formerly occupied this hill, the principal was the Asylum, erected by Romulus in order to people his new city. The house of Romulus was composed of canes, rushes, &c.; and every year the priests superstitiously repaired it with similar materials. Here was the Tabularium, or Archive, where were deposited the laws and consulta of the senate, and every other public act, written on tables of bronze. Vespasian repaired the Capitol, and had three thousand new tables made, the former having been defaced when the library and other buildings were destroyed by lightning. It is supposed to have stood where the arches and Doric columns are now seen, behind the Senators' Palace, towards the Campo Vaccino. Here was the Curia Calabra. Here also stood the house of Manlius, the defender of the rock, destroyed on account of the treachery of its master. The temple of Juno Moneta was built on its site. The number of temples on this hill was very considerable: some make them amount to sixty. But the great quantity of statues in marble, metal, silver, and gold, erected to heroes who had deserved well of the republic, causing great confusion, Augustus removed great part of them to the Campus Martius.

All these noble edifices, once the ornament of the mistress of the world, have fallen a victim to the ravages of time, and the still more destructive plunder of invading barbarians. At first this hill was only accessible from the south; but after the Campus Martius was inhabited, another road was opened towards the north. The first among the moderns who promoted the decoration of the Campidoglio was Pope Paul III. who, after a design of Bonarrotti, constructed the spacious steps.

CAPREOLS, in Roman carpentry, the struts or braces of a trussed roof.

CARACOL, is used sometimes to denote a staircase in the form of a helix, or spiral.

CARAVANSERA, in the East, a large building, or inn, for the reception of travellers, and the lodging of caravans. It is usually a large square of buildings, with a court in the middle, surrounded with galleries and arches, under which runs a kind of banquette, or elevation, some feet high, where travellers rest themselves, and make their lodging as well as they can; their baggage, and the beasts that carry them, being fastened to the foot of the banquette. Over the gate there are frequently small chambers, which the caravanseraskier, or director, lets out at a very dear rate, to such as wish to be retired.

CARCASE, the work of a house before it is either lathed or plastered, or the floors laid.

Carcase, or Naked Flooring, that which supports the boarding above, for walking upon, and the ceiling below, by a grated frame of timber, consisting of three tiers of beams, called *joists;* the middle tier being transverse to the other two. The beams of the middle tier, called *binding-joists*, support the other two tiers: the beams forming the upper tier, called *bridgings*, or *bridging-joists*, support the boarding, and are frequently notched upon the binding-joists: the lowest row of beams, called *ceiling-joists*, are either framed into the binding-joists, with pulley or chase mortises, flush with the under edges of the said joists, or are notched and nailed to them below. When the floor is very much extended in both dimensions, another set of large beams, called *girders*, the whole depth of the three tiers, are introduced, for shortening the bearings of the binding-joists, which are mortised and tenoned into the girder on both sides of it. The under edges of the binding-joists should be so framed, as to be below the under side of the intermediate girder, about half an inch, to prevent the ceiling from cracking; and the girder must be furred, to range with the under edge of the ceiling-joists. The general scantlings of these timbers are as follow, viz., girders, 12 by 13 inches; binding-joists, 10 by 4; bridging-joists, 5 by $2\frac{1}{2}$; and ceiling-joists, 3 by $2\frac{1}{2}$. The distance which these timbers are commonly placed in the clear is as follows: the binding-joists from 4 to 6 feet, which is also that of the ceiling-joists; and the bridgings 11 or 12 inches apart. As the girders go the whole length of the room, they have no fixed bearing; when they extend to 20 feet and upwards, they should be trussed. When the breadth of a room extends to 30 feet and upwards, the girders should be framed like the truss of a partition, with an upper and lower beam, and with posts, braces, and struts: for this purpose, a sufficient depth for the floor should be allowed, from two to three feet. Girders should never be placed over openings, unless they be supported by strong arches. When a lintelled opening comes under the place where the end of the girder should be, the end of the girder must be changed to the nearest solid bearing, which will throw its direction into an oblique position. The wall-hold for girders in brick buildings, may be from 9 to 12 inches, and for binding-joists, 6 inches. In stone buildings, for girders, from one foot to two feet, according to the thickness of the wall, and for binding-joists, 9 inches. In thick walls there may be two rows of wall-plates.

Carcase Roofing, that which supports the covering by a grated frame of timber-work, consisting of three tiers of timber, parallel to each other, and to the sloping surface of the covering. The most general disposition of the timbers is the following: the first tier and support is a row of timbers, inclined to the pitch of the roof, supported at various points by other timbers, which, with the inclined timbers, form as many vertical frames, perpendicular to the sides of the building as there are inclined timbers: each frame is called a *truss:* the inclined timbers in the upper part of the truss are called *principal rafters:* the principal rafters support a set of horizontal timbers transversely, and parallel to each other, called *purlins:* the purlins support the third and last tier of timbers of the frame, transversely or parallel to the principal rafters: the timbers of the last tier are called *bridging*, or *common rafters.* The upper surfaces of the principals, those of the purlins, and those of the common rafters, are sometimes framed flush with each other, or in the same inclined plane, in order to save room, or to conceal more of the roof: in this way the purlins must be tenoned, and the principals mortised to receive them; the small rafters and purlins are also tenoned and mortised together. But the best and strongest mode of carcase framing is, to make the purlins bridge over the principals, and the common rafters over the purlins. The principals rest upon a horizontal piece of timber, on the wall head, called the *raising*, or *wall-plate:* when the purlins bridge over the principals, and the small rafters over the purlins, the small rafters rest at the bottom upon a piece of timber called a *pole-plate.* The manner of joining the timbers in carcase roofing and flooring may be seen in the article Carpentry; other particulars relative to roofing, may be seen under Roofing, Truss, and Boarding.

Sometimes the covering is only supported by purlins resting upon the principal rafters; in this case, the length of the boards is disposed parallel to the principal rafters; but this position does not give so great strength to the roof as that which is horizontal.

CARDINAL SCAPI, in Roman joinery, the stiles of doors.

CARINA, in Roman antiquity, a building in the form of a ship.

CARNEDDE, in British antiquity, heaps of stones; supposed to be druidical remains for confirming and commemorating covenants.

CAROLITIC COLUMN. *See* Column.

CARPENTER (from the French *charpentier;* formed from *charpente*, timber; or, probably, from the Latin, *carpentarius*, a maker of *carpenta*, or carriages), an artificer, whose business it is to cut, form, and join timber, for the purpose of strengthening and supporting various parts necessary in the construction of buildings.

Carpenter's Rule, is generally used in taking dimensions, and in casting up the contents of timber and artificers' work.

It consists of two equal pieces of box, each one foot in length, connected together by a folding joint: in one of these equal pieces there is a slider, and four lines marked at the right hand, A, B, C, D; two of these lines, B, C, are upon the slider, and the other two, A, D, upon the rule. Three of these lines, viz., A, B, C, are called *double lines*, because they proceed from one to ten twice over in the length; these three lines are all exactly alike, both in numbers and division. They are numbered from the left hand towards the right, 1, 2, 3, 4, 5, 6, 7, 8, 9, 1, which stands in the middle; the numbers then go on again to 10, which stands at the right-hand end of the rule. These numbers have no determinate value of their own, but depend upon the value you set on the unit at the left hand of this part of the rule; thus if you call it 1, the 1 in the middle will be 10, the other figures which follow will be 20, 30, &c., and the 10 at the right-hand end will be 100. If the first, or left-hand unit be called 10, the middle 1 will be 100, and the following figures will be 200, 300, 400, &c., and the 10 at the right-hand end will be 1000; and thus, whatever be the value of the first unit, the second unit in the middle is always ten times greater; and whatever is the value of the first and second unit, the following numbers to the right denote so many times that value as the number expresses.

The fourth line, D, called the *girt line*, is a single line, proceeding from 4 to 40. Upon it are marked W G at 17·15, and A G at 18·95, the wine and ale guage points, to make it serve the purpose of a guaging-rule.

The use of the double lines, A and B, is for working the rule of proportion, and finding the areas of plain figures. And the use of the girt line D, and the other double line C, is for measuring of timber. On the other part of this side of the rule, there is a table of the value of a load, or 50 cubic feet, of timber, at all prices, from sixpence to twenty-four pence, or two shillings, per foot.

On the other side of the rule are several plane scales, divided into 12th parts, marked *inch*, $\frac{3}{4}$, $\frac{1}{2}$, $\frac{1}{4}$, &c., signifying that the inch, $\frac{3}{4}$ inch, &c., are each divided into 12 parts. These scales are useful for planning dimensions that are taken in feet and inches. The edge of the rule is divided into inches, and each of these inches into eight parts, representing half inches, quarter inches, and half quarters.

In this description, the rule is supposed to be folded; let it now be opened, and pull out the slider, you will find the back of it divided like the edge of the rule, so that altogether it will measure one yard, or three feet, in length. The slide is very useful in taking inside dimensions for any length not less than one foot, nor greater than three feet.

Some rules have other scales and tables upon them; as a table of board measure, one of timber measure, a line for showing what length for any breadth will make a foot square, also a line showing what length for any thickness will make a solid foot. The former line serves to complete the table of board measure, and the latter the table of timber measure.

The thickness of the rule is generally about a quarter of an inch; this face is divided into inches and tenths, and numbered, when the rule is opened, from the right-hand towards the left, 10, 20, 30, &c., to 100, which falls upon the joint. The other half is numbered in the same manner, and the same way. The scales serve for taking dimensions in feet, tenths, and hundredths of a foot, when the contents are found by decimals.

Carpenter's Square, a square, of which both stock and blade consist of an iron plate, of one piece; it is in size and construction as follows:—one leg is 18 inches in length, numbered on the outer edge, from the exterior angle, with the bottom of the figures adjacent to the interior edge: the other edge is 12 inches long, and numbered from the extremity towards the angle; the figures are read from the internal angle, as on the other side; each of the legs is about an inch broad. This implement is not only used as a square, but also as a level and measuring rule. Its application as a square, in taking measures, is so easy as not to require example; but its use in taking angles may be thus illustrated: suppose it were required to take the angle which the heel of a rafter makes with the back; apply the end of the short leg of the square to the point of the heel and back, with the edge of the square level across the plate; extend a chalk line from the ridge of the roof to the said heel-point, and the division on the perpendicular leg of the square which the line falls upon, will mark the inches, and show how far it deviates from the square in 12 inches.

Carpenter's Work, in the mensuration of artificers' work, includes the taking of the dimensions of every description of timber necessary in the construction of buildings, finding their contents, and valuing the same.

The works done by the carpenter, in the general construction of buildings, are the preparation of piles, sleepers, and planking, or other large timbers in the foundations, centerings to vaults, wall-plates, lintels, and bond-timbers, naked flooring, partitioning, roofing, battening to walls, ribbed ceilings to form vaulting for lath and plaster, &c. These are not necessarily used in the construction of every edifice: piling and planking, or other timbers used in the foundation, are only incidental, depending upon the insufficiency of the ground to be built upon; the remaining articles may be all used in the most substantial and elegantly constructed houses.

Large and plain articles, where a uniform quantity of materials and workmanship is expended, are generally measured by the square of 100 superficial feet.

Piles may be made at per piece, and driven by the foot run, according to their diameter, and the quality of the ground.

Sleepers and planking are measured and valued by taking the superficial contents in yards or squares.

Plain centering is measured by the square; but as the ribs and boarding are two different qualities of work, they ought to be measured and valued separately; one dimension of the boarding is taken by girting it round the arch, the other is the length of the vault.

Centering for groins should be measured and valued as common centering, but in addition thereto, the angles should be paid for by the foot run, over and above; that is, the ribs and boarding ought to be measured and valued separately, according to the exact superficial contents of each, and the angles by the lineal foot for workmanship in fitting the ribs and boards, and for the waste of wood occasioned by the operation. Wall-plates, lintels, and bond-timbers, are measured by the cubic foot, under the denomination of *fir-in-bond*.

Naked flooring may either be measured and valued by the square, or by the cubic foot, according to the description of the work, and the quantity of timber employed. In forming an idea of its value, it is proper to observe, that in equal cubic quantities of small and large timbers, the small timbers will have a greater superficies than the large ones, and therefore the saving will not be in a ratio with the solid contents; consequently the value of the workmanship will not follow the cubic quantity or said ratio. The difficulty of handling timbers of the same length increases with the weight or solidity, as the greater quantity requires greater power to handle it, and consequently a greater expenditure of time: and though the time may not be exactly in a ratio with the solid quantity, there will be no great difference, as the respective sections will not vary considerably in their dimensions; and as the value of the sawing upon a cubic foot is comparatively small to that of the work done by the carpenter, the whole value of labour and materials may be ascertained with sufficient accuracy where the work is uniformly of one description.

In naked flooring, where girders are introduced, they interrupt the uniformity of the work by mortises and tenons. In this respect, the price ascertained by the cubic quantity of the girders, would not be sufficient at the same rate per foot, as the other parts, not only on account of the great difference of size, but as it is cut full of mortises to receive the tenons of the binding-joists, it occasions a still greater disparity in the quantity of workmanship. A correct method, therefore, of valuing labour and materials, would be to measure and value the whole by the cubic quantity, and allow an additional rate upon every solid foot of girders; or if the binding-joists were not inserted in the girders at the usual distances, a fixed price for every mortise and tenon, in proportion to their size, which would keep a ratio with the area of the end of the girder.

As the binding-joists are sometimes pulley or chase mortised, to receive the ceiling-joists, and sometimes notched to receive the bridging-joists over them, they ought to be classed by themselves, at a superior price per foot cube, or at an additional price for the workmanship, above that of common joisting: this should always be allowed according to the description of workmanship, whether the ceiling-joists be put in their pulley mortises and tenons, or the bridgings notched or adzed down.

Partitions may be measured by the cubic foot, but the sills, top pieces, and door heads, should be measured by themselves, according to the solid quantity, at an additional rate, because both the uniform solidity, and the uniform quantity of workmanship, are interrupted by them. In trussed partitions, the braces should be rated by the foot cube, at a superior price to that of the quartering, for the trouble of fitting the ends of the uprights upon their upper and lower sides, and for forming the abutments at the ends.

In roofing, all the timbers should be measured by the cubic foot, classed as the difficulty of execution, or as the waste occasioned, may require. Common rafters may be rated the same as joisting or quartering; purlins at a superior price, for the trouble of fitting or notching down the common rafters; the notching of the purlins themselves, upon these principles, should be valued at per piece or notch. The various parts of trusses should be arranged separately; the joggles should be paid for at per piece, including the tenons at the ends of the struts; the mortising tie-beams and principals, and making the tenons of the truss-posts, should likewise go together; and the mortising and tenoning at the ends of tie-beams and principals, in another class; strapping should be paid for according to the number of bolts. In all these matters, regard must be had to the size and description of the work; common or bridging rafter-feet at per piece.

Battening to walls is best measured by the square, according to the dimensions and distances in the clear of the battening.

Ribbed ceilings should be measured according to the cubic quantity, making a proper allowance for the great waste of stuff; the price of labour will be regulated by the description of the work, and also by the cubic quantity of timber.

Trimmers should be measured separately, at such a price as to include not only the mortises and tenons of the joisting inserted into them, but the tenons at their extremities, and the mortises of the trimming-joists, which are to receive them. In this way, it would be unnecessary to take any account of the tenons at the ends of the bridging-joists, or of the mortises in the trimming-joists to receive the ends of the trimmer.

It would be endless to enumerate the various methods of measuring each particular species of carpenter's work; the leading articles only are here observed.

As soon as the shell of a building is finished, that is, previous to the floors being laid, or the ceilings lathed and plastered, all the timbers should be measured, that no doubt may exist as to the actual scantlings of the timbers, or of the description of the workmanship.

In taking the dimensions, it must be observed, that all pieces which have tenons, must be measured to the extremities of the tenons. Principal timbers, as binding-joists and girders, go at least nine inches into the wall, or one-third of its thickness, if more than 27 inches.

In taking the dimensions of bond-timbers and wall-plates, the several laps must be added to the lengths. When there is a necessity for cutting out parallel pieces from the sides of truss-posts, as in king or queen posts, if the pieces cut out exceed 2½ feet in length, and 2½ inches in thickness, they should be deemed pieces fit for use; but their lengths should not be reckoned so long by six inches, as the saw can hardly be entered with less waste.

The boarding of the roof is measured by the square, according to the thickness and quantity of the boards, and the manner of jointing them. In measuring for labour and materials, the most accurate method is, first, to find the cubical contents, the price of the cubic foot, including the prime cost, carting, sawing, waste, and the master's profit; then add the price of labour, properly measured, in the same manner as for the journeyman. Labour and materials are variable, and have no relation whatever to each other; consequently they cannot be reduced to single tables. The value of the cubic foot may be calculated by having the prime cost of the load, or 50 cubic feet: for example, let it be required to find the price of a cubic foot, when the price of the load is £10.

	£	s.	d.
50 feet cube fir, prime cost	10	0	0
Cartage	0	5	0
Sawing	0	10	0
7 cube feet waste	1	8	0
	12	3	0
20 per cent profit on the above	2	8	7
Master's price per load	£14	11	7

Then as 50 cubic feet are to one cubic foot, so is £14. 11s. 7d. the price of 50 cubic feet, to the price of one cubic foot. Thus,

```
                £.   s.   d.
50 : 1 : :     14   11    7
               20
             ----
              291
               12
             ----
       5,0) 349,9
             ----
       12) 69 49/50
             ----
              5 9
```

So that the price of the cubic foot wants only the fiftieth part of a penny to be 5s. 10d. This is the rate of the master's price for the fir, exclusive of labour.

The foregoing are the methods by which the various parts of workmanship should be analyzed, in order to discover a legitimate ratio of prices; but we regret to add, that no particular account of time has been kept, in which the execution of certain uniform portions of work have been done, and by which alone we are enabled to give accurate calculations. The method of lumping work by the square, is not to be depended on, in the general admeasurement of buildings, as the surface is not always of a uniform description of workmanship; thus, in hipped roofs, the greatest trouble is at the hips, in cutting and fitting the jack-rafters, which are fixed at equal distances thereon, and therefore such a price may be fixed upon the cubic quantity of hips and vallies, as will not only pay for the workmanship in themselves, but also for the trouble of cutting and fitting the jack-rafters.

It is impossible to fix a proper rate, including both materials and workmanship, as the one may be stationary, while the other is variable. With respect to materials, the value of any quantity may be easily ascertained, whatever be the price per load; but the far greater difficulty lies in fixing proper rates of workmanship; however, admitting that the time of executing every species of work were known, there would be no difficulty in establishing certain uniform quantities, which would give the real value at any time; the following is a specimen of the several rates of workmanship, by which the prices may be regulated at any time, admitting them to be right for the present. Each rate consists generally of three places of decimals on the right side of the point, and sometimes an integer on the left side. This table shows also the customary methods of measuring.

To find the price of the common measure of any kind of workmanship, at any time.—Multiply the wages of the workman by the rate; then, whatever denomination the wages is per day, the integers of the product, if any, will be of the same denomination, and the decimals will be parts of the same.

Example.—The centering of cylindric vaults is 2.033 per square; now let the wages per day be 5 shillings, or 60 pence; then $2.033 \times 5 = 10.165$ shillings per square, and by multiplying the decimal parts by 12, we obtain the pence. Thus—

$$\begin{array}{r} .165 \\ 12 \\ \hline 1.980 \end{array}$$

1.980 penny, or very near two pence; so that the value of a square of centering is nearly 10s. 2d.

Again, suppose the wages to be 5s. 6d. per day, then $2.033 \times 5\frac{1}{2} = 11.181$ shillings, or 11s. 2d, nearly: and thus for any other example.

TABLE I.

CENTERING.

	Fixed
	per square.
For cylindric plain vaults	2.033
	per ft. super.
For groins	.057
For gauged brickwork	.073
For brick trimmers bridgewise	.041
For coach-head trimmers	.057
	per ft. run.
For apertures	.02

TABLE II.

MISCELLANIES.

	Fixed
	per ft. run.
Fir-in-bond and wood bricks	.008
Fir-in-templets, lintels, and turning pieces	.025
Planing fir from the saw, per foot super	.017
Rebating fir up to 2 inches by ¾	.025
Rebating from 2 inches by ¾ to 3 inches by 1¼	.041
Single beading up to ¾ inch	.008
Single quirk beading from ¾ inch to 1¼	.012
Return beads to be paid for at a double rate.	

TABLE III.

QUARTER PARTITIONS.

	Fixed
	per square.
Common four inch	1.033
Five inch	1.113
Six inch	1.307
Six inch circular plan	1.888
Trussed frame with king-post	1.743
Trussed, both king and queen posts	2.226

TABLE IV.

NAKED FLOORING.

	Fixed
	per square.
Ceiling floor, framed, with tie-beams, binding, and ceiling-joists	1.355
Ceiling floor with tie-beams and ceiling-joists only	1.065
Ceiling-joists only	.646
Single framed floor, trimmed to chimney and well holes, less than 9 inches deep	1.355
The same, above 9 inches	1.646
The same, if trimmed to party walls, add extra per square	.388
Single framed floor, with one girder	1.936
Strutting to be paid for extra.	

Continuation of Table IV.

	Fixed
	per square.
Single framed floor-case and tail bays	2.130
For every extra-cased bay add per square	.484
Framed floors, with girders, binding, and ceiling-joists	3.581
Ground joists bedded	.775
Ground-joists bedded and framed to chimneys	.968
Ground-joists pinned down on plates, and framed to chimneys	1.065
	per ft. run.
Girders reversed and bolted	.097
Truss girder-braces 4 inches by 4	.194
If any of the above works be done in oak, add one-third.	

TABLE V.

ROOFS.

Common Shed Roofing.

	Fixed
	per square.
One story high	.968
Two stories	1.033
Three stories	1.113

Single Span Roofing.

One story high	1.065
Two stories high	1.113
Three stories high	1.210
If the above have purlins, add per square .194; or if the purlins be framed diagonally, add double, or	.388
Hips and valleys	.08
In *common kirb roofing*, add extra per square when one side is kirbed	.194
When three sides	.357
When four sides	.516
Girt roofing, with framed principals, collar beams, and purlins	2.323
Framed with principals, beams, king-posts, purlins, and common rafters	3.484
If the principals and rafters are framed flush, and the purlins housed in, add .387 per square to the above.	

Continuation of Table V.

	Fixed
	per square.
Framed with principals, beams, king-posts, queen-posts, and common rafters, three stories	— .549
The same, four stories	4.84
	per ft. run.
Hips and valleys	.145
Hip, and ridge rolls fixed on iron	.048
Bedded plates to common span roofing	.008
Bedded plates to common span roofing, as above	.028
Diagonal and dragon pieces	.065
Angular ties and struts	.032
Rafter-feet and eaves-board	.032

TABLE VI.

GUTTERING.

	per ft. super.
One or 1¼ inch deal, and bearers, including 6-inch side layer board	.057
The same in kirb roofs	.073

TABLE VII.

FURRINGS OR BATTENINGS.

	per square.
If the stuff be ¾ inch by 1½	.872
But if the stuff is to be cut out, add .146 per square.	
Battenings with quarters, 3 inches by 2	.92
Battening to quarters, 3 inches by 2, to window piers	1.355
If the battens be fixed to plugs, add .29 per square.	
When any of the above are circular on the plan, add half as much more.	

TABLE VIII.

BRACKETING, INCLUDING PLUGGING.

	Fixed
	per ft. super.
To straight cornices	.089
To coved straight cornices	.065
If circular on the plan, add one half more.	
To groins in passages less than 4 feet wide	.162
To the same, above 4 feet	.121

CARPENTRY, the art of employing timbers in the construction of buildings.

The important and useful art to which the general name of carpentry is given, is so intimately connected with the comforts and requirements of man, in every stage of civilized society, that no apology can be necessary for the length to which our observations on it must necessarily extend. In a work especially devoted to architecture, it of course must occupy a prominent place; for carpentry may be considered of so great importance, that no man may pretend to be an architect who is not well acquainted with its principles and its practice. Carpentry may be divided into two grand branches—*Carpentry* and *Joinery.* The first includes the larger and rougher kinds of work, or that which is essential to the construction and stability of an edifice: and, generally, all the work wherein timber is valued by the cubical foot.

Joinery, (called by the French *menuiserie*, from *menu*, small, and *bois*, wood, or small wood employed in that art) includes all the interior finishings and ornamental work, and is generally valued by the superficial foot.

Carpentry itself is properly divided into three branches, viz., *descriptive*, *constructive*, and *mechanical*.

Descriptive carpentry shows the lines or methods for forming every species of work in plano, by the rules of geometry. To this branch of the art, sometimes called "finding," the celebrated Monze gave the name of *descriptive geometry*.

Constructive carpentry shows the practice of reducing the wood into forms, and joining the parts, according to the intention or design of the architect, and thereby forming a complete whole.

Mechanical carpentry shows the relative strength of timbers, and the strains to which they may be subjected by their arrangement and disposition.

In this article, after a few preliminary observations on what may be termed the "HISTORY" of carpentry, it is intended to give such definitions as may conduce to a comprehension of the theory and practice of the art, and then to show the progressive improvements made by the several English writers in carpentry; the various rules for forming the timbers, and for the individual operations, being shown under their respective heads. *See* particularly CONSTRUCTIVE, DESCRIPTIVE, and MECHANICAL CARPENTRY.

History.—This art is of such general and important use, that there can be no doubt of its being of the highest antiquity. Little of its history, however, has been transmitted to us from the ancients. Pliny and Vitruvius are almost the only authors whose writings on the subject have reached modern times; but as their observations are merely confined to the choice and felling of timber, they are of no use as to the constructive part, and only demonstrate that such an art existed.

The practice of carpentry in its rudest form must of necessity have commenced in the very earliest ages; for in the first attempts at the construction of the primitive buildings of those days, carpentry must have been brought into exercise. It is probable that the necessity of introducing the pediment roof, occasioned the first use of timber frames, and consequently the art of carpentry in building. The invention of the pediment roof is justly attributed to the Greeks; as the oldest buildings of this description are to be found in their country; they also appear to have used timber for other purposes, as in the framing of floors, and the construction of rustic buildings.

In warm countries, furnishing stone or marble, it is probable that the use of timber was not very frequent, and that it was confined to movable articles, where lightness was an essential quality; we must, therefore, not look to these climates for any traces of the art.

The next great people, in succession of time, to the Greeks, were the Romans, who seem to have employed timber for all, or nearly all, the purposes that the moderns are acquainted with. They not only constructed their roofs, but whole buildings, of timber: in Vitruvius we have a description of their manner of constructing the architraves of Tuscan temples, and of the foundation of arched ceilings and floors, in timber work. The Romans also used wooden cornices. The theatres and amphitheatres at Rome, and in different parts of Italy, were at first constructed of timber; as we read of the wooden theatre of Pompey, and the amphitheatre built of the same material, by Augustus, to exhibit the shows on account of the victory at Actium. The roofs of the Roman buildings were not always concealed; the timbers were sometimes exposed, and in magnificent buildings they were gilt, as in the basilica of St. Peter, erected by Constantine; sometimes they were encrusted with bronze.

Though circumstances require certain dispositions of timbers in a building, the timbers will still admit of infinite decoration, without injury; and sometimes so much as at first view to conceal the principal use. In the middle ages, carpentry partook of the style of building called *Gothic;* the roofs were pitched very high, but were frequently defective, on account of the want of tie-beams, which were omitted in order to obtain more lofty ceilings; height being one of the predominant features of this species of architecture.

Carpentry has been cultivated by the modern Italians. Serlio, in his first book, exhibits a construction for naked flooring, with timbers shorter than either of the dimensions of the area to be covered; in the fourth book he shows some very curious and strong methods of framing doors, according to the principles of trussed work; and in the seventh book, he has some very good forms for the trusses of roofs. The wooden bridges of Palladio are most excellent examples.

Among the French, the construction of wooden domes has been improved by Philibert Delorme, and Moulineau; and the centerings of arches and bridges by Perronet.

In England, the very curious construction of naked flooring, exhibited in the works of Serlio, has been demonstrated and improved by Dr. Wallis, and carried into execution, in the theatre of Oxford, by Sir Christopher Wren, who also designed the wood trussing of the dome of St. Paul's, and contrived a very curious scaffolding, which supported itself without anything below it, for the purpose of building and painting the interior dome. The art of carpentry has been much cultivated of late years in England, so that it has now begun to assume a scientific form. In accuracy and celerity of execution our workmen are unequalled.

Of late years the improvements in the manufacture of iron, both *cast* and *wrought*, have caused the introduction of that material into buildings in every variety of form—as *girders, beams*, &c. The floors, and sometimes even the roofs of those intended to be secured from fire, have been constructed of iron; and iron hooping is now used instead of bond-timbers in walls. The use of this material, however, as a substitute for wood, does not change the principle, as both materials are affected by the same gravitating laws.

The operations to which timber is subjected, from the time of its arrival in the carpenter's yard, in its natural state, to the period of its final employment in a building, may be classed under two general heads; as, those which relate to individual pieces, and those that relate to their connection with others.

Under the first head is the pit-saw, by which whole pieces of timber are divided, and reduced into scantlings. This term (from the French, *enchantillon*) means the dimensions in breadth and thickness, without respect to the length.

Planing is the operation of reducing the wood to a smooth surface, by means of an instrument called a *plane*, which consists of a chisel fixed in a frame, serving at once as a handle and a regulator to the edge, which cuts the wood in thin shavings as the plane is moved to and fro by the workman. The operations of the plane, besides that of reducing timber to a uniform surface, are those of grooving, rebating, and moulding: the latter not being necessary in carpentry, we shall only describe the former two: Grooving is the reducing a piece of timber below the surface, so as to take away a prism, and thereby leave a channel consisting of two surfaces of equal breadths, and another surface, of equal breadth, joining the other two, parallel to the surface from which the recess is made, generally forming two individual right angles.

Rebating is the reducing of a piece of timber, by taking away a prism at the angle, so as to leave only two sides, each of a parallel breadth, forming an internal angle, generally a right angle: so that in grooving and rebating, the groove or rebate is always less than the original depth of the stuff or piece out of which it is formed. The latter operation is particularly used in door-cases and the frames of casement-windows; the rebate forming a kind of ledge for the door or casement to stop against.

The implements which the carpenter has occasion to employ in the several operations, will be seen under the head Tools.

The principal operations, after the pieces are formed, consist in the joining of timbers: two pieces of timber may be joined so as to form either one, two, or four angles, oblique or right. A notched joint is formed by cutting out of the thickness of each piece, a part in the form of a parallelopiped; so that when the two pieces are joined, the substance left at the reduced thickness of the one piece, fills the excavation of the other, as far as it goes into its depth. If the thickness of the part left be equal to that of the part taken away in each piece, and the thickness of the part left of the one piece be equal to the thickness of the part left of the other piece, the joint is then said to be halved. In making one angle, the excess or excavation is formed at the end of each piece, and consists of two plane surfaces, one perpendicular, the other parallel to the two opposite faces, and in the plane of the angle. In forming two right angles, one piece must, of course, project on both sides of the other, and the other only on one side; the excavation or recess made in that which projects on both sides, consists of three plane surfaces, one being parallel, and the other two at right angles to the faces; the excavation or recess made in that which projects on one side, consists of two plane surfaces, in the like positions. In forming four right angles, the notch of each piece consists of three sides, two of which are at right angles, and the other parallel to the faces. One piece of timber may also be joined to another, so as to form only one or two adjacent angles, by notching one piece on three sides at the ends, and so forming a projecting prism, called a *tenon*, the sides of which are respectively parallel to the sides of the piece, and by excavating the end of the other piece, to receive the tenon, which is made to fit exactly. The two pieces thus formed at one or more angles to each other, may, if found necessary, be fixed by means of wooden pins, or nails, spikes, screws, bolts, straps, or other metal fastenings.

The two celebrated Italian authors, Serlio and Palladio, have given designs in carpentry. The British authors who have written on this useful art, are Godfrey Richards, at the end of his *Translation of the First Book of Andrew Palladio*, third edition printed 1676; Moxon's *Mechanical Exercises*, second edition printed 1693; Halfpenny's *Art of Sound Building*, printed 1725; *The Carpenter's Companion*, by Smith, printed 1733; *Ancient Masonry*, by Batty Langley, printed 1733; *The British Carpenter*, by Francis Price, printed 1735; *The Gentleman's and Builder's Repository*, by Edward Hoppus, printed 1738; *The Builder's Complete Assistant*, by Batty Langley, printed in 1738; *The Builder's and Workman's Treasury*, by Batty Langley, printed in 1741; *The Builder's Jewel*, by the same author; *The London Art of Building*, by William Salmon, the third edition, printed in 1748; *The British Architect*, by Abraham Swan, second edition printed in 1750; *Designs in Carpentry*, by the same author, printed in 1759; several pieces of carpentry, in *A Complete Body of Architecture*, written by Isaac Ware, published in 1768; *The Carpenter's and Joiner's Repository*, by William Pain, printed in 1778; *The Carpenter's Pocket Directory*, by the same author, printed in 1780; *The Golden Rule*, by the same, printed in 1781; *The British Palladio*, by the same, printed 1788; *The Practical Builder*, by the same author; *The Practical House Carpenter*, by the same author, printed in 1791. The following are productions of the Author of the present Work: *The Carpenter's New Guide*, in 1792; *The Carpenter's and Joiner's Assistant*, printed in 1792. Likewise, the various articles on carpentry, in Rees' *Cyclopædia; A Treatise on Carpentry*, in the *Edinburgh Encyclopædia;* and a treatise on the same subject, in his *Mechanical Exercises*. A long article on Carpentry, in a Supplement to the *Encyclopædia Britannica*, was written by Professor Robison, of Edinburgh; and an article on Carpentry, in *A Course of Lectures on Natural Philosophy and the Mechanical Arts*, by Thomas Young, M. D., late Professor of Natural Philosophy in the Royal Institution of Great Britain.

We shall here give extracts from these authors, in order to mark the various methods and progressive improvements in the scientific and practical parts of carpentry, particularly that part which relates to geometrical description.

Godfrey Richards, in his general title, at the end of the translation above referred to, writes thus:

"*Of Roofs.*—Rules and instructions for framing all manner of roofs, whether square or bevel, either above or under pitch, according to the best manner practised in England.

"Also to find the length of the hips and sleepers, with the back or hip mould, never yet published by any architect, modern or antique; a curiosity worth the regard, even of the most curious workman; exactly demonstrated in the following rules and designs, by that ingenious architect, Mr. William Pope, of London.

"Having raised the walls to their designed height, and made the vaults, laid the joists, brought up the stairs, and performed all those things spoken of before; we are now to raise the roof, which embracing every part of the building, and with its weight equally pressing upon the walls, is a band to all the work; and besides defends the inhabitants from rain, from snow, from the burning sun, and from the moisture of the night; adds no small help to the building, casting off from the walls the rain water, which although for a while it seems to do but little hurt, yet in process of time is the cause of much damage. The first men (as saith Vitruvius) built their houses with flat roofs, but finding that thereby they were not defended from the weather, they (constrained by necessity) began to make them ridged (that is to say) raised in the middle. These roofs are to be raised to a higher or lower pitch, according to the country in which they are; wherefore in Germany, by reason of the great quantity of snow that falls there, they raise their roofs to a very great pitch, and cover them with shingles, which are small pieces of wood, or of thin slate or tiles; for if they should raise them otherwise, they would be ruined by reason of the weight of the snow. But we, who dwell in a more temperate country, ought to choose such a pitch as may secure the building, and be of a handsome form: therefore we divide the breadth of the roof into four equal parts, and take three, which makes the most agreeable pitch for our country, and is the foundation for the raising of any manner of roof, whether square or bevel; as appears in the following designs and descriptions."

"*The manner of framing a floor, with the names of each member.* (*See* Carpentry, *Plate* I. *Figure* 1.

"1. The thickness of the wall, and lintel or wall-plate; and if it be in timber-work, then a bressummer.

PLATE I.

Fig. 1.

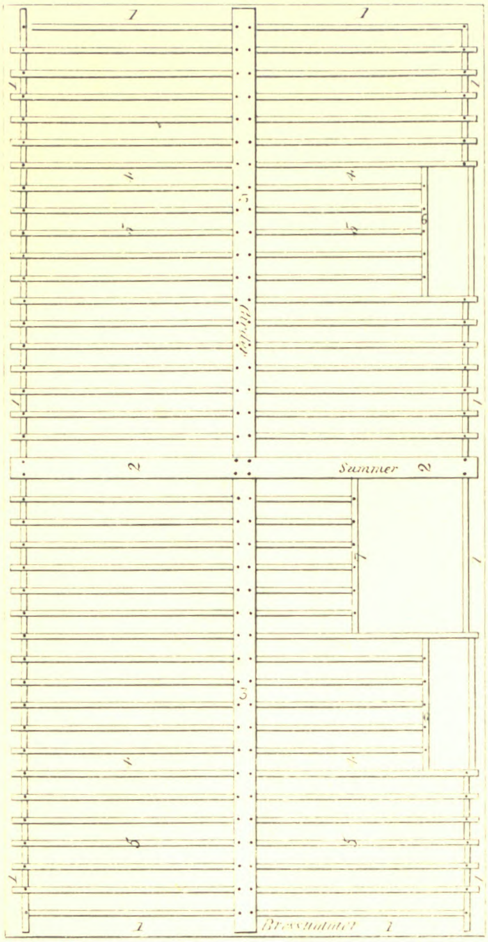


Fig. 2.

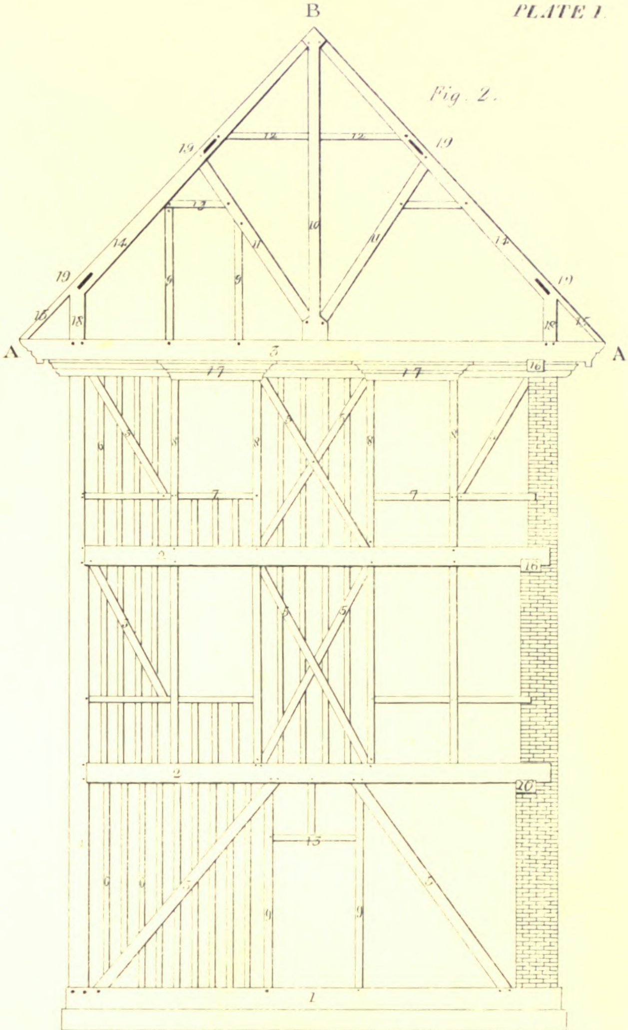


Fig. 3.

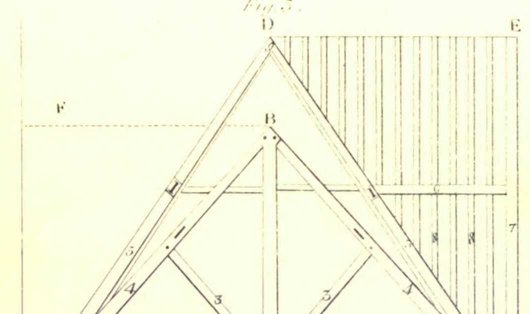
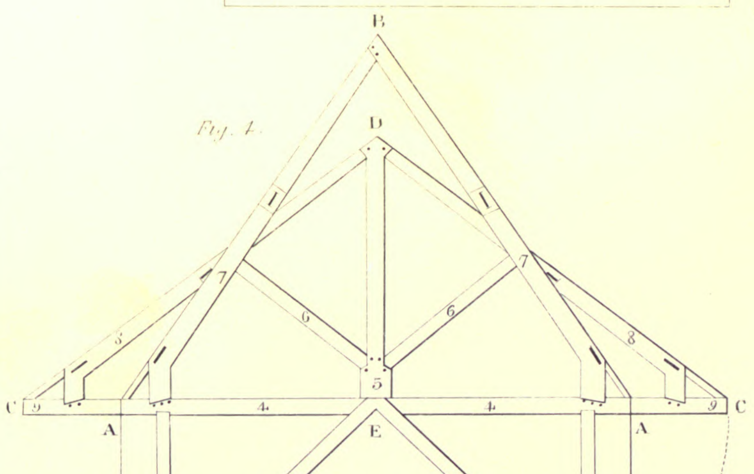


Fig. 4.



P. Nicholson.

R. Thew.

"2. The summer.
"3. Girders framed into the summer.
"4. Spaces between the joists.
"5. Joists.
"6. Trimmers for the chimney way.
"7. Trimmers for the staircase, or well-hole for the stairs."

Figure 2.—" *Of the Design.*

"A A The breadth of the house, cantalivers, cornices, and eaves.

"A B The length of the raftings and furrings, which ought to be three-fourths of the breadth of the house, A A.

"The principal rafters to be cut with a knee (as in the Design) that they may the better support themselves and the burthen over them, upon the upright of the wall, and also secure that part from the dripping in of the rain, which otherwise would happen if the rafters were made straight and furred.

"The beams to the roof, or girder to the garret floor, ought to project without the work, as far as the furring or shredding, which is the projecture of the cornice.

"This manner of framing the roof will be useful from 20 to 30 feet, or thereabouts.

"1. Ground plate.
"2. Girder, or binding interduce, or bressummer.
"3. Beam to the roof, or girder to the garret floor.
"4. Principal post, and upright brick wall.
"5. Braces.
"6. Quarters.
"7. Interduces.
"8. Prick-post, or window-post.
"9. Jaumes, or door-posts.
"10. King-piece, or joggle-piece.
"11. Struts.
"12. Collar-beam, strut-beam, wind-beam, or top-beam.
"13. Door-head.
"14. Principal rafters.
"15. Furrings, or shreddings.
"16. Ends of the lintels and pieces.
"17. Bedding, moulding of the cornice over the windows, and space between.
"18. Knees of the principal rafters, which are to be of one piece.
"19. Purline mortises."

Figure 3. "*Design of the gable end, or roof.*—Let the whole length of the gable end, or roof, A A, be 20 feet, divide the same into four equal parts; take thereof three for the length of the principal rafter, A B, and placing that perpendicular from the point C, to the point D, beget the length of the sleeper A D, which will be 18 feet. And the length of the dormer's principal rafter, from A to E, when laid to its pitch upon the back of the principals, will reach to the level line F B, or top of the principal rafter; and this is a general rule for all breadths.

"1. Summer, or beam.
"2. King-piece, crown-post, or joggle-piece.
"3. Braces, or struts.
"4. Principal rafters.
"5. The sleeper.
"6. Purline of the dormer.
"7. Principal rafter of the dormer.
"8. Single rafter of the dormer, standing on the sleeper and purline.
"9. Point of the sleeper.
"10, 11. The thickness of the wall and lintels, or wall-plates."

Figure 4.—" *Of the Italian or hip roof.*

"A A The breadth of the roof, being 20 feet.

"A B The length of the sleepers or hips, being 18 feet, which is proportionable to the breadth of the house.

"E D The height of the roof perpendicular.

"C D The length of the hip, and the angle which it maketh upon the diagonal line, which is showed by the pricked line G, from F to C.

"1, 2. The wall and lintels.
"3. Dragon-beam for the hip to stand on.
"4. Beam on summer, wherein the dragon-beams are framed.
"5. King-piece, or crown-post.
"6. Struts or braces from the crown-post to the hip-rafter.
"7. Hips, as they make the angle equal to the breadth of the house.
"8. Hips, as they make the angle in the diagonal lines from corner to corner.
"9. The additional length which the hips make upon the diagonal lines, more than the breadth of the house."

"*Of flat roofs*.—(CARPENTRY, *Plate* II. *Fig.* 1.)—Within a camber-beam and rafters joggled in, whose weight lieth not chiefly in the middle, and may be so made, that, without hanging up the beam, the principals may discharge the weight; and how drips may be made to walk on.

"1. Camber-beam.
"2. Principals joggled into the camber-beam.
"3. The place where the principals are joggled in.
"4. Puncheons, or braces.
"5. Drips to walk on, and may be made with the less current, that the roof may be made the more pitch, for the strengthening thereof; and may be made higher or lower, according to the building and discretion of the architect.
"6. Battlement."

Figure 2.—"A flat roof with a crown-post, or king-piece."

Figure 3.—" *Of the hip roof.—Instructions to find the length and back of the hip, so as it may answer the side and the end of the perpendicular line of the gable end, the two skirts, the side of the roof in plano, or lying in ledgment with the hip and gable end, the diagonal and perpendicular lines being laid down proportional to any breadth or length, by which the most ingenious may serve himself, and an ordinary capacity (already acquainted with the use of the ruler and compass) may plainly demonstrate all the parts of a roof, whether square or bevel, above pitch or under pitch, by lines of proportion, as may appear in the Design following:—*

"Suppose the roof 20 feet broad, and in length 30, 40, or 50 feet, more or less. Let A B C D be the sides and ends of the said roof, one end to be hipped, the other a gable end; draw the lines A B C D the breadth and length of the roof; then draw the gable end A B E, whose sides or principal rafters being three-fourths of the breadth of the house, then draw the perpendicular line E F, the height of the gable end, which line is of general use to level the ridge of all roofs; and if the other end be hipped, as in the Design, D C O, then it serves to find the length of the hip, and the back of the hip, so that it may answer both sides and ends of the roof; always observing, that the middle of the breadth of the house is as I H; then draw the line K L N through the centre I, which will make right angles to the line E F H O, both in bevel and square houses. Then extend the line A B, on both sides to O, being the length of A E, or E B, the length of the principal rafters, or three-fourths of the breadth of the house

So will O N and O K make the length of the ridge I F; and K D and C N, the two skirts.

"*To find the length of the hip.*—Draw the diagonal line D I and I C, over which the hip is to hang when in its due place; then take the perpendicular line E F, and place it from the point I to P P, perpendicular to the diagonal or base lines D I and I C, at I; so is I P and I P, the pitch of the hip, equal to the gable end, E F: and when erected, will hang perpendicular to the point I; then take P D, the hypothenuse of the triangle D I P. and C P, the hypothenuse of the triangle C I P, placing them from D to G, and C to G gives the length of the hip D G C, and when laid to their pitch, will all meet perpendicular to the point I.

"*To find the back of the hip, so that it may answer both sides and ends of the roof, whether square or bevel.*—Lay the ruler from the point L to the point H, and from the point H to M, and mark where it cuts the diagonal lines D I and I C at Q Q; then set one foot of the compasses on the point Q, and extend the other foot to the hip lines D P and C P, at the nearest distance; with that, mark the point R upon the same diagonal lines; then draw the pricked lines L R H and H R M, which make the back of the hip for the two corners of that roof.

"This rule serves for all roofs, whether over or under pitch."

Figure 4.—"*Of roofs bevel at one end, and square at the other; the gable end square, and the bevel end hipped.*

"Suppose the breadth of the roof to be 20 feet, the length more on one side than on the other, as in the Design, A B C D, then draw the gable end, A E B, whose sides, from A to E, and from E to B, are three-fourths of the breadth of the house, or the length of the principal rafters; then draw the perpendicular, E F, the height of the roof from the floor; and, if kneed, then from the top of the knee, as in the design of a kneed rafter, before-going.

"The sides of the roof, which make the ridge G H I K, to be drawn as described in the foregoing design.

"Divide the breadth of the roof in two equal parts, as F L Q, then take the distance L N, which is the half breadth of the house, and make it parallel to C Q D, as M L M, and L will be the point whose perpendiculars, O T, will meet the principals, rafters, and hips."

"*To find the length of each hip, distinct one from the other.—Of the longest hips.*—Draw the diagonal line L C, and take the height of the gable end, E F, and place it perpendicular to L C, at O; so have you the height of the roof perpendicular from O L, equal to E F, the gable end; and the line O C will be the length of the hip-rafter, which will be equal to C H, the skirt for that side of the hip, and C P the side of that hip end.

"*To find the back of the longest hip*, C O.—Lay the ruler from the point M to Q, and mark where it cuts the diagonal line at R; then set the foot of the compasses at the point R, and extend the other foot till it touch the line C O at the nearest distance; then make it touch the diagonal line at S, then draw the lines M S Q, which is the back of the hip for that corner of the roof.

"*To find the shortest hip.*—Draw the diagonal L D, and take E F, the perpendicular of the gable end, as before, and place it from L to T, perpendicular to L D; then draw the line T D, which is the length of the hip for that corner, and is equal to the skirt, D I, and the side of that hip, D P, which, when erected, will meet with the other principals, perpendicular to the point L.

"*To find the back of the hip.*—Lay the ruler from the point Q to the point M, and mark where it cuts the diagonal line L D, at V: extend the compasses from the point V, to touch the line T D at the nearest distance, and carry that distance on the diagonal line to the point W; then draw the pricked lines M W Q, which will make the back of that hip fit for that bevel corner.

"And this rule serves for all bevel roofs, whether over or under pitch."

Figure 5.—"*Of a roof bevel at both ends, and broader at one end than the other.*

"A B C D. The length and breadth of the house.

"E F G. The length of the rafters, or pitch between the widest and narrowest ends, about the middle of the house, to stand over the pricked line T T, for the foot F to stand, on the one T, the foot G to stand on the other T.

"H H. The point of the two hip ends, when brought to their due place, will be perpendicular to P P, and will meet the sides I K, L M, over the points P P.

"O, O, O, O. The points of the perpendiculars, and length of the hips, from A B C D.

"Q, Q, Q, Q. The backs of the hips, or hip-mould to each corner.

"R, R, R, R. The points to find out Q, the point for each back.

"S S, S S. The lines representing half the breadth of the house, parallel to each end.

"T T. Representing the middle of the house.

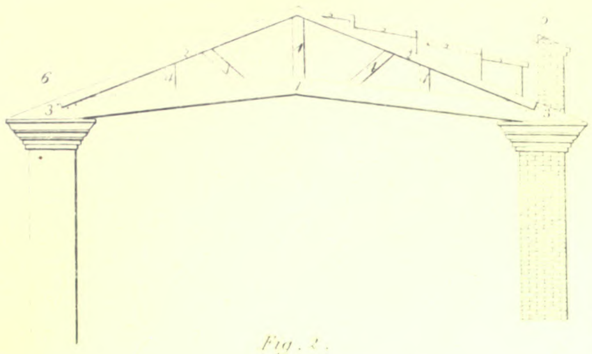
"Notwithstanding the bevel ends, you may place your beams for your principal rafters to stand on a square, or so near a square as may be, or between both, as from the ends of the pricked lines I K, L M, bringing the outside of them straight under P P, which will be more handsome for the house in the inside, although it bevels outward."

The foregoing descriptions and diagrams contain all that is said on carpentry by Godfrey Richards; we shall now add a few observations.

In the explanation of *Figure* I, *Plate* I., CARPENTRY, we have the names of the several timbers which constitute a floor, and the manner in which they are disposed. In this explanation, and the plan which accompanies it, we find girders, summers, and bressummers. The summer runs parallel to the front of the building; another piece of timber is placed in the front, parallel to, and in the same level with the summer; if the front timber terminate the apertures at their height, and the wall be of brick, this timber is called a *lintel;* but if the lower side of the timber do not terminate the windows, it is called a *wall-plate.* If the front wall is constructed of timber-work, then the level piece of timber in the floor, and in the front of the house, is called a *bressummer*, which in modern carpentry, when employed in the same office, still retains that name; and hence the term *bressummer* signifies a summer in the breast or front of the building. The use of the summer was to support the ends of the adjacent girders; and the bressummer was not only to support the end of the one girder, but to tie the front together. In the present construction of houses, summers are not employed. In old carpentry, the girders supporting the joisting were sustained at their ends by the summers and bressummers, lintels, or wall-plates. In modern carpentry, the girders are sustained by opposite walls, upon plates or lintels, and are still used over every extensive bearing to support the joisting.

In modern timber-buildings, and partitions, the same names are still used for the same things, as in old carpentry, wherever the things themselves are employed, except in a few instances, viz., the *interduces* are now called *interties;* the middle beam of the roof went by several names, as *collar-beam*, *strut-beam*, *wind-beam*, or *top-beam;* but of

Fig. 1.



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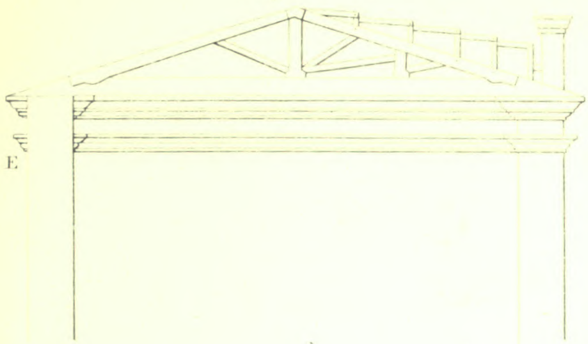

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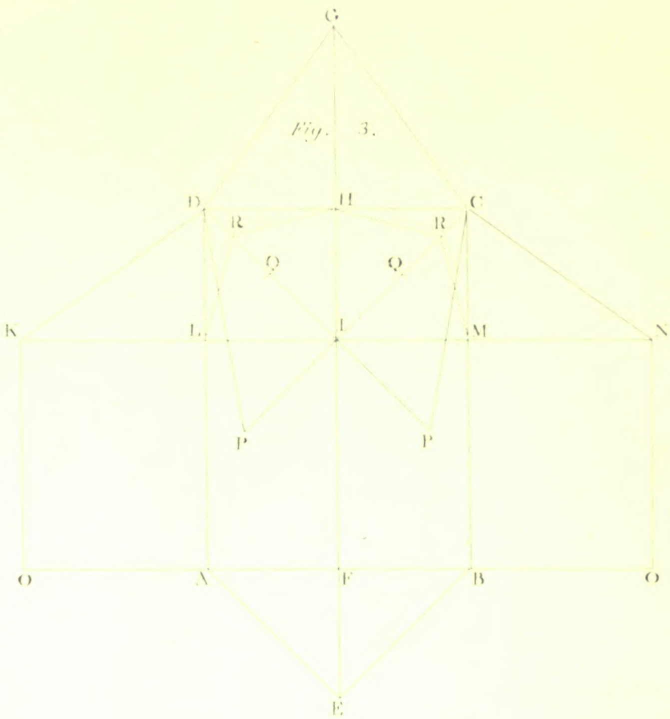

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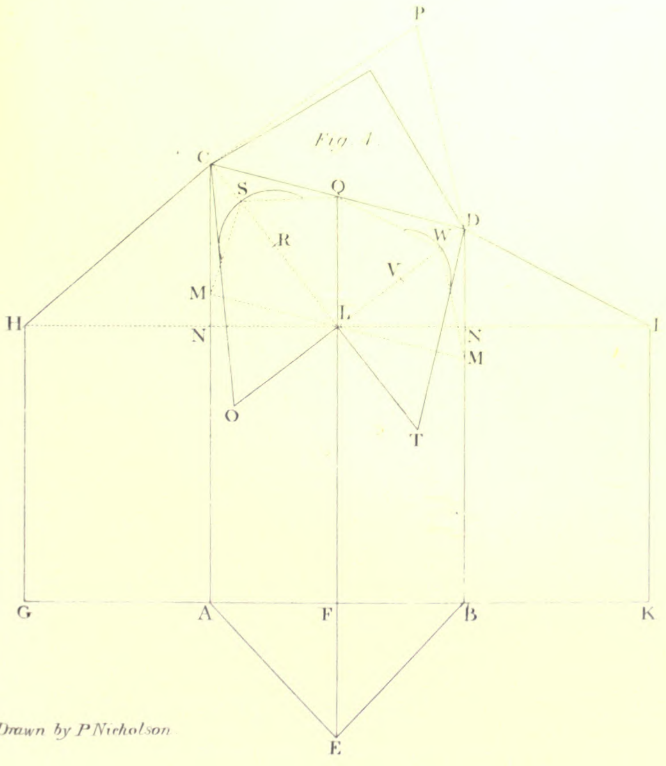

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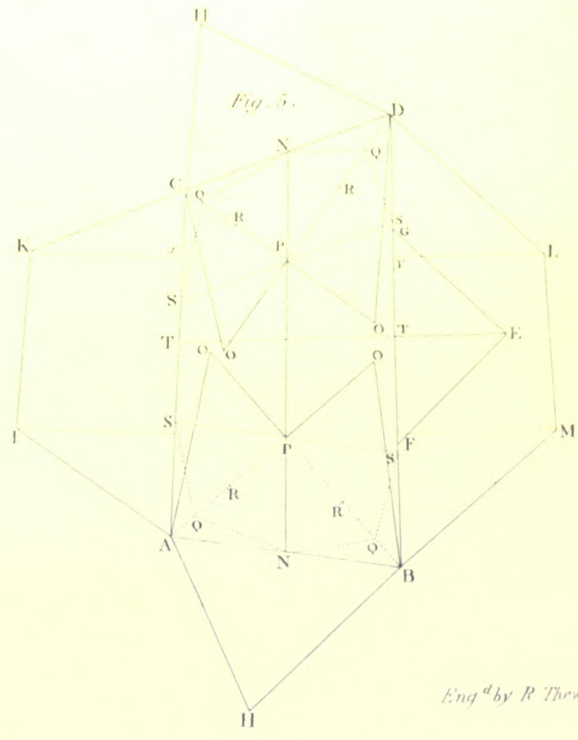


Drawn by P Nicholson

Eng^d by R Thew

these names, only that of *collar-beam* is retained. At present we have no *kneed-rafters*, therefore neither furrings nor shreddings are necessary as in *Figure* 2; the *prick-posts* are now called *jamb-posts, window*, or *door-posts;* the vertical timber hanging from the vertical angle of the roof, and supporting the principals, went formerly under the names of *king-piece, crown-post*, or *joggle-post;* but now it retains only the name of *king-post.* The nomenclature employed in London and its vicinity is here alluded to.

The timbers in the internal angles, at the meeting of the two inclined sides of a roof, were formerly called *sleepers*, but now they are termed *valley-pieces*, or *valley-rafters*, see *Figure* 3; in which may be seen also a method of finding the length of the hip, without making any plan of the roof.

Plate II. *Figures* 3, 4, 5, show the manner of finding the lengths and backs of the hips, as at present. The discovery of this principle is generously ascribed to Mr. Pope, of London, by the author now quoted.

Thus much for the work published by Godfrey Richards.

The carpentry published in Moxon's *Mechanical Exercises*, contains nothing more than the names and applications of timbers, which are the same as those described by Godfrey Richards.

In *The Art of Sound Building*, Mr. Halfpenny shows the methods of tracing the angle-brackets of coves, regular and irregular groins, the common ribs in each return being of one common height.

The following specimens will show what has been done by this author. He likewise shows how to find the arch for the aperture of a window, of a given width and height so as the angles may be in vertical planes, according to legitimate principles; but he does not, in any instance, show the method of beveling the edge of the angle-ribs, so as to range with ribs fixed in the returns.

Plate III. *Figure* 1. "*To find the angle or mitre-bracket of a cove.*—First, draw the base A B of the regular bracket, and from A draw A D, perpendicular and equal to it, and draw the line D B, and continue the line D A to C, so that A C be also equal to A B; then extending your compasses from A to B, and setting one foot in A, with the other describe the arch, or quarter of a circle C B, and from the point D draw D F, perpendicular to D B, and equal to D A, or A C, and another as B E from B, likewise equal to D A, and draw the line F E, which will be parallel to D B. This being done, divide A B into a number of equal parts, not exceeding two inches and a half, and through the divisions of them draw lines parallel to A C, to touch the arch C B, which continue out to the line D B, and this line will be divided likewise into the same number of equal parts as A B is. Lastly, from the divisions of the line D B, draw lines parallel to D F, and in each of them, from D B, lay off its respective parallel (from A B to the arch B C) and at the points whereat they end, stick small nails, or pins, and take a thin lath, and bend it round the nails, or pins, observing that it touches them all, and with a pencil, or anything else proper to make a mark, describe the arch F B round the edges of the lath; and this is the arch for the angle or mitre bracket."

Figure 2. "*If the lesser arch of an irregular groin be a given semicircle, it is required to form a larger one (not a semicircle) so that the intersection of those two arches shall beget, or make the arch-line of the angle to hang perpendicular over its base; as also to draw that arch-line of the angle.*—First, draw the lines A B and C D, to represent the walls from whence the arches spring, and draw the line C B, and on the line A C describe the semicircle A E C, and divide A C into any number of equal parts, from whence draw parallel lines to C D, to touch or come to the arch A E C, and if these parallels are continued out to the line C B, they will divide it into the same number of equal parts as A C is; and if from each of the divisions of this last line parallels to A C are drawn, they will divide the line A B into the same number of equal parts as A C, or C B, is divided into. This being done, continue A C to I, so that A I be equal to E *f*, and continue D B to K, so that K B be likewise equal to E *f*, or A I, and draw the line I K. Moreover, at the points C and B raise the perpendiculars C N and B O to C D, each of the same length as E *f*, or A I, or B K, and draw the line N O. Lastly, from the divisions of A B, draw parallels to A I (that is, continue the parallels drawn from the divisions of the line C B to the line I K) and from the divisions of C B parallels to C N. Then set off the heights or lengths of each of the parallels in the semicircle A E C, upon the correspondent parallels to A I and C N, and stick in nails whereat they terminate; and if a lath be bent round them, so as to touch them all, and a pencil be moved round the edge of it, the arches A H B and C M B will be found; which was required to be done.

"*Note.*—The pricked lines in this, and all other examples of this kind, show that one parallel line has a relation with the other. For example: the lines *f* E, *g* H, *l* M, are all equal to one another; so that if the three arches A H B, A E C, and C M B, were raised perpendicularly upon the lines A B, A C, and C B, and a line drawn from H to M, and another from M to E; then would the line M H be parallel to, and directly over the pricked line *l g*. In like manner, the line E M would be parallel to, and directly over the pricked line *f l*. Understand the same of the other parallels and pricked lines in this figure, and any others of the like nature."

Figure 3.—"*Having one centre given for an unequal-sided groin, to form the other, so that the intersection thereof shall produce the angle, or mitre-arch, to hang perpendicularly over its base; and, moreover, to draw the curve thereof.*—Draw the lines A B and B D, and D C and C A, each equal to one another, to represent the walls from whence the arches spring, and on the line A B describe the given arch A F B. This being done, divide the line A B into any number of equal parts, from whence raise perpendiculars to A B to touch the arch A F B, and draw the diagonal lines A D and B C. Then take the line E F, and set it perpendicular to the lines A C, A D, C D, C B, B D, from A to O, from A to I, from C to P, from C to S, from C to L, from D to K, from D to T, from D to V, and from B to M, and from B to Z, and draw the straight lines O P, I K, S T, L M, and V Z. Now divide the base lines B D, D C, C A, A D, and B C, each into the same number of equal parts as A B is divided into, and from the points of division draw parallel lines to touch the lines O P, S T, V Z, L M, and I K. Then take the lengths of the perpendiculars to A B, drawn to touch the given arch A F B, and set them off in the correspondent parallels drawn from the points of division of the several bases upwards, and the arches B *y* D, D *v* C, C *q* A, A *h* D, and C *n* B, will be described as in the foregoing examples (*Figures* 2 and 3) whose heights *x y*, *w v*, *r q*, *g h*, and *g n*, are each equal to E F, as likewise all the other correspondent heights, from the bases to the curves that are formed.

Figure 4.—"*The arch line of a large ceiling, or vault, supposed to be semicircular, being given: how to form the curve of a lesser arch, that shall intersect the side thereof, to give way for doors or windows, so that their intersection shall produce the groin to hang perpendicularly over its base; as also to form the curve-line thereof.*—First, draw the lines A B, B D, D C, and C A, to represent the walls from whence the arches spring, and describe the two given semicircular arches A O B, C L D, and in the line B D set off the span of the intersecting arch from *v* to *t*. This being done, set off the height you design to raise the lesser arch *v z t* from *g* in the line A B, perpendicularly to touch the arch in *h*, and from *v* to *r*, and *t* to *u*, and draw the line *r u*, which halve in the point *z*, and draw the line *z y*, parallel to *v r*, or *t u*. Then strain a line, or lay a straight rule from *h* through *g*, towards *x*; as also from *z* through *y*, towards *x*, and these two lines will cut one another at *x*, from whence to the points *v* and *t*, draw the lines *x v* and *x t*. Now set off *g h* perpendicular to *x t* from *x* to *w*, and from *t* to s, and draw the line s *w*, and divide *g* B into any number of equal parts at pleasure from the divisions of which, draw perpendiculars to *g* B, to touch the arch A O B between the points B and *h*, and divide *v y* and *y t*, the halves of the base *v t*, each into the same number of equal parts as *g* B, is divided into: as likewise the base *x t*, and from the points of division draw parallel lines to touch the lines *u r* and s *w*. This being done, take the lengths of the lines that were drawn from the points of division of *g* B, perpendicularly to touch the part B *h* of the arch A O B, and set them off in the correspondent parallels from *y v* to *z r*, and from *y t* to *z u*; as likewise from *x t* to *w* s. Then, if at the extent of each line, as you set it off in the parallels, you stick in nails, as in the foregoing examples, and bend a thin rule about them, you will describe the sought arches *v z t* and *w t*, whereof *v z t* is the true intersecting arch, and *w t* the curve line of the groin that is correspondent thereto.

"After the very same manner the arches *k m z* and *k p* are drawn."

In his explanations of the diagrams, he is tolerably intelligent; but he has departed from truth and reason in the two following problems:—

"*The arch of a round tower, or any other circular building, being given, wherein a semicircular window is to stand, how to find a centre, so that the mason or bricklayer shall twin their arches thereon without crippling them.* (See *Plate* III. *Figure* 5.)

"First, draw the arch A F B, from the centre E, to represent the arch line of the wall, and set the width of the window from D to C, which halve at H, and draw the line L M, which halve at N; from whence describe the semicircle L O M. This being done, divide the semi-diameter L N into any number of equal parts, from the division of which, draw parallel lines to O N, the arch of the quadrant, which parallels continue out to divide the arch F C into the same number of parts as L N is; and from the points of division in the arch F C draw perpendiculars to the parallels, each equal in length to the correspondent parallel of the quadrant L O; and from the points of the divisions of the line H C (made by continuing out of each of the aforesaid parallels) draw right lines to the extreme points of the aforesaid perpendiculars, as from G to H. This being done, if the line G H be laid off in the parallel O N, continued out from H to I, and the rest of these lines last drawn be laid off in the respective continuations of the parallels, the extreme points of these lines being joined, will form the curve C I; which, when set in its due position, will hang perpendicular over the arch C F, having its points coinciding with the extremities of the perpendiculars drawn from the extremities of the perpendiculars drawn from the divisions of the arch C F."

Figure 6.—"*The centre whereon the arch of a bow-window is turned being given, how to find another centre that shall answer parallel to it, according to the upper edge of the surface of the arch.*—First, describe the arch B K C, according to the directions laid down in the last problem, and set the width of the flat surface of the arch from B to A, and from C to D; and draw the lines A D, B C, and halve them at F and E, from whence draw a perpendicular of a length at pleasure to H. Then in any convenient place (*Figure* 6, No. 2) draw a line at pleasure, as from A to G, and from A draw to A G the perpendicular A F. Then take E I, in No. 1, and set it from A to B, No. 2, and F I from A to C. This being done, take the semi-diameter B E, or E C, No. 1, and set it from A to D, No. 2. Also, take A B, or C D, and set it from D to E, and draw the line E C, which set in the line E H, from F to *g*. Again, take the width of the flat surface of the arch A B, or C D, and set it in the line E H, from K to 7, and divide the remainder from 7 to *g*, into seven equal parts. Also, divide the arch B K, into seven equal parts. Then take K 1, in the line E H, between your compasses, and setting one foot in 1, with the other strike the arch 1 at pleasure: then take K 2, and strike the arch 2: also take K 3, K 4, K 5, and K 6, severally, and strike the arches 3, 4, 5, and 6. When this is done, open your compasses, and divide from A to *g*, keeping the points of them on those arches, till you have gotten seven equal distances from A to *g*; at the points of which, if nails be stuck in, and a thin rule be bent round them from A to *g* along the edge thereof the arch A *g* may be drawn. And in like manner may the arch D *g* be drawn."

This description is so far intelligible, that we perfectly understand his geometrical process; but it is so void of truth, that no geometrical reasoning can be applied, unless it were to prove the contrary of his assertion: the arch which would be required to stand perpendicularly over such a plan upon a semicircular centre, would not be in the same plane, which is the case with the one he has found, and asserted to be right.

In the construction of the ribs of niches for plastering, he is extremely obscure, and takes only the most common and easy cases; such as might occur to every one, even to those who are not much in the habit of thinking, as the reader will observe in the following quotations:—

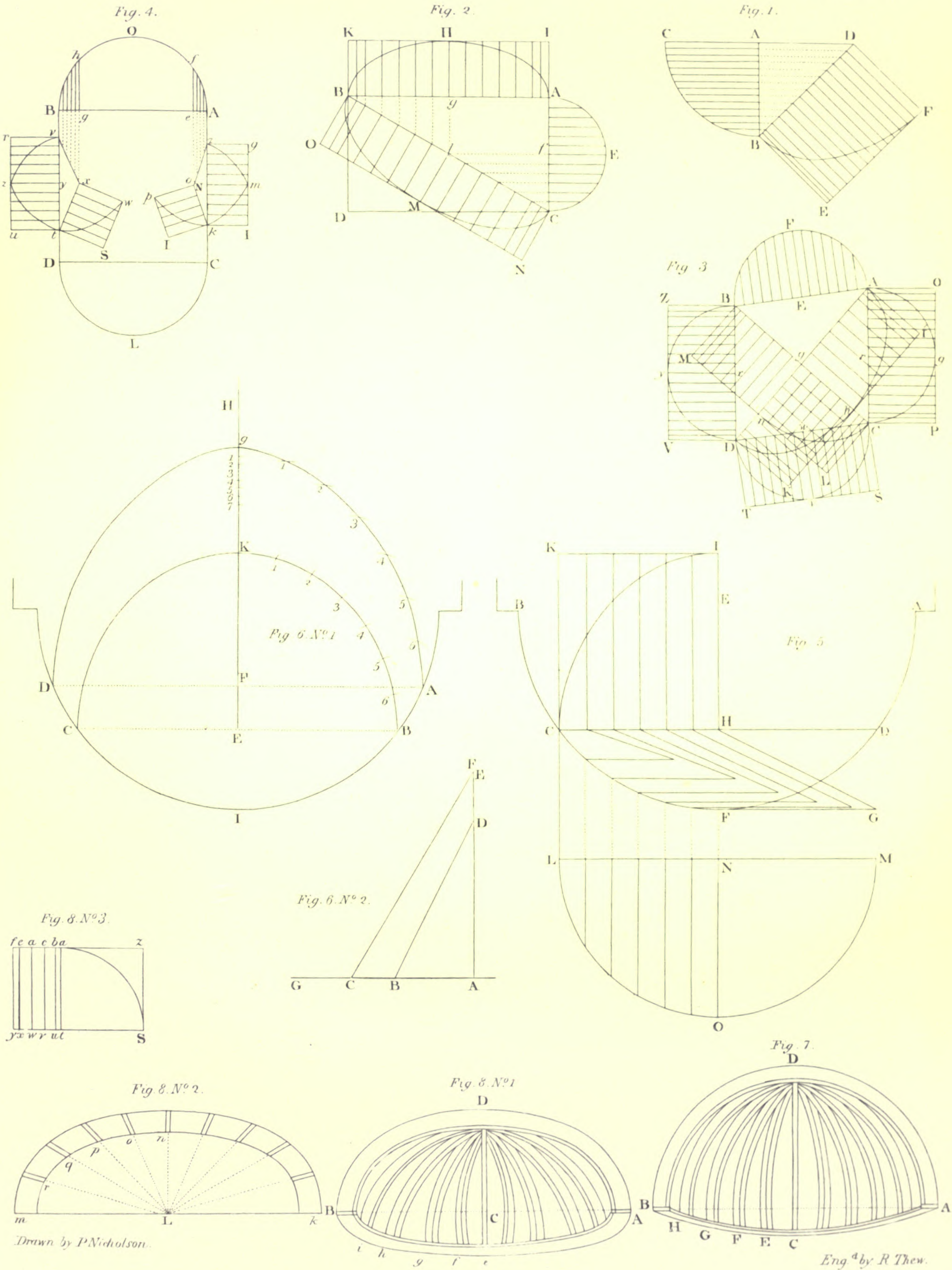
Figure 7.—"*How to form a semicircular niche with ribs, as is usual when it is to be plastered.*—First, describe the semicircular plate A C B, as also the semicircular front rib A D B, equal to it, and fix the plate A C B level in the place where it is to continue, and upon it set the front rib A D B perpendicular on A B. This being done, describe the quadrantal ribs D C, D E, D F, D G, and D H, each equal to A D or B D, and place them about 8½ inches from one another, on the plate A C B, as at C, E, F, G, and H, so as to meet in one point, at D, on the crown of the front rib A D B; and thus is one half of the work finished. And after the same manner may the other be done."

Figure 8.—"*How to form an elliptical niche, with ribs for plastering.*—First, describe *Figure* 8, No. 1 and 2, *k n m* being a semi-ellipsis, representing the plates whereon the ribs stand, and being equal to A D B, or A *e* B. The pricked lines L *n*, L *o*, L *p*, L *q*, L *r*, and L *m*, represent the base lines of the ribs *e* D, *f* D, *g* D, *h* D, *i* D, and B D; so likewise do the lines S *t*, S *u*, S *v*, S *w*, S *x*, and S *y*; and the perpendiculars *a t*, *b u*, *c v*, *d w*, *e x*, and *f y*, do represent the rising of the ribs *e* D, *f* D, *g* D, *h* D, *i* D, and *b* D, which is equal in length to C D; observing that within those lines the different arch of each rib is to be described, viz., the arch S *a* is a quadrant of a circle, having *t* for its centre, and is equal to the arch of the rib *e* D:—The lines S *u*, S *z*, equal to *z b*, *b u*, are the semi-transverse and conjugate axes of a semi-ellipsis, whose arch S *b*, is equal to the arch of the rib *f* D, which may be struck either with a trammel, or by the intersection of lines. Moreover, the lines S *z*, S *v*, equal to *v c*, *c z*, are the semi-transverse and conjugate axes of a semi-ellipsis, whose arch is equal to the arch of the rib *g* D; and so of the rest.

"Now, having the ribs all ready, set the front rib, A D B perpendicular on the plate A *e* B, as at A B, and fix the feet of the short ribs on the plate A *e* B, as at *e*, *f*, *g*, *h*, *i*, which correspond with the points *n*, *o*, *p*, *q*, *r*, and their points

CARPENTRY.

PLATE III.



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a, *b*, *c*, *d*, *e*, to the crown of the front rib at D; and thus may you finish your work."

We now proceed to Smith's *Carpenter's Companion*, and though he presents nothing new in geometrical principles, his observations are very judicious and worthy of transcription; and his practical remarks, though perhaps objectionable in a few instances, are more to the purpose of a general connected detail of what should be done in the constructive part of carpentry, and more systematic, than those of most other writers; though the examples and designs which he shows are not generally the best. He begins his introduction thus:

"The usefulness of carpenter's work in building, and the little notice taken of it by authors who have treated of architecture, and the few there be that rightly understand it, prompted me to write the following treatise.

"Carpenter's work is one of the most valuable branches of architecture; it was contemporary with the first ages of the world; and with the knowledge of this art, Noah closely and firmly connected those timbers in the ark, which were so nicely wrought, that they not only kept the water from penetrating into it, but were proof against the tempest and the rolling billows, when, in its womb, it carried all the tenants of the earth and air.

"Those naval preparations, through all ages of the world, as well as those stupendous temples and edifices, erected in all countries, demonstrate the perfection of this art. The innumerable *floating buildings*, which roll from one country to another, through tempestuous storms, tossed from the mountain's height to the depths of the ocean, without injuring the vessel, evidently show the vast use and judgment of carpenter's work.

"But as that branch of it which relates to *templar* or *domal* uses, is the subject of this work, I shall only treat of its usefulness in them; and may venture to affirm that carpenter's work is the chief tie and connection of a building, supplying the ligaments which bind the walls together.

"The bond-timbers, which strengthen and tie the angles of a building, and prevent its separating, is the work of the carpenter. Linteling over doors and windows, with other dischargements of weight, it is his care to perform.

"Bond timbers in cross walls, when settlements happen, if they are well applied, prevent the cracking of the walls, for they keep the whole together, and every part settleth alike, which would fill the buildings with gaps and chasms if neglected.

"Next for the floors; the rightly framing them, by trussing the girders, by placing them on joists, so that they come near no funnels of chimneys; the manner of tenanting, tusking, framing of timbers for chimneys, stairs, &c. I say, all these it is the business of the carpenter to see carefully performed.

"Partitions of timber, their manner of trussing to prevent cracking, settlements, &c., and the discharge of weight of girders, beams, or cross walls, is carpenter's work; as is, likewise, the framing of timber bridges.

"Roofs of various sorts, for common houses, large edifices, or churches, their manner of framing, the height of their pitch, their strength, usefulness, &c., with the various manner of performing all these works, is the subject of this treatise, which I have rendered intelligible to every capacity, by designs of several sorts, and have described them in such a manner, as will render the work useful to carpenters; particularly to those who are unacquainted with the manner of performing these operations of framing.

"The first thing which the carpenter must consider, for the carrying on a building, is the plan, in which you are to prepare your timber, in having it cut into proper scantlings, which shall be hereafter noted.

"You are to prepare for lintelings and bond-timbers; for lintels over doors or windows, stuff of five inches thick and seven broad, and it is a slight way of building to put in any of less scantling; as for door-cases their manner of making, and scantlings of stuff, it is needless to speak of; it is the best way to have them put in when the foundations are brought up high enough for them. Bond-timbers should be dovetailed at the angles of the building and cross walls. And here note, that it is a durable, though expensive way, to have all fir timber, which is laid in the walls of the building, to be pitched with pitch and grease mixed together; the quantity of grease, one pound to four pounds of pitch. All these things are the care of the carpenter.

"Bond-timbers should be four or five inches thick for cross walls, and in the angles of a building, six or seven inches, and proportionably broad; six or eight feet long in each wall; and it would not be amiss to place them six or eight feet distant all the height of the building, in every angle and cross wall; these, if a building be on an infirm foundation, cause the whole to settle together, and prevent the cracks and fractures which happen, if this be neglected.

"We come now to the floors, in which these things are to be observed—the magnitude of the room, the manner of framing, and the scantlings of the timber. For the first, you are to observe to lay the girders always the shortest way, and not to have a joist at any time exceeding twelve feet in length.

"The first common method of framing floors, is where the joists are framed flush with the top of the girder." (*The trimming-joists supposed to come against chimneys and stairs, are always thicker than common joists, being weakened by mortising.*) "The scantling of joists, when a floor is framed in this manner, ought to be as followeth:

Common Joists.		Trimmers.	
ft. long.	Scantling in inches.	ft. long.	Scantling in inches.
5	7 by 2¼	5	7 by 3
6	7 by 2½	6	7 by 4
8	7 by 2¾	7	7 by 5
9	8 by 3	8	8 by 4
10	8 by 3¼	9	8 by 5
11	8 by 3½	10	9 by 6
12	9 by 4		

"These are such proportions as will render the work sufficiently capable of sustaining any common weight.

"The next manner of framing floors is with binding-joists framed flush with the under side of the girder; and about three or four inches below the top of the girder, to receive the bridgings, which are those which lie across the binding-joists, and are pinned down to them with pins of wood, or spikes of iron. These binding-joists should be framed about three feet, or three feet six inches distant from one another, and their thickness four or five inches, or in the proportion to the length of their bearing, as trimming-joists.

"These floors, if they settle out of a level with the building, are made level when the bridgings are put in, which is generally after the building is covered in, and near completed; they are generally double-tenanted. The binding-joists are chased, and the ceiling-joists tenanted into them, and put in generally after the building is up. These ceiling-joists should be 13 or 14 inches apart, and the scantling 2 or 3 inches square, and in large buildings 3 and 4. As for the bridgings, which lie on the top of the binding-joists, they may be placed 12 or 14 inches distant, their scantling 3 and 4, or $3\frac{1}{2}$ and 5, their bearing being only from binding-joist to joist, which is 3 feet, or 3 feet six inches, and these are laid even with the top of the girder, to receive the boarding. We come now to speak of girders; and first, for their scantling, take these proportions:

ft. long.	Scantling in inches.		
	B.		D.
10	8	by	10
12	$8\frac{1}{2}$	by	10
14	9	by	$10\frac{1}{2}$
16	$9\frac{1}{2}$	by	$10\frac{1}{2}$
18	10	by	11
20	11	by	12
22	$11\frac{1}{2}$	by	13
24	12	by	14

"And observe, that as every weight, added to the weight of the timber in the floor, in itself occasions it to settle, the girders should be cut camber; if a 10 feet bearing, half an inch camber; if 20 feet bearing, an inch camber, &c., in proportion to the length of the bearing.

"And farther to strengthen the girder, and prevent its sagging, as it is called among workmen, that is, its bending downwards, I have given you several ways of trussing girders, which have been most of them practised.

"The manner of trussing these girders, is, first, to saw the girder down the middle, the deepest way; then take two pieces of dry oak, about $4\frac{1}{2}$ or five inches wide, and 4 inches thick; let half the piece be let into one side of the girder and half into the other.

"Another way, which is by cutting the girder through, and driving a wedge against the ends of the trusses. When these are thus prepared, bolt them together with iron bolts and keys; or much rather, a screw at the end of the bolt.

"Some carpenters cut their girders down the middle, and bolt them together, without trussing, only changing the ends different from what they grew, whereby the grain of the wood is crossed, and it becomes much stronger than if it had continued without sawing down the middle, and thus putting it together.

"Some, in trussing girders, make use of other trusses.

"The girder being thus trussed and put together, proceed in framing the joists, as in common floors. The strongest way being double-tenanting and tusking, as is shown in the binding-joists. Before I leave this part of floors, I shall observe to you, that the best and most workmanlike manner of framing floors, is to plane the upper edge of your joists straight; for the straighter and truer your joists lie, the truer your boarding will lie, which is a great ornament to a magnificent room; but if you frame without binding-joists, and lay on bridgings, plane the bridgings and lay them very straight and level; this care taken will save a great deal of trouble in laying down the boarding, which you are often forced to cl ip and fur up, to make them lie even, and those furrings are not only troublesome, but are apt to give way, and occasion the creaking of the boards as you walk on them. It would be a good way to turn arches of brick over the ends of the girders of the floors, because if any alteration happens, they are easily taken out.

"I come now to partitions of timber, with their manner of framing. Timber partitions have these properties attending them: they take up less room, and are cheaper than those of brick.

"As to roofs, there is a plate to go round a building, which may or may not be deemed a part of the roof; it may be deemed the foundation and tie of the roof and walls; or it may be taken as only that on which the roof lieth. These plates are to be dovetailed at the angles, and tenanted together in their length, several ways. The beams of the roof, which serve as girders to the ceiling-floors, (and into which all the principal rafters of the roof are tenanted,) are dovetailed, or what by workmen is termed *cogged* down, to the plate, which prevents its flying out from the foot of the rafter, whose butment is against it; and in the angles of a building, pieces dovetailed across the angles of the plate, serve to keep it from spreading, and is the foot of the hip.

"The common pitch of roofs is to have the rafter's length, if it span the building at once, to be three-fourths of the breadth of the building. Some make them flatter, as a pediment pitch; and the old Gothic way was to make them the whole breadth.

"The common pitch is not only unpleasing to the eye, but is attended with this inconvenience; if there is a gutter round the building, the steepness of the roof occasions the rain to come with so sudden a velocity into the pipes which are to convey the waters from the gutters, that they fill the gutter; and sometimes so fast, that the water runneth over the covering of the roof, and does great injury to the timber, &c., of the building: and the steeper the roof is, the longer the rafters, and the greater quantity of timber must be used in the roof, as well as the more weight from the great quantity of timber and the weakening the principal timbers, by adding more to its own weight.

"And the pediment pitch is inconvenient, in lying too flat, for those climates so frequently subject to rain, and heavy snows, which last would press and vastly incommode the building, and would lie much longer on the roof, its declivity being so small; besides, in keen winds, attended with rain, the rain would drive in under the covering of slate or tiles, and create much decay in the timber.

"Proportion of beams whose bearing varieth; take the following rule:

Length of Beam in feet.	Scantling in inches.		
12	6	by	8
16	$6\frac{1}{2}$	by	$8\frac{1}{2}$
20	$6\frac{1}{2}$	by	9
24	7	by	$9\frac{1}{2}$
28	$7\frac{1}{2}$	by	$9\frac{1}{2}$
32	8	by	10
36	$8\frac{1}{2}$	by	$10\frac{1}{2}$
40	$8\frac{1}{2}$	by	11
44	9	by	12

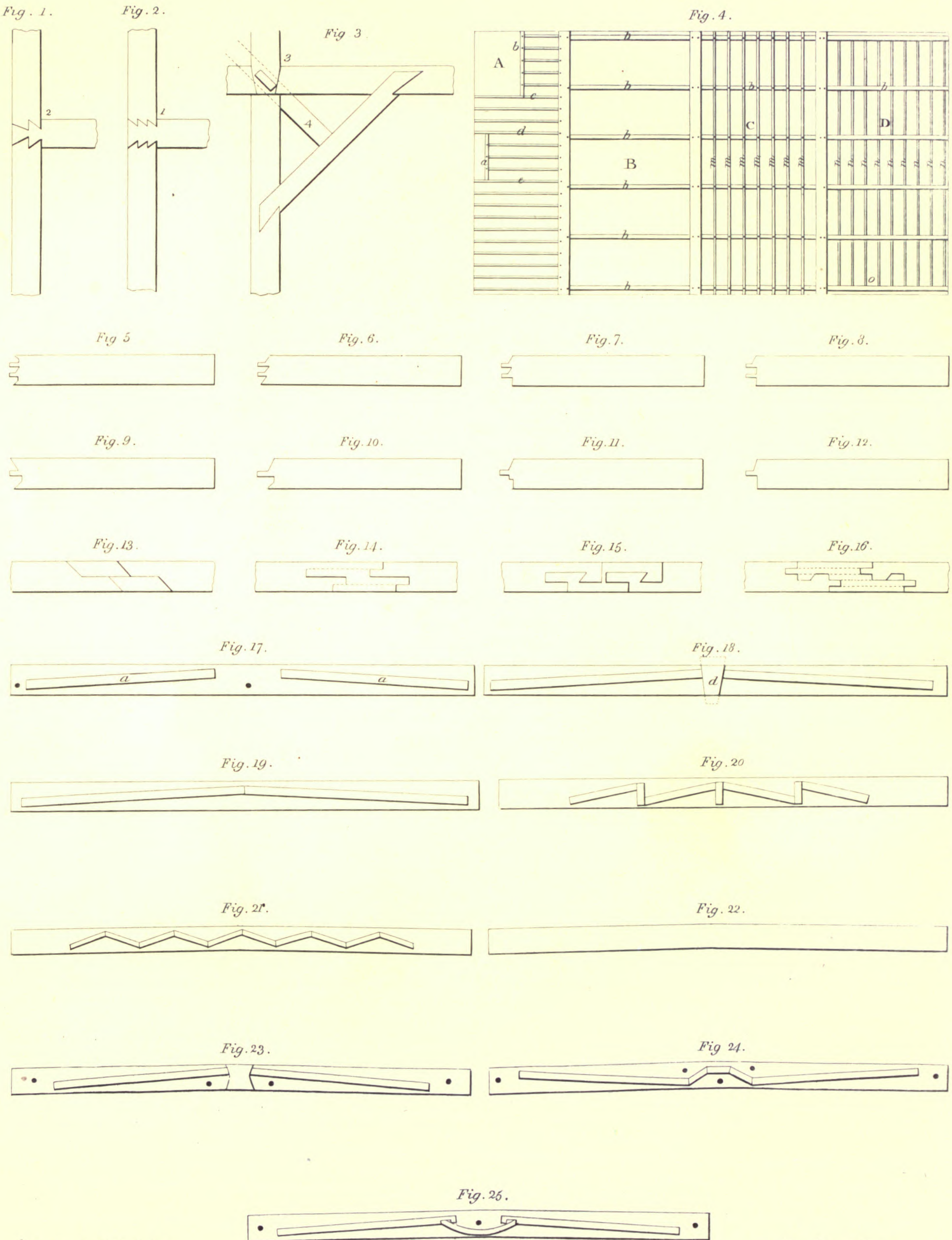
"The principal rafter should be nearly as thick at the bottom as the beam, and diminish in its length one-fifth or one-sixth of its breadth; the king-posts should be as thick as the top of the principal rafter, and the breadth according to the bigness of the struts you intend to let into them, the middle part being left something broader than the thickness.

"Struts may diminish, as the rafters do, one-fifth or one-sixth of their length. In placing struts and collar-beams, the dividing the rafter into as many equal parts as you propose bearings, is the rule, because every part of the principal will have its equal distant bearings.

"Purlins are of the same thickness as the principal rafter, and the proportion of the breadth is six to eight; that is, if the rafter be six inches thick, let the purlins be six inches thick, and eight inches broad; if it be nine inches thick, the breadth of the purlins is twelve inches broad, &c.

CARPENTRY.

PLATE IV.



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"N.B. The purlins are those pieces into which the small rafters are tenanted, and they are tenanted into the principal rafter. Length of purlins is generally from six to eleven feet, not exceeding that length.

"Small rafters: their scantlings two inches and a half, and four inches; three inches, and four inches and a half; and three inches and a half, and five inches; according to the magnitude of the roof and length of the rafters. Small rafters should not exceed seven feet in length in a purlined roof; if it happen that the length of the principal be above fifteen feet, it is best to put in two tier of purlins in the length of the rafter."

In respect to the construction of roofs for coves, he has the following observations: "The use of coving a room of considerable height, is, first, the making of it much lighter than it would otherwise be, if level in the ceiling; the rays of light in a cove are reflected back again into the room, which would be otherwise lost and confused in a roof with a flat ceiling.

"Likewise, all rooms with circular roofs or ceilings are more commodious and useful for entertainment, for music, &c. The angles of incidence are always equal to those of reflection; so the undulation of sounds flying on any cove or spherical part of a building, reverberate on the audience; and if spherical, no part of the sphere can receive the vibration, but it will return in the same direction from whence the undulation first began. The reflecting rays of light, and the reverberation of sounds, proceed from the same cause, and from incidents naturally affecting the eye and the ear."

It may be proper here to state, that though the reflection of sound is analagous to that of the rays of light, the laws and modifications by which sound is propagated to the ear, are less perfectly understood: it may, however, be observed, that in vaulted apartments, it is necessary to reduce the pitch of the voice, and to speak slowly and distinctly. The best writers recommend the ceilings of theatres to be arched, as has been practised in some of the most distinguished edifices of this kind in Europe.

This author likewise gives the method of finding the length of hips, both with and without a plan, as shown by Godfrey Richards, at the end of his *Translation of the First Book of Palladio.*

The work of Mr. Smith contains, in all, thirty-three plates of carpentry, arranged in the same order as he has treated the subject. Of these, twenty are plates of roofs, some of which are tolerably good examples, and at the end are five plates of timber bridges. His methods of joining-work are shown in the following descriptions and their corresponding diagrams.

Plate IV. shows his method of cocking beams down upon the wall-plates; Figure 1, by two dovetails, and Figure 2, by three dovetails. Dovetailing is a very bad method at the best; for, when the taper is small, the shrinking of the timber allows the beam to be drawn out of the socket in proportion to the quantity to which it is reduced in its breadth. The fewer the number of dovetails in the breadth, the weaker will the end of the beam be, or otherwise they must hvae less taper; and if the number of dovetails are increased, the parts of them formed on the end of the beam will be apt to split off. But, in modern Carpentry, the beam can never be drawn from the wall-plate, as the abutting parts are in a plane perpendicular to the length of the beams.

Figure 3, shows his method of framing wall-plates at the angles, with the diagonal and dragon pieces, where all the timbers appear to be let in flush with each other. This mode is much inferior to the present practice, where both the angle-tie and dragon-piece are fixed above the plates, which position not only allows a much firmer hold one to another, but also a much better support for the hip-rafter to stand upon.

Figure 4, represents four different methods, shown by him, for naked flooring. "The first method of framing is that marked A, where the joists are framed flush with the top of the girder; the two cross joists, marked *a* and *b*, are called *trimming-joists;* that marked *a* is supposed to come against a chimney; that marked *b* is the stairs." Here he shows that the joists *a* and *b*, should be thicker than the common joists, because of the mortising; but with equal reason he should have allowed the joists *c*, *d*, *e*, into which the joists *a* and *b* are framed, to have also been stronger; for one mortise in the middle of a beam will weaken the beam as much as if it had been cut full of mortises. He gives no name to the joists *c*, *d*, *e*, which should have been named, in order to transfer the idea from one to another, without circumlocution, or having recourse to description. His next manner of framing floors is that shown at B. "The six joists marked *b* are the binding-joists framed flush with the under side of the girder, and about three or four inches below the top of the girder, to receive the bridgings, which are those marked *m* in the floor, and which lie across the binding-joists," at C. In the other compartment, D, are shown the ceiling-joists, *n*, the bridgings being supposed to be removed for the purpose of showing them.

Figures 5, 6, 7, 8, he says, show the manner of tenoning the binding-joists, the tenons being generally made double.

Figures 9, 10, 11, 12, he observes, are common tenoning, which seems to imply a less sufficient method than the former. These last four examples, with the single tenons on the end of each, are much to be preferred to the double ones on the ends of Figures 5, 6, 7, 8, which are not only difficult to execute, but are calculated to weaken the mortised piece, which is to receive them, by the slanting shoulders of the tenons; his observation is the very reverse of what is now asserted, as he observes, in page 17 of his work, "the strongest way being double tenanting and tusking, as is shown in the binding-joists."

Figures 13, 14, 15, and 16, are exhibited in the third plate of his work, but he does not describe them; we suppose them to show the method of lengthening beams. The two methods, Figures 15 and 16, are extravagant ideas, being not only difficult to execute, but weak as a tie, and incapable of making a sufficient resistance to a longitudinal strain.

Figures 17, 18, 19, 20, 21, 22, 23, 24, 25, are various methods which he shows for trussing girders. He observes, that the trussing pieces or cores are let half into each flitch, and the scantlings of these pieces to be about 4½ or 5 inches wide, and 4 inches thick. Figure 18, he says, "is another way, which is by cutting the girder through, and driving a wedge against the ends of the trusses, as the wedge *d;* when these are thus prepared, bolt them together with iron bolts and keys, or, much rather, a screw at the end of the bolt." This method, though not the best, is certainly a tolerable approximation to what may be called good. He does not mention how the pieces *a*, *a*, are to be tightened in Figure 17. He observes, that "some in trussing girders, make use of other trusses," as in Figures 20 and 21. These hardly deserve comment, being the weakest forms that can be conceived. The trussed girders, represented by Figures 24 and 25, he claims as his invention, with one inverted arch, which he proposes to be of iron. Nothing could be more unmeaning than these examples.

The observation which he makes in respect to Figure 24, is void of principle, and contrary to mechanical strength;

his words are, "The upper arched one I take to be of great strength, though the trusses are inverted; for the pressure being upon an arch whose butment is good, I think a great weight can no way occasion the bending of the girder."

We come now to the *British Carpenter*. Though Mr. Price's order of treating his work is not so regular as the method adopted by Smith, his descriptions and observations are very correct; and, with the exception of a few references, there is hardly anything wrong.

This author begins with the scarfing of beams, as represented in *Plate* V. of our Work, Figures 1, 2, 3. 4, 5. 6. He says that the methods shown by the diagrams 3, 4, 5, 6, are the strongest; perhaps in consequence of their being tabled into one another; and that represented by Figure 6, has this property, that the pieces may be put together without any waste at the ends; he observes, that it is not his intention to limit the lengths of these scarfings, but only to show the manner of tabling the pieces together: he might also have said, that though nothing determinate with regard to the lengths of scarfings could be done, the greater the extent of the joint in the direction of the fibres of the beam. the more will it be disposed to resist separation, though there will be a greater waste of timber. Those represented by Price are much superior to those in Smith's work.

He then describes the method of trussing girders of greater extent than 24 feet, as we have shown in Figures 7 and 8; and proposes that the pieces which are to constitute the core be made of good dry straight-grained English oak, 4 inches by 3. or 6 by 4, as the strength may require, and let half into each piece; the pieces of the core being inserted in the one half, so as to abut firmly at the ends, and the two flitches put together so that the internal braces may abut firmly at the ends of the other flitch, and then bolted together, will complete the girder; he prefers that of Figure 8, to Figure 7, as being divided into three parts, it raises the pitch of the braces, and though the middle part is left untrussed, it may be looked upon as an inflexible solid, as the proportion of the breadth to the length is reduced much nearer to a ratio of equality than the dimensions of the whole beam, the depth being the same in both cases. The flitches, he observes, may be mortised through at the lower end of each truss, and the core tightened by wedges driven therein. Girders constructed in the manner of these two examples are much better calculated to perform their office, than those before given by Smith, which are void of every principle of mechanical science.

This author then speaks of the method taught by Alberti, as follows:—"Take two pieces or flitches, being well dried, and turn the but end of the one to the top end of the other, without trussing at all, and bolt or screw them together."

Mr. Price then proceeds to the various joints in roofing, as in Figure 9, which represents the junctions of the struts and principals with a king-post.

Figure 10, is another mode, which he uses where the breadth of the bottom of the truss-post will not allow a right-angled abutment to the direction of the strut: he makes the angle on the end of the tenon, with good reason, equal to the angle made by the shoulder, but on the contrary side, so that the two abutments may contract each other's efforts in moving the strut up or down on the side of the said post.

Figure 11, represents his method of forming the end of the tie-beam and lower end of the principal, so as to form a joint with double mortise and tenon, which, he says, presents greater resistance than when made with single mortise and tenon.

Figure 12.—No. 1 and 2, show the proportion which the mortise or tenon ought to have to the breadth of the stuff, either for the joints of roofs or truss partitions, by making the tenon or the mortise one-fourth of the breadth of the whole, and keeping the mortise and tenon in the middle.

Figure 13. No. 1 and 2, another mode for the same purpose, not much in request at the present time.

Figure 14. No. 1 and 2, the manner of joining the binding-joists and girders in floors, the same as used in the present time, with a tusk or sloping shoulder, and the double resistance or butment.

Figure 15. "No. 1 is called a *bridging-floor*, as being framed with a binding or strong joist in every three or four feet distance, and flush to the bottom of the girder, so that when the house is covered in, you pin down your bridgings thereon, and flush with the top of your girder; and this is the best way of carcase-flooring." The section of this floor taken transversely across the binding-joists is shown at No. 2, Figure 15. Mr. Price observes, that the best way to lay girders, "is not to lay them over doors or windows, nor too near chimneys; and, at the same time, to have the boards lie all one way;" and hence the oblique position of the girder, as here represented, is occasioned by the fireplace.

Figure 16. No. 1, a carcase-floor with single joists, or without bridging-joists. These are framed flush with the top of the girder, "and have every third or fourth joist the depth of the girder. and those between more shallow." No. 2 shows the ends of the joists, and the ceiling-joists framed into the deep joists. No. 3, the sides of the deep joists, with the pulley-mortises, in order to receive the ceiling-joists.

Mr. Price then proceeds to lay down the sides of roofs in plano, and shows the backings of the hips in the same manner as has been detailed by Godfrey Richards in the former part of this article, according to Pope's principle.

We shall here transcribe one of his examples, in which he attempts to show, for the first time, a method for finding the joints of purlins upon hip-rafters: his process, which is as follows, is tedious; his diagram and explanation are both obscure and defective, but show some novelty of form and geometrical skill in lines.

"Admit the plan (Plate VI., Figure 1, No. 1) was required to be enclosed with a hipped roof: first, find the middle of it, as *f*; then draw the bases of your several hips, as *a f*, *b f*, *c f*, *d f*, and *e f*; resolve on some pitch or height, as in No. 2, at *f g*; to this section bring all the bases of your respective hips, as the letters of reference show; this gives you the length of each respective hip; therefore, from the section No. 2, you describe the skirts round the plan No. 1, as *a b g*, *b c g*, *c d g*, *d e g*, and *e a g*, which form the roof required.

"To find the back of any hip, do thus: Draw a line at pleasure, crossing the base of the hips at right angles, as the line *h i*, which crosses the base of the hip *c f*; observe where it passes through the sides of the plan; on the base line of this hip, raise its section from No. 1, as *c g f*; lastly, place one foot of your compasses in the intersection, as at *y*; open the other foot, till it touch the hip *c g* at its nearest distance; draw a small section till it cross the base, as at *k*; so is *h k k i* the back of that hip; *and is the most exact, and easiest method that ever was delivered for this purpose;* the shadowed part, o, is the section of the supposed timber the hip is shaped out of, being cut off at right angles with its side and back. What is said of this explains the hip *a f*, whose back is *l m n*, and its section P is shaped so as to have the purlin come square against it; the letters of reference show the rest."

"*To find the side joint of a purlin* (*in case the hip be not shaped as above*) *so as to cut it by a templet, supposing there be no room, or occasion to frame it into the hip.*—For example, take any two hips from the plan No. 1, as *e f* and

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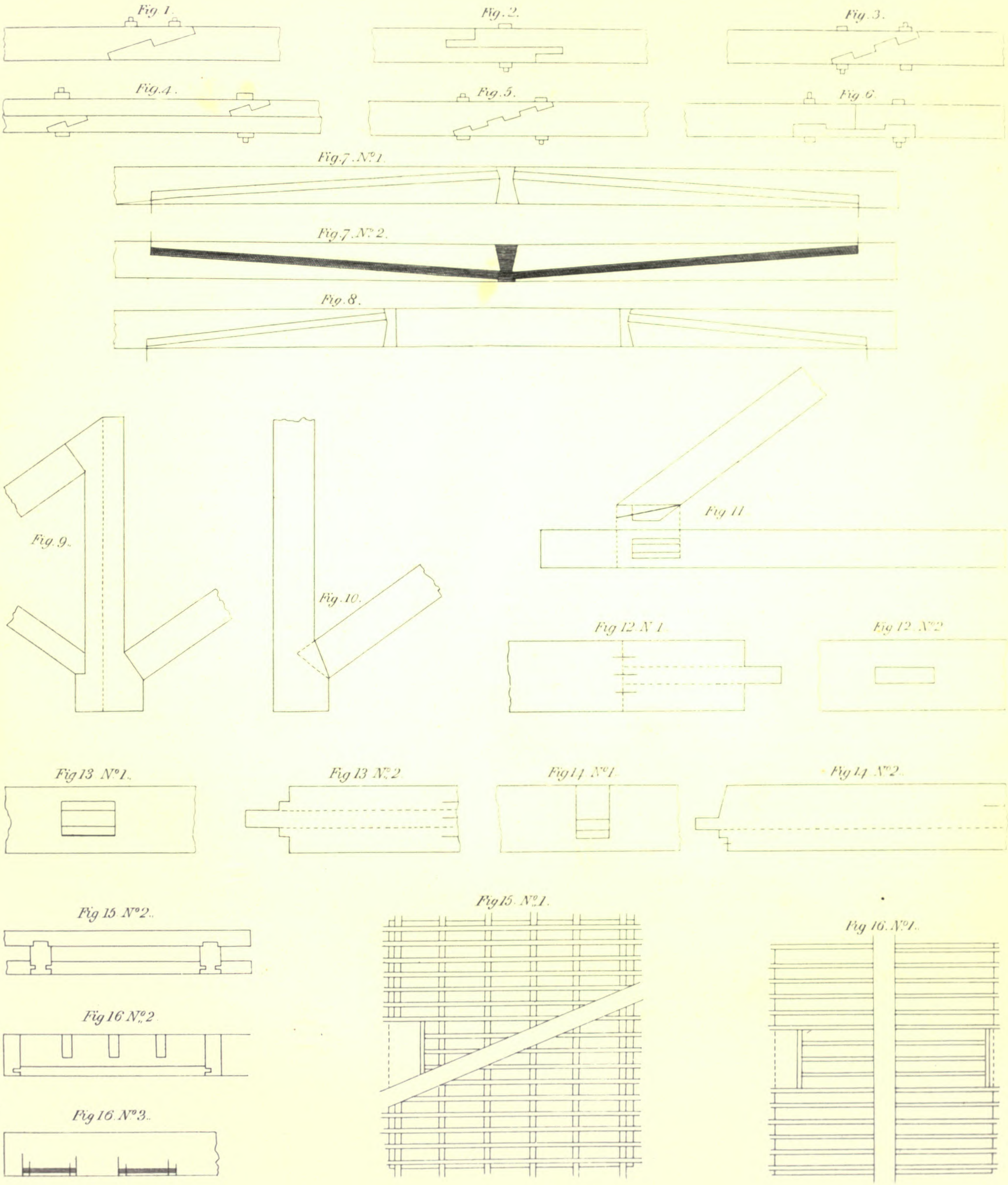

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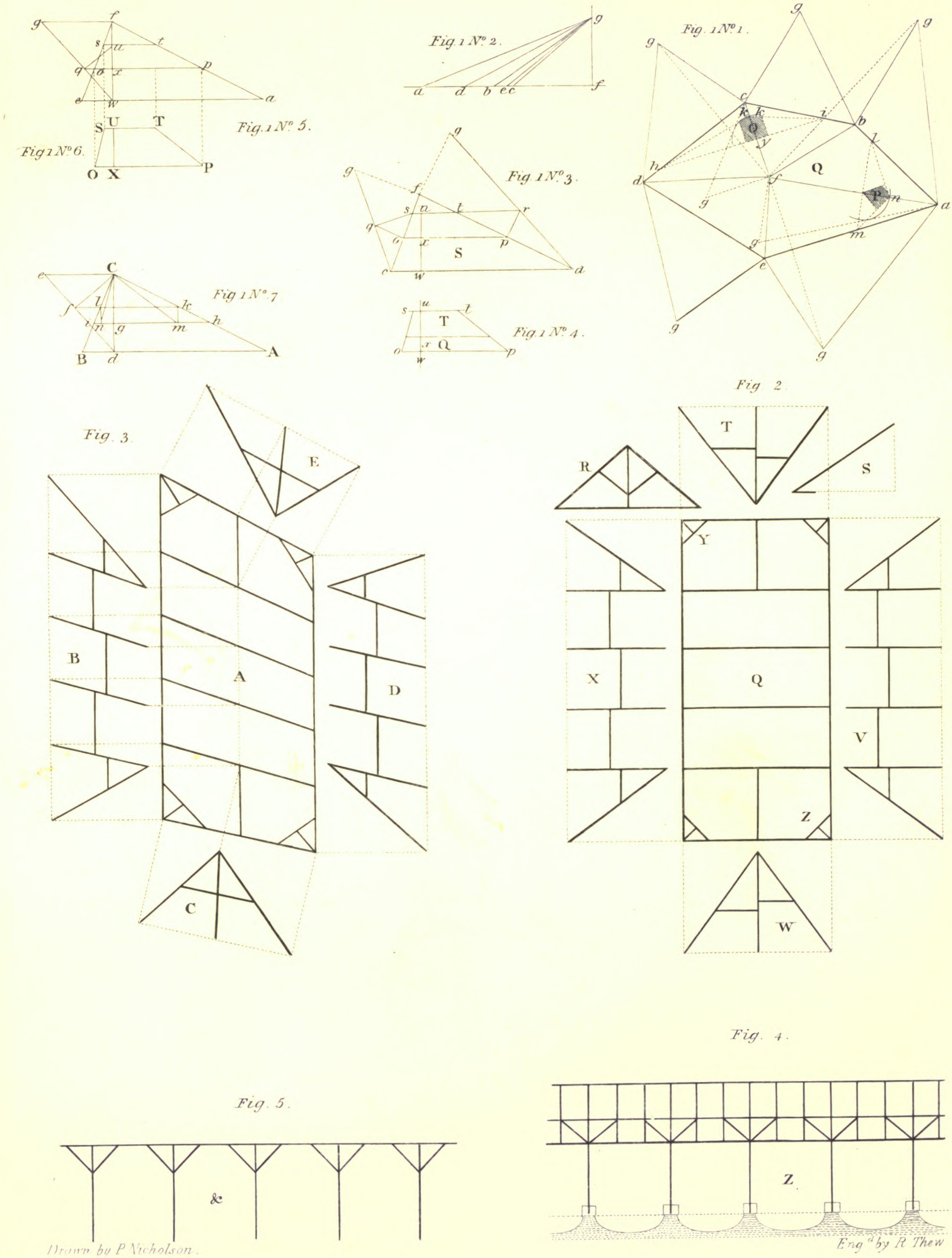

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a f, which to keep from confusion is transferred as to No. 3, and admit the plan of the purlin to be *o p;* first, raise the sections of the hips from No. 2, as *e f g* and *a f g*, as the letters show; then raise perpendiculars at *o* and *p* to the back of the hips, as *o q* and *p r;* lastly, draw a line from the point *q*, and at right angles from the back of the hip *e g* (as it is so near to a square, or else it should be drawn from the back of a rafter standing at right angles with the sides of the plan) observe where it cuts the base line, as at *s;* draw the line *s t* parallel to the purlin: lastly, draw the line *t r*. From all which you take the templet Q in T (see No. 4) in the following manner: Draw the line *u w* in No. 3 at right angles from the side *a e*, which transfer to No. 4, as *u w;* take from No. 3 the distances *u s* and *u t*, and transfer them to No. 4; take also the distances *x o* and *x p* in No. 3, and transfer them to No. 4; take also the distances *s q* in No. 3, and transfer to No. 4, as *s o;* lastly, take from No. 3 the distances *t r*, and transfer to No. 4, as *t p;* so that Q is the templet to cut the side, and the skirt *e a g* is the templet to cut the back. I think any farther explanation needless, because by a little serious inspection, the reader may see that all the lines necessary to be understood in a roof, are contained in this Plate.

"That is, all the parts of a roof may be cut by templets, as these lines, and the explanations of them, do direct: and although I have shown but one example for the cutting of any purlin that comes against a hip, as explained in *h k i*, (Figure 1, No. 1) I hope it will be sufficient, because the method in *l*, *m*, *n*, cuts off all such difficulties, and is equally strong."

In this description, he is unintelligible, vague, and erroneous: there is a certain tendency towards the principle, but he loses sight of it. He is negligent in directing his reader to raise perpendiculars at *o* and *p*, the bases of the two hip-rafters, instead of raising a section at right angles to the base and to the wall-plate *a e*. He tells us to "draw the line *u w* in S (which is here No. 3) at right angles from the side *a e*, which transfer to T (or No. 4) as *u w;*" but he makes no use of this line, which is the line on which the width of the templet should have been extended. Then he says: "Take from S (No. 3) the distances *u s* and *u t*, and transfer them to T (No. 4); take also the distances *x o* and *x p* in S (No. 3), and transfer them to T (No. 4);" but he does not show how the distance between the lines *p o* and *t s* are obtained in T (No. 4); and thus, after a long and tedious description, he leaves the construction vague, and obtains nothing but uncertainty. We shall here complete what he has unsuccessfully attempted.

Let the same plan *a f e* be laid down at No. 5, as at No. 3; draw *f w* perpendicular, and *f g* parallel to *a e;* make *f g* equal to the height of the roof, and join *g w;* let *p o* be the place of the purlin, parallel to *a e*, meeting the bases of the hips at *o* and *p;* produce *p o* to meet *w g* at *q;* draw *q u* perpendicular to *w g*, meeting *f w* at *u;* parallel to *a e*, draw *t u s*, meeting the bases *f a* and *f e* of the hips at *t* and *s*.

In No. 6, draw U X, which make equal to *u q*, No. 5; draw T U S and P X O perpendicular to U X; make U S, U T, X O, X P, respectively to *u s*, *u t*, *x o*, *x p*, and join T P and S O; then P O S T is the templet required, or any parallel portion of its breadth.

The reader will observe that this is found by much fewer lines; and there is no occasion for raising the sections of the hips, but only the section of the rafter at right angles to the wall-plate.

No. 7 is another invention of the author of this Dictionary, founded upon the same principle as No. 5 and 6; but the construction is confined to one diagram, thus: Let A B C be the seat of the part of the roof; describe the section C *d e* as before: draw C *f* perpendicular to *d e*, cutting *d e* in *f;* from C *d* cut off C *g* equal to C *f;* parallel to A B draw *k f*, cutting A C and B C in *k* and *l;* likewise draw *h i* parallel to A B; perpendicular to *k l* draw *k m* and *l n*, cutting *h i* at *m* and *n;* and join C *m* and C *n;* then will the angles at *m* and *n* of the triangle C *m n* be those required for forming the end of the purlin, in order to form a junction with the hip-rafter.

We now return to Mr. Price, who, in laying down the framing of roofs in plano, or in ledgement, begins thus: "Every man who frames roofs, does first piece his plates, cock or dovetail down his beams on the said plates, and prepare pieces on which his hips are to stand; as appears in this plan Q, at Y and Z." (See *Figure* 2.)

"Then he frames his principals, as R, and likewise his hips, as S, into pieces prepared for them to stand on; and although all these respectively are framed for the generality on the floor, and when in practice is the best way, they are here placed by themselves to avoid confusion.

"I hope the pricked lines are enough to show that the *skirts* T, V, W, X, are laid out agreeably to the plan Q; and in which are shown that one purlin lies above the strut, and the other below it; for if they were all to lie in a right line, in the first place it cuts the stuff to pieces so as to weaken it still more, and at the same time you lose your pinning.

"Here is shown a method to turn up your hips without backing at all; and is thus: your hips being first framed into the pieces they are to stand on, take a broad board, or small panel, lay it on the place where your respective hip stands, and there mortise it as if it was your beam; cut off the corners of it, so as to make its angles agreeable to your plan, whether square or bevel; lastly, when you come to turn up your hip in framing the skirts, slip this mould, as V, upon the tenon at the foot of your hip, and then give it a tack with a nail, and the angles of that board will turn up a hip as desired, and is far preferable to any other method whatever.

"But because sometimes buildings must be level, and necessity requires the beams to be laid so, to miss some chimney or window; therefore let A (*Figure* 3) represent a bevel plan, whose beams also lie bevel at the time of framing; and that is just as much as half the beam that the rafter stands on; the skirts B, C, D, E, are the same way shown as before.

"I hope it will not be taken ill, my saying that a man must be deprived of sense, who would run into almost endless trouble of cutting his timbers all bevel, unless some unavoidable necessity require it, but rather use the method I propose in plate E." (That is, *Figure* 2 of this article.)

The method of laying roofs in plano is first shown by Price. It seems to have been much practised in his time, and indeed till lately; but to perform the work in this way, requires the most ample space, and the utmost care of the carpenter in placing his timbers; without this it will be difficult to bring the work together with exactness. In the present practice, the timbers may be all cut to their lengths and angles before they are applied to their places, and then they may be fitted together on the ground before they are raised on the building.

In roofing, his rules for finding the pitch of the rafters for different coverings, are these (page 15 of his work): "A leaden covering requires the height two-eighths or one-fourth of the breadth of the beam; a pantile covering, three-eighths; and plain tiles, four-eighths or one-half, which brings the vertical angle of the roof to a square."

But in the following plate, H, of his work, he is not very consistent; he delivers different rules, which are to the following purpose: divide the breadth into six equal parts for pantiles, into seven for slates, and into eight for plain tiles; then in each of these the whole number, wanting two, will be the height of the roof; that is, pantile $\frac{4}{6}$, slates $\frac{5}{7}$, and plain tiles $\frac{6}{8}$, of the breadth of the beam."

The following observations, with respect to the trusses of roofs, are very judicious:

"That the less in number the divisions or pieces are, that compose each truss, the stronger it is; for even the shrinking of the wood will let a well-framed truss sag or drop in process of time; for which reason I cannot help recommending English oak, particularly for king-posts." He recommends square bolts in preference to round ones; "for this reason: if you use a round bolt, it must follow the auger, and cannot be helped; by this helping the auger-hole, that is, taking off the corners of the wood, you may draw a strap exceedingly close, and at the same time it embraces the grain of the wood in a much firmer manner than a round one can possibly do." With respect to strapping, he observes: "If it be objected that there is too much trust reposed on the iron-work, may it not be asked, if any common strap at the bottom of a king-post was ever known to break by continual pressure? Witness the straps in a theatre, to which is fixed a prodigious weight." With respect to timbers, he says, "If purlins are used, they ought to be agreeable in number to their supports;" "but if bridged, need not be regarded."

The following designs, which he shows for the fronts of buildings, which are required to have the ground story open, and supported with story-posts, may be useful to some:

"In *Figure* 4, is shown the manner of a timber front, supposed to be open underneath, in form of an arcade. And for such open fronts, the foundation should be laid on reversed arches, which will strengthen it very much; by this means, the ground bears between one post or pillar and the other, as well as under the same.

"If on it you would have brickwork, or even stone, then support the bressummer, as is shown in *Figure* 5, which manner of framing renders it as strong between the posts or pillars as it is directly on the same, and this seems sufficient to explain proper bearings for partitions."

Mr. Price then proceeds to circular domes, and in their construction shows, for the first time, how the purlins are to be squared; his description is as follows:

"Of what has hitherto been described, nothing appears so beautiful when done, as domes or circular roofs; and, as far as I can perceive, nothing has appeared so difficult in doing, therefore it will be proper to speak something of them."

Plate VII. Figure 1.—"Let B represent a plan, in which let *b*, *b*, *b*, be the plate on the supposed wall; and let *c*, *c*, *c*, be the kirb on which stands a lantern, or cupola; also let *a*, *a*, *a*, represent the principal ribs.

"From the plan B make the section A; in which the kirb or plate *b* should be in two thicknesses; as also that of *c*; by which it is made stronger; and indeed the principal ribs would be much better to be in two thicknesses. The best timber for this use is English oak; because abundance of that naturally grows crooked. As to the curve or sweep of this dome A, it is a semicircle; although in that point, every one may use his pleasure; and in it are described the purlins *d*, *e*, from which perpendiculars are dropped to the plan B; so that *f* is the mould the lower purlins are to be cut out by, before they are shaped or squared for use; and that of *g* is the mould for the upper purlins. I rather show it with purlins, because under this head may be shown the manner of framing circular roofs in form of a cone.

"To shape these purlins, observe, in A, as at *d* and *e*, they are so squared, that the joints of the supposed small ribs are equal. Observe, as at *e*, the corners of the purlin, from which the perpendiculars are let fall to the plan B. So that your purlin being first cut out to the thickness required, as appears in *e*, and also to the sweep *f*; so that *k* is the mould for the bottom, and *l* the mould for the top; by which, and the lines for the corners of the said purlin *e*, the same may be truly shaped and squared.

"N.B. This particular ought to be well digested, it being a principal observation in a circular roof.

"From the purlin *d*, in the section A, perpendiculars are dropped to the plan B; in which it appears that *h* is the mould for the top, and *i* the mould for the bottom; so may this be squared, which completes the performance. As to other particulars, due inspection will explain them. If any should say, a dome cannot be done so safe without a cavity as usual, let them view St. Stephen's, Walbrook, Stock's-market, built by that great architect, Sir Christopher Wren."

He then shows the method of covering polygonal buildings:

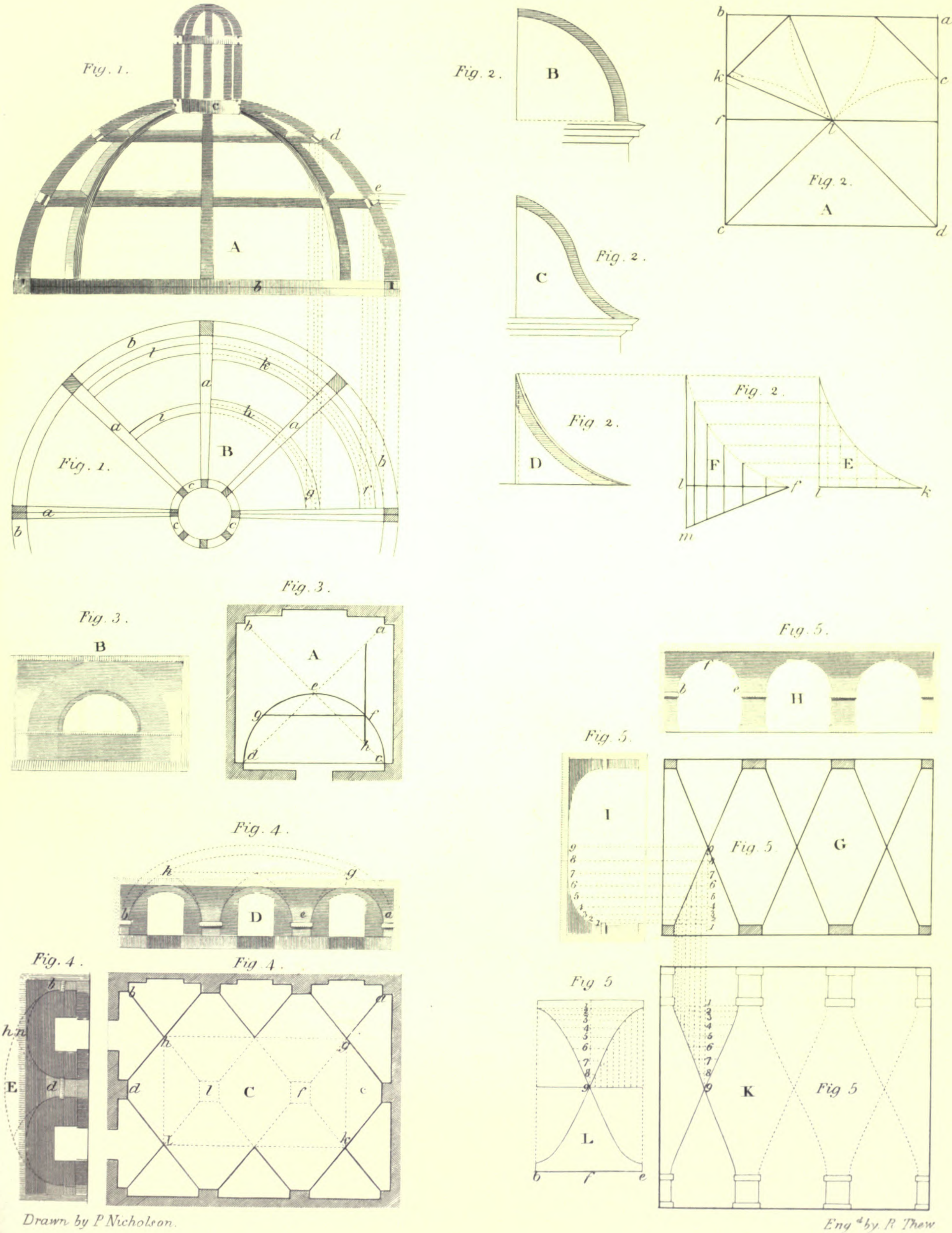
Plate VII. Figure 2. "Let A be the plan, the upper part of which is half an octagon. It is observable that a circular roof, as B, should extend no farther than the upright of its support, and there made so as to carry off the water; whereas an ogee roof, as C, may extend to the extremity of the cornice, without injury to its strength, or offence to the eye of the most curious: also, a hollow roof, as D, may extend to the extremity of the cornice.

"It appears to me, that many angles of a cupola give it beauty; therefore the sweep E (*Figure* 2) is a regular curve, the base line *l k* being taken from the angle of the octagon in the plan A, as at *l k*. This curve, E, is divided into a number of equal parts, in order to trace the common rib, F, from the said angular rib, E: observe, in A, the base of the common rib, *f l*, which is placed in F, as from *l* to *f*; continue the perpendicular, *l*, at pleasure; take the base *l k* in E, on which are the perpendiculars dropped from the curve, and observe to place that distance, *k l* in E, from *f* in F, to any part where it cuts the perpendicular *l* in F, as at *m*; from these divisions raise perpendiculars, so by continuing the base lines from the divisions in E, to these perpendiculars in F, their intersection or meeting is a curve, or sweep, exactly agreeable, and which, indeed, may serve as a standard rule to trace any moulding whatever.

"To back the said angle-bracket, D, observe to describe the thickness of it on your plan, as in A at *k*, which shows how much your mould must be shifted, as may appear in D. This also may be observed to be a general rule for the backing of any bracket."

These methods are certainly founded on truth, but his diagrams are not laid down in the most obvious way; being so scattered as not only to be tiresome to the eye, but to occasion also a long and tedious description. He then proceeds with the centerings of groins, as follows:

Figure 3. "Let A be the plan of a vault to be centered for groins. At *a*, *b*, *c*, *d*, are piers, generally prepared in with the foundation, which bear the weight of the brickwork. First, resolve on the curve you would have, as *d e c*, being a semi-circle, which is shown by the section B. Begin in A at *d e c*; centre through as it were a common vault, and board it; which being done, to make your groin set centres, as from *a* to *c*, and from *b* to *d*, divide the curve *d e c* into four equal parts, as at *g* and *f*; so are *g e f* small centres, you will want to nail on the centres first boarded, whose place or plan is at *h*; these small centres may be put in at pleasure, according to the bearing of your boards, that is, as to the distance between each centre. To make your groin straight on its base, at some little height over the centres, strain a line from *b* to *c*,



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or from *d* to *a*, from which drop perpendiculars on your boarding, first fixed at as many places as you please; there drive in nails, and bend a straight rod till it touch them all; and then, with a pencil or chalk, describe the curve so formed, to which bring the boards to be nailed on these little centres, and their joints will form a straight groin."

Figure 4. "Let C be a plan of greater extent, and which suppose to be supported by two piers, as *f*, *l*. The section D is composed of entire semicircles, then consequently your curves in the section E will be elliptical, as *b n d*, and may be described with a trammel. What was said in A explains this at one view.

"If these pillars should be in the way, view the plan and sections again: first, form the principal curve, as D at *a g h b*, being an ellipsis, so that the centres will be a Gothic sweep against the windows, as *e g a*: trace the curve *d h b* in E, agreeable to *e g a* in D, with which centre it, as shown in A, and make good your groins to the sides: lastly, make a flat centre, as at *g h i k*, which flatness is shown in either of the profiles or sections D and E, and fix it on your centres before completed, which doubtless due inspection will make plain, and hereby you avoid the pillars, which are equally firm.

"N.B. The cause of these centres against the windows being a Gothic arch, proceeds from their making part of the whole sweep or arch, which though it does not add to its beauty, it does to its strength in a particular manner."

After showing how to find the groined lines, as it were by a mere mechanical process, the method of finding the groined lines on the body centre, he then shows how the same may be found upon true geometrical principles, which may be looked upon as the foundation of all kinds of cylindrical soffits.

"Regarding variety, I have given here another method for vaults, and which, indeed, may give more pleasure to the reader, as being a curiosity never before published, and may appear more intelligible than that in the foregoing."

Figure 5. "View the plan G and its section H, which is composed of entire semicircles, as *b f e*: see also the section I, which is an ellipsis traced from *b f e* in H; but for use, nothing is more true than the trammel.

"See this plan again, and also its section I, from which is described the curvilinear face K, and also the face of the semicircular arches, as L, all being alike. And this is what I call a more accurate method for finding the groin, so as to be straight over its base, and at the same time gives a standard rule whereby to account for any curve, or face of a ceiling whatever. The curve in I is divided regularly, though seemingly into unequal parts, which being drawn to the groin in the plan O, as appears by the figures 1, 2, 3, 4. 5, 6, 7, 8, 9, and which are transferred into L at 1, 2. 3, &c. Also the circle *b f e* in H is divided into eighteen equal parts; the half consequently into nine, which appears from *b* to *e* in L. This method doubtless will be plain, and therefore needs no farther explanation.

"That of K belongs to the section I, extended as it were, and that of L belongs to one of the small arches of H, also stretched out, they being all alike."

Here it must be observed, that he has stretched out the piers, which are of no use, the covering only being wanted, and he has extended all the compartments of the plan in plano at K, which is absurd, one of each being all that is necessary; for they cannot be extended in contiguity, nor any two contiguous parts on the plan, though each adjoining part may be done separately.

"N.B. To find the groin by a more common method, do thus: Erect a straight piece of a board, or the like, on the corner of the pier the groin springs from, and drive in a nail at the point of the groin's meeting, on which fasten one end of a chalked line, straining it tight, slide it down the side of the said straight piece, and it will form the groin so as to stand perpendicularly over its base."

Mr. Price then proceeds to the methods of covering the parts of coved ceilings adjoining the angles, and also the coverings of domes, as follows:

Plate VIII. Figure 1. "*Suppose* M *to be the plan of a ceiling, as a b c d, and it is required to have a large frame, gulochi, or panel.*—First, produce some side or end of the room, as N. Let it be required to describe the curvilinear face of the cove. The extent of the end of the said room is *a b f e*, and it is coved one-fourth part of the height, at *m b*. The said frame or panel being *g h*; the quarter circle *m g* is divided into eight equal parts, which are transferred to P, so that *m g h l* is the face of O, as stretched or extended out, on which any thing proposed to be described therein may be truly performed.

Figure 2. "In Q is shown the plan of a niche, or dome; if a niche, let it be demanded to be fineered with walnut-tree, &c. If a dome, let it be required to be covered with boards or lead. Divide it into any number of parts, as here into nine, which transfer to S, as appears from *h* to *l*. Describe the section also, as R, being a quarter of a circle, which divide into any number of parts, as here into five, as is shown in the figure from *h* to *i*, which transfer in the plan Q from *a* to *f*; middle some one division, as from 4 to 5; then take those distances from R, and transfer them to S, as from *f* to 5, so that each division is halved or middled, as *f a*, *f a*: on these lines place the distances from Q, as at *e*, *d*, *c*, *b*, to 1, 2, 3, 4, in S, and these will form such curves as shall meet.

"N.B. The more parts it is divided into, the better and truer it will be performed."

In this description, he is far from being clear, as we shall here explain. "*Take the distances from* R, *and transfer them to* S, *as from f to* 5." But the extent of the line from *f* to *a* at S does not contain the whole stretch of the arch *h i* of the section R, as it contains only four of the equal parts, whereas there are five; one part should have been described to be below the line *f f f*, &c., as the diagram S shows. The words "*so that each division is halved, as, f a, f a*," *&c.*, have no meaning. "*On these lines place the distances from* Q, *as at e, d, c, b, to* 1, 2, 3, 4, in S, *and these will form such curves as shall meet*:" this is extremely obscure, and ought to have been thus described: From the points *b c*, *d e*, in Q, describe the several arcs meeting each of the radii *a f* and *a* 4; then at S, through the divisions, 1, 2, 3, 4, draw lines at right angles; upon these lines, and on each side of the said points, 1, 2, 3, 4, set off the several arcs at Q, beginning with *f* 4, at the bottom of S, and through the points on each side of the line *f a* describe the two curves, and the space comprehended between them and the bottom line is the board required.

It must be observed, that though it is sometimes convenient to detach the parts of a diagram when it would occupy too much space, it is by no means so obvious as one connected figure. In this respect, Mr. Price is very obscure, in transferring to so many different figures.

He then shows the nature of oblique or rampant arches, the tracing of, and the manner of finding the base or seat of the angle ribs of an annular groin, as follows:

Figure 3. "That of A, is supposed to be the mitre-bracket of a cove, whose projection is *b c*; and the height thereof is *a b*; the curve being a segment, or part of a circle, let it be demanded to trace a curve from it, as B, which shall be agreeable thereto, if applied as a common bracket, *e d* being its height, as before, and *e f* its projection; first, divide the given curve A, into a number of parts, or take points thereon promiscuously, which will answer as well. From these divisions, or points, drop perpendiculars to some straight line, as that of *a c*, observing their meeting with the said line *a c;* and in practice take off all these distances on a lath, or rod, applying the proper end thereof to the projection of the common bracket B, as *f*, observing where the other end passes through the perpendicular line *e d*, as at *g;* there raise indefinite perpendiculars from the said points, then draw the line *d f*. Lastly, transfer the distances, as from the straight line *a c*, in A, to the figures, to that of *d f* in B; which, no doubt, inspection will explain, more especially if the letters and figures be duly observed.

"Now view the same figure A again; and admit it were the curve of a common bracket, let it be demanded to trace a mitre or angle bracket from it, as C; *g h* being its height as before, and *h i* its projection (the method of finding which in either case, no doubt, will be well known to every one:) take the line, as *a c* in A, which in practice (as was before observed) I suppose to be on a rod, or lath, with its divisions, or points on it, and transfer it to C, as *g k;* then draw the line *g i;* lastly, from the said points on the line *g k*, draw base lines, observing their meeting the line *g i;* at which respective places raise perpendiculars, and transfer your several heights from A, as before, observing to place each in its due position. And although the abundance of points should render this method somewhat confused, it may be evaded by making but few points, and driving nails therein, round which a straight lath being bent till it touch them all, the curve may be described with a pencil, &c.

"N.B. This may serve as a general rule for all such curves as are not regular, or cannot be formed with a trammel, supposing either to be the given curve. The principal curve being formed on any plain superficies, it may be taken off on a lath, as before was observed; and by it the required curve may be described on a piece of slit deal, &c., of a width equal to the deflection of the arch from a straight line, with an allowance of wood capable of holding it together.

Figure 4. "That of D, represents a common bracket for a plastered cornice, whose shape the plasterer ought always to be consulted for: let it be required to trace a corner, or angle-bracket from it, as E; first, draw base lines from the respective angles *a*, *b*, *c*, *d*, to the line *t r*, as 1, 2, 3, 4; also perpendiculars to the line *r s*, as 5, 6, 7, 8; and (because an example for finding the projecture of the angle or mitre bracket, may be required) observe to make *r u* equal to *r s;* so is *u s* the projecture of the said angle or mitre bracket; and the points will be *w*, *x*, *y*, *z;* so that by transferring this said line with its points as before to E, as also those of the height as before, draw perpendicular and base lines, when, as no doubt inspection shows, their meeting gives the shape of the bracket as desired, and this also may serve as a standard rule in any such case. As to shifting this mould (in practice) so as to give the said angle-bracket its true back, there seems to have been enough said in plate P.

"Such things as the construction and use of lines, are not conceived by every one; therefore, because I would omit nothing that I think would prove useful, I have inserted several more examples of tracery, the knowledge of which seems indispensably necessary.

Figure 5. "That of T is a regular semicircle, as *a b c*, from which is traced the raking (or rampant) one U; that of W is a regular ellipsis, as *d e f*, from which is traced the raking one X; that of Y is a regular segment (or part of a circle) as *g h i*, from which is traced the raking one Z; the manner whereof being so plain, a farther explanation seems needless.

"As to the particular use of this kind of arches, I must leave to the determination of the curious, and have nothing farther to say on that head, than that if occasion require either of them to be executed, there is no other true way to describe them.

Figure 6. "That of F is a plan of circular groins, whose extent is *a b c d*, an example of which may be seen in St. Clement's Danes, Strand, and in several other circular buildings; and, in my opinion, is a curiosity worthy of regard. To find the plan of these groins, do thus: Divide from *a* to *b*, into a number of parts, as into ten; the lines *a b* and *d c* being continued, meet in a point as *g*, being the centre of the curves *a d* and *b c;* from which strike curves from the points in *a b* to *d c:* divide also from *a* to *d*, into ten parts, which being drawn to the centre *g*, divides the line *b c* into the same number of parts equally; so that the meeting of these lines is the plan of the groins, as *a e c* and *b e d*, and their upright is H, I, K, L, each being traced from the semicircle *a b f* in G, being the principal curve. As to the method whereby it is done, enough has been said of the foregoing examples to explain it; the letters of reference show plainly what part of the plan each curve belongs to, which being bent agreeable thereto, will strictly correspond with each other.

"N.B. If the principal curve had been a segment, or part of a circle, or an ellipsis, the method of performing would have been the same.

"This plan would be difficult in performance, if required to be ribbed with timber for plastering, but if to be centered for brickwork, it would be much easier; because the centres might be placed as from the line *a b* to that of *c d*, as in a common vault. The curves of each centre would be different, on account of its being taper, but the height is equal; these centres should be boarded as others are, the boards requiring to be taper only.

"To make groins so as to hang over the plan, the sides *a b e* and *c d e* must not be centered as usual; but have ribs agreeable to the plan, and placed horizontally, so that the boards would stand as it were upright; as in domes, which was explained in the foregoing plates, which shows the method for finding the curvilinear form of any ceiling.

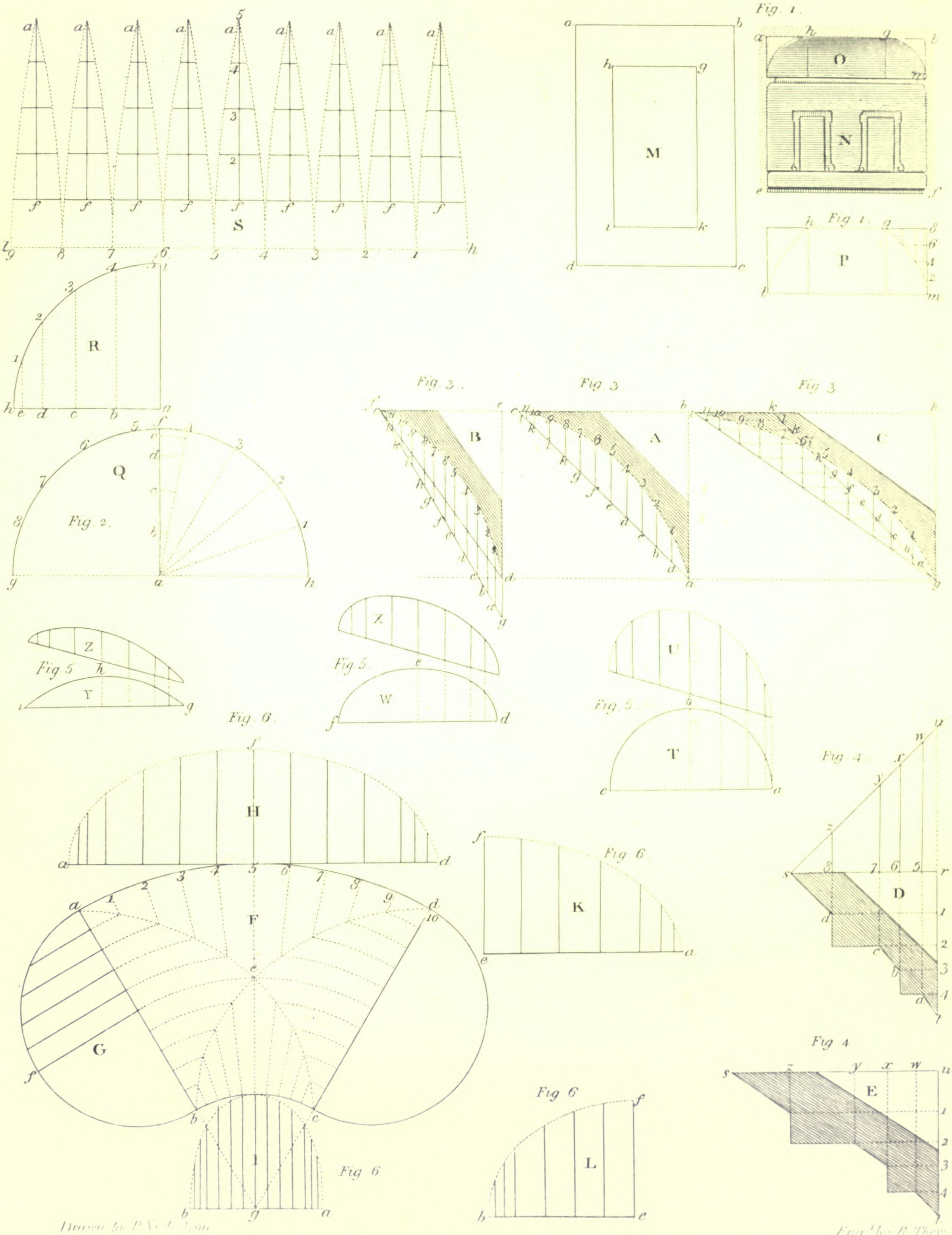
"N.B. The foregoing must be well understood, in order to describe on the centres first boarded, the accurate curve of the groin; which can be done by no other method than is there shown.

"If this plan were to be executed with ribs of timber for plastering, then the groins must be performed by the methods, as will be hereafter inserted, for the twisted rails for staircases, on account of their plan not being a regular curve."

This method of constructing an annular groin, is of no other use than that of finding the seats of the lines of concourse of the meeting of the curved sides. It does not show how the boarding is to be formed geometrically, neither does it give the least idea of constructing the ribs of a plaster groin. The line of concourse of the two sides may be obtained by plumbing up from the base, but even this circumstance is not mentioned by Mr. Price, nor any other application of this construction. If it were required to construct the ribbing for a plaster groin, the method here shown is perfectly adapted to the formation of the ribs in thicknesses, as the whole of the ribs round the curves are extended in plano. But the glueing up of the ribs in thicknesses is altogether nugatory, when applied to the purposes of carpentry. Another mode, which we would propose, in order to bring this method into use in groin ribbing, is, to get the ribs cut into two thicknesses, say 1½-inch stuff, and kerf each of them from one side; then put the two kerfed sides toge-

Carpentry.

PLATE VIII.



Drawn by P. Nicholson.

Eng.d by R. Thew.

ther, and nail or bolt them to the curve: to prevent them from extending before they are fixed, nail a temporary piece across the two extremities, and set them in their places; then when the other ribs are nailed against them, they will remain firm, and this without much trouble of construction. —In this operation, the kerfs must run in lines perpendicular to the base, otherwise they will not bend to the plan.

A TABLE FOR THE SCANTLINGS OF TIMBER.

A Proportion for Timbers for small Buildings.

Of Fir		Of Oak	
Bearing Posts of Fir		**Bearing Posts of Oak**	
Height	Scantling	Height	Scantling
if 8 feet	4 in. square	if 10 feet	6 in. square
10	5	12	8
12	6	14	10
Girders of Fir		**Girders of Oak**	
Bearing	Scantling	Bearing	Scantling
if 16 feet	8 in. by 11	if 16 feet	10 in. by 13
20	10 12½	20	12 14
24	12 14	24	14 15
Joists of Fir		**Joists of Oak**	
Bearing	Scantling	Bearing	Scantling
if 6 feet	5 in. by 2½	if 6 feet	5 in. by 3
9	6½ 2½	9	7½ 3
12	8 2½	12	10 3
Bridgings of Fir		**Bridgings of Oak**	
Bearing	Scantling	Bearing	Scantling
if 6 feet	4 in. by 2½	if 6 feet	4 in. by 3
8	5 2¾	8	5½ 3
10	6 3	10	7 3
Small Rafters of Fir		**Small Rafters of Oak**	
Bearing	Scantling	Bearing	Scantling
if 8 feet	3½ in. by 2½	if 8 feet	4½ in. by 3
10	4½ 2½	10	5½ 3
12	5½ 2½	12	6½ 3
Beams of Fir, or Ties		**Beams of Oak, or Ties**	
Length	Scantling	Length	Scantling
if 30 feet	6 in. by 7	if 30 feet	7 in. by 8
45	9 8½	45	10 11½
60	12 11	60	13 15

Principal Rafters of Fir			Principal Rafters of Oak		
	Scantling			Scantling	
Length	Top	Bottom	Length	Top	Bottom
if 24 ft.	5 in. & 6	6 in. & 7	if 24 ft.	7 in. & 8	8 in. & 9
36	6½ 8	8 10	36	8 9	9 10½
48	8 10	10 12	48	9 10	10 12

A Proportion for Timbers for large Buildings.

Of Fir		Of Oak	
Bearing Posts of Fir		**Bearing Posts of Oak**	
Height	Scantling	Height	Scantling
if 8 feet	5 in. square	if 8 feet	8 in. square
12	8	12	12
16	10	16	16
Girders of Fir		**Girders of Oak**	
Bearing	Scantling	Bearing	Scantling
if 16 feet	9½ in. by 13	if 16 feet	12 in. by 14
20	12 14	20	15 15
24	13½ 15	24	18 16
Joists of Fir		**Joists of Oak**	
Bearing	Scantling	Bearing	Scantling
if 6 feet	5 in. by 3	if 6 feet	6 in. by 3
9	7½ 3	9	9 3
12	10 3	12	12 3
Bridgings of Fir		**Bridgings of Oak**	
Bearing	Scantling	Bearing	Scantling
if 6 feet	4 in. by 3	if 6 feet	5 in. by 3½
8	5½ 3	8	6½ 3½
10	7 3	10	8 3½
Small Rafters of Fir		**Small Rafters of Oak**	
Bearing	Scantling	Bearing	Scantling
if 8 feet	4½ in. by 3	if 8 feet	5½ in. by 3
10	5½ 3	10	7 3
12	6½ 3	12	9 3
Beams of Fir, or Ties		**Beams of Oak, or Ties.**	
Length	Scantling	Length	Scantling
if 30 feet	7 in. by 8	if 30 feet	8 in. by 9
45	10 11½	45	11 12½
60	13 15	60	14 16

Principal Rafters of Fir			Principal Rafters of Oak		
	Scantling.			Scantling	
Length	Top	Bottom	Length	Top	Bottom
if 24 ft.	7 in. & 8	8 in. & 9	if 24 ft.	8 in. & 9	9 in & 10
36	8 9	9 10½	36	9 10	10 12
38	9 10	10 12	48	10 12	12 14

"Although this table seems so plain as to need no explanation, it may not be amiss to observe some particulars, such as that all binding or strong joists ought to be half as thick again as common joists; that is, if a common joist be given three inches thick, a binding-joist should be four inches and a half thick, although the same depth.

"Observe also, that if conveniency do not allow of posts in partitions being square, in such cases, multiply the square of the side of the posts, as here given, by itself; for instance, if it be six inches square, then as six times six is thirty-six, consequently to keep this post nearly to the same strength, find some number that shall agree thereto; as suppose the partition to be four inches thick, then let your post be nine inches the other way, so that nine times four is thirty-six, being the same as six times six; so that the strength is nearly the same, although being equal in its squares is best for the strength.

"Posts that go the height of two or three stories, need not hold this proportion, because at every floor it will meet with a tie; admit a post was required of thirty feet high, and in this height there were three stories, two of ten feet, and one of eight. Look for posts of fir of ten feet high, their scantling is five inches square, *i. e.* twenty-five square inches; which double for the two stories.

"And take also that of eight feet high, being four inches square, *i. e.* sixteen square inches, all which being added together, make sixty-four square inches; so that such a post would be eight inches square. On occasion it may be lessened in each story as it rises.

"I do not insist that the scantlings of timber ought to be exactly as by this table is expressed, but may be varied in some respects, as the workmen shall see fit; the reason of its being inserted, is in consideration of the scantlings of timber, as formerly settled by act of parliament, and which, if compared, will prove the necessity and use of this table.

"As to plates on walls, or bressummers to support walls, I do not find they can come into any regular proportion, as the rest do, therefore must be left to discretion.

"And as I have herein described a great variety of the principal things requisite to be known by every carpenter, I shall conclude this part with my wishes that it may prove as useful as my earnest endeavours have been to make it so."

It is singular that in the foregoing table, the oak scantlings are greater than those of fir. Oak is more cohesive than fir, but fir is less compressible by forces acting in the direction of the fibres; oak is therefore more fit for ties, and fir for struts, or straining pieces. But Mr. Price, in this table, inconsiderately and indiscriminately makes the oak scantlings larger than those of fir.

The following observations, in the introduction to Price's work, are very judicious, and worthy of transcription.

"Nevertheless, it may not be improper, in this place, to mention some general observations. There is a moisture in all timber; therefore all bearing timber ought to have a moderate camber, or roundness: for till that moisture is in some sort dried out, the said timber will sag with its own weight; and that chiefly is the reason girders are trussed when used, as in its place will be shown. But here observe, that girders are best trussed when they are first sawn out, for by their drying and shrinking, it tightens the trusses in them yet more.

"Observe also, that all beams, or ties, be cut, or forced in framing, to a camber, or roundness, such as an inch in the length of eighteen feet; and that principal rafters be also cut, or forced up to a camber, or roundness, as before: the reason of this is, all trusses, though ever so well framed, by the shrinking of the timber, and weight of the covering, will sag, and sometimes so much as to offend the eye of the beholder; so that by this preparation your truss will ever appear well.

"Also observe, that all case-bays, either in floors or roofs, do not exceed twelve feet if possible; that is, do not let your joists in floors, your purlins in roofs, &c., exceed twelve feet in their length, or bearing; but rather let the bearing be eight, nine, or ten feet; which should be observed in forming a plan.

"Also, in bridging-floors, do not place your binding or strong joists above three, four, or five feet apart; and that your bridgings or common joists are not above ten or twelve inches apart, that is, between one joist and the other.

"Here also observe, never to make double tenants or tenons for bearing uses, such as binding-joists, common joists, or purlins; for, in the first place, it weakens very much whatever you frame it into; and, in the second place, it is a rarity to have a draught in both tenons, that is, to draw your joint close by the pin: for the said pin, by passing through both tenons, (if there is a draught to each,) must bend so much, that without the pin be as tough as wire, it must needs break in driving, and consequently do more hurt than good."

We are now come to Mr. Batty Langley, in whose numerous publications are to be found many particulars relating to Carpentry. In his *Builder's Complete Assistant*, published 1738, page 147, the fourth edition, he has the following observation:—

"When partitions have solid bearings throughout their whole extent, they have no need to be trussed; but when they can be supported but in some particular places, then they require to be trussed in such a manner, that the whole weight shall rest perpendicularly upon the places appointed for their support, and nowhere else. Partitions are made of different heights, to carry one, two, or more floors, as the kinds of buildings require.

"The first things to be considered in works of this kind are—the weight that is to be supported, the goodness and kind of timber that is to be employed, and proper scantlings necessary for that purpose."

So far his observations are tolerable; but his subsequent reasonings are drawn rather from his own caprice, than from the principles of science, as will be seen in the following quotations:

"The strength of timber in general is always in proportion to the quantity of solid matter it contains. The quantity of solid matter in timber is always more or less, as the timber is more or less heavy; hence it is, that all heavy woods, as oak, box, mahogany, lignum-vitæ, &c., are stronger than elder, deal, sycamore, &c., which are lighter or (rather) less heavy; and, indeed, for the same reason, iron is not so strong as steel, which is heavier than iron; and steel is not so strong as brass or copper, which are both heavier than steel. To prove this, make two equal cubes of any two kinds of timber, suppose the one of fir, the other of oak; weigh them singly, and note their respective weights; this done, prepare two pieces of the same timbers, of equal lengths, suppose each five feet in length, and let each be tried up as nearly square as can be, but to such scantlings, that the weight of a piece of oak may be to the weight of a piece of fir, as the cube of oak is to the cube of fir; then those two pieces being laid horizontally hollow, with equal bearings, and being loaded in their middles with increased equal weights, it will be seen that that they will bend or sag equally, which is a demonstration that their strengths are to each other as the quantity of solid matter contained in them."

This is reasoning only from conjecture, and therefore the consequence must be erroneous. The relation between weight and strength is not general. In some instances the very reverse takes place to what this author asserts.

"As the whole weight on partitions is supported by the principal post, their scantlings must be first considered, and this should be done in two different manners, viz., first, when the quarters, commonly called *studs*, are to be filled with brickwork, and rendered thereon; and, lastly, when to be lathed and plastered on both sides.

"When the quarters are to be filled between with brickwork, the thickness of the principal posts should be as much less than the breadth of a brick, as twice the thickness of a lath; so that when these posts are lathed to hold on the rendering, the laths on both sides may be flush with the surfaces of the brickwork. And to give these posts a sufficient strength, their breadth must be increased at discretion; but when the quarters are to be lathed on both sides, or when wainscoting is to be placed against the partitioning, then the thickness of the posts may be made greater at pleasure. The usual scantlings for the principal posts of fir, of 8 feet in height, is 4 or 5 inches square; of 10 feet in height, 5 or 6 inches square; of 12 feet in height, 6 or 7 inches square; of 14 feet in height, 7 or 8 eight inches square; of 16 feet in height, from 9 to 10 inches square. But these last, in my opinion, are full large, where no very great weight is to be supported. As oak is much stronger than fir, the scantling of oak-posts need not be so large as those of fir; and therefore the scantlings assigned by Mr. Price, in his *Treatise of Carpentry*, are absurd, as being much larger than those he has assigned for fir-roofs. To find the just scantling of oaken posts that shall have the same strength of any given fir-posts, this is the rule:

"As the weight of a cube of fir is to the weight of a cube of oak of the same magnitude, so is the area of the square end of any fir-post to the area of the end of an oaken post, and whose square root is equal to the side of the oaken post required."

He might as well have asserted, that as the weight of a cube of steel is to the weight of a cube of lead, so is the area of the square end of any steel bar to the area of the end of any leaden bar; which proposition would have led to manifest falsehood. In the rule he has not mentioned the length, which, if taken into the consideration, would bring a very different result; as timber is considerably weakened by its length. The rule is therefore not only erroneous, but defective also.

With respect to Mr. Price's table, we have only to observe that as there are no details of experiments on the strength of oak and fir, when employed as posts, we cannot decide in this matter. It must, however, be observed, that the fibres of fir are straight, whilst those of oak are very crooked; whence it is reasonable to conclude that a body with straight fibres is better adapted to resist compression than one whose fibres are crooked; and this supposition is strengthened, if not confirmed, by the experiments of Muchenbreuk, who asserts, that though oak will suspend half as much again as fir, it will not, as a pillar, support two-thirds of that load. Now if we can put any dependence on these experiments, fir should be used in cases of compression, as in story-posts, partitions, &c., and oak in cases of tension, as ties, truss-posts, &c.

"The distances of principal posts are generally about ten feet, and of the quarters about fourteen inches; but when they are to be lathed on both sides, the distances of the quarters should be such as will be agreeable to the lengths of the laths, otherwise there will be a great waste in the laths. The thicknesses of ground-plates and risings are generally from two inches and a half to four inches, and are scarfed together."

With respect to lintels, bond-timbers, and naked flooring, he observes as follows:

"For the better disposing of the weight imposed on girders, lintels should always be firmly bedded on a sufficient number of short pieces of oak, laid across the walls, vulgarly called *templets*, which are of excellent use.

"Let girders be laid in piers, or in lintels over windows; it will in both these cases be commendable to turn small arches over their ends, that in case their ends are first decayed, they may be renewed at pleasure, without disturbing any part of the brickwork; and for their preservation, anoint their ends with melted pitch and grease, viz., of pitch four, of grease one; and, indeed, were lintels to be covered with pitch and grease also, it would contribute very greatly to their duration.

"In the carrying up the several walls of buildings, it should be carefully observed, to lay in bond-timbers on templets, as aforesaid, at every six or seven feet in height, cogged down and braced together with diagonal pieces at every angle, which will bind the whole together in the most substantial manner, and prevent fractures by unequal settlement.

"The distances of girders should never exceed twelve feet, and their scantlings must be proportioned according to their lengths; as by experience it is known that a scantling of 11 inches by 8 inches is sufficient for a fir-girder of 10 feet in length, the area of whose end is 88 inches, it is very easy to find the proper scantling for a girder of any greater length, suppose 20 feet, by this rule: As 10 feet, the length of the first girder, is to 88, the area of its end, so is 20 feet, the length of the second girder, to 176, the area of its end.

"Now to find its scantlings, that, being multiplied into each other, shall produce 176 inches, the area found, one of them must be given, viz., either the depth or thickness. In this example, the given depth shall be 12 inches, therefore divide 176 by 12, and the quotient is 14 inches and two-thirds, which is the other scantling, or breadth required."

In this example, the length is regarded; but in the first instance, in the dimensions of the given piece, he does not say which of them is the depth. This should have been noticed, as the strength of a piece of wood with its greater dimension disposed vertically, is to the strength of the same piece with its less dimension in the same position, as the greater dimension is to the less. Another uncertainty will arise from the proportion; for if the scantlings are not in the same ratio, the strength will be more or less in the one, as the vertical dimension may be greater in proportion to the horizontal than those of the other piece. Mr. Langley should have noticed this also. He has assumed 12 inches as the depth, then finds the breadth to be 14 inches and two-thirds, by dividing 176 by 12; but this is only guessing at the proportion, which might be properly stated by the rules of algebra, as follows: What two numbers are those, whose product is 176, and whose proportion is in the ratio of 11 to 8? Take x for the greater, and y for the less of the two numbers; then we have

$$xy = 176$$

$$x : y :: 11$$

$$8x = 11y$$

From the first equation we have

$$x = \frac{176}{y}$$

and from the second, $$x = \frac{11y}{8}$$

Therefore, $$\frac{11y}{8} = \frac{176}{y}$$

$$11y^2 = 1408$$

$$y^2 = 128$$

consequently, $$y = (128)^{\frac{1}{2}} = 11.3 \text{ nearly};$$

and by dividing by 11.3 inches, the depth, we should then have the breadth. We have here taken it for granted, that the former part of his proposition is true, but, indeed, nothing can be more erroneous; for their lengths are not in the ratio of the areas of their sections, when the pieces are of equal strength, but their lengths are in the ratio of the breadth multiplied into the square of the depth; or if their sections be similar figures, the lengths will be in the same ratio as the cubes of their vertical dimensions. By this method, if two pieces of timber were of the same thickness, and of equal strength, the lengths would be as the depths; whereas they are as the square of the depths. So that, besides the ambiguity of his rule, allowing the data to be properly fixed, the results would give the dimensions of the section much too great, in calculating from a given beam of less length to one of a greater; and much too small in calculating from a greater length to a smaller one. In calculating the strength of beams, it is material to recollect the loss of strength in large beams, occasioned by their weight, as the strength of beams is not in the same ratio with the stress occasioned by their weights, but in a much less degree: but as we shall hereafter discuss this subject, under the article STRENGTH OF MATERIALS, we shall for the present take leave of the subject, and return to our author.

"To prevent the sagging of short girders, it is usual to cut them camber; that is, to cut them with an angle in the midst of their lengths, so that their middles shall rise above the level of their ends, as many half inches as the girder contains times ten feet. And, indeed, girders of the greatest length, although trussed, should be cut camber in the same manner."

It may be proper here to notice, that the cambering of girders does not prevent them from sagging, though perhaps it may obviate their becoming concave on the upper side. With regard to trussing girders, the flitches should not be cut to a camber, but brought into this state in the act of trussing.

"The next order is joists, of which there are five kinds, viz., common-joists, binding-joists, trimming-joists, bridging-joists, and ceiling-joists. First, common-joists are used in ordinary buildings, whose scantlings in fir are generally made as follows, viz.:

Common joists, as used in small buildings.	
Length in feet.	Scantling in inches.
6	6½ by 2½
9	6½ by 2½
12	8 by 2½

In this table, it may be observed, the increase is not very regular: why should the scantling of the joist 9 feet in length, be no more than that of 6 feet? This must be a mistake

"But in large buildings, the scantlings are much larger, where it is common to make joists of the following dimensions:

Common joists, as employed in large buildings.	
Length in feet.	Scantling in inches.
6	5 by 3
9	7½ by 3
12	10 by 3

"As oak is much heavier than fir, it is customary to make the scantlings of oak-joists larger than those of fir; but I believe it to be entirely wrong, for the reason before given, relating to the strength of timber.

"Secondly, binding-joists are generally made half as thick again as common-joists of the same lengths;" and "are framed flush with the under surface of the girders, to receive the ceiling-joists, and about 3 or 4 inches below their upper surfaces, to receive the bridging-joists; so that the upper surfaces of the bridging-joists may be exactly flush or level with the girder to receive the boarding.

"The distances that binding-joists should be laid at, should not exceed 6 feet, though some lay them at greater distances, which is not so well, because the bridging and ceiling-joists must be made of larger scantlings to carry the weight of the ceiling and boarding, and consequently a greater quantity of timber must be employed. But, however, as this particular is at the will of the carpenter, I shall only add, that the scantlings for bridgings of fir, to their several lengths, are as follow:

Bridgings of fir.	
Bearing.	Scantling.
feet.	inches by inches
6	4 by 3
8	5 by 3
10	7 by 3

"Their distances from each other, about 12 or 14 inches."

He then proceeds with roofs, as follows:

"As the common method of framing the trusses of principal rafters of large roofs, is to lay the whole weight of the beam and covering upon the feet, they therefore should be secured at the beam with iron straps, to prevent their flying out, in case that the tenons should fail; but as I apprehend this method was capable of improvement, I therefore considered, that if under the lower parts of principal rafters, there be discharging struts framed into the beams and pricked posts, they will discharge the principal rafters from the greatest part of the whole weight."

This is certainly an improvement, but not of his, as it is to be found in Price's *Carpentry*, among his designs of roofs; it gives an additional security to the principal rafters, so that if the outer abutment should fail, the roof will still be supported by the inner one.

He gives the scantlings of fir-timbers in a roof, as follows:

Beams.	
Length.	Scantling.
feet	inches by inches
30	6 by 7
45	9 by 7
60	10 by 8½
75	10½ by 10
90	12 by 10½

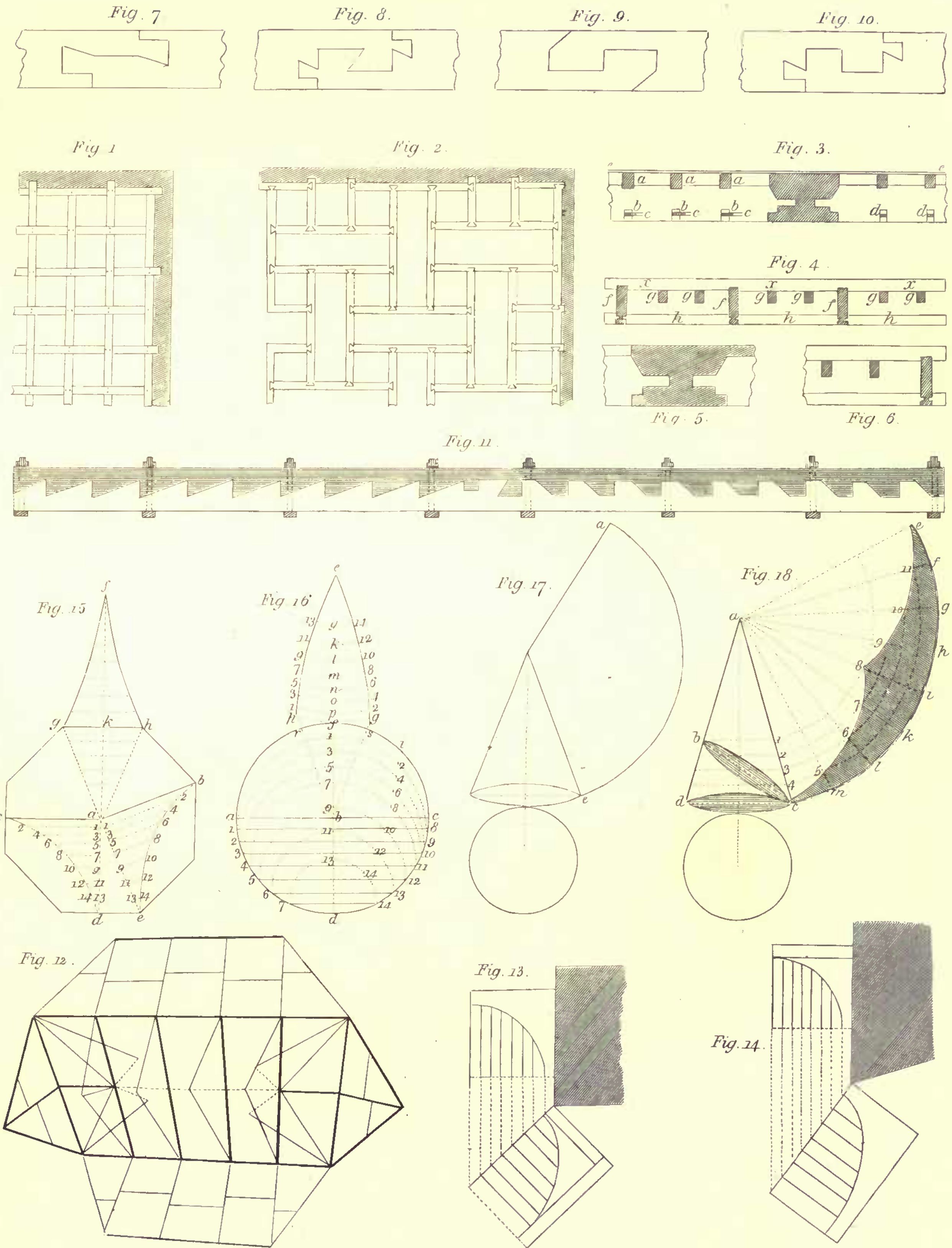
Principal Rafters.		
Length.	Scantling at Top.	Scantling at Bottom.
feet.	inches by inches.	inches by inches.
24	5 by 6	7 by 6
36	7 by 6	9 by 7
41	9 by 7	10 by 7½
60	10 by 7½	10 by 9
72	10 by 9	11 by 9½

Small Rafters.	
Length.	Scantling.
feet.	inches by inches.
8	4½ by 3
10	5 by 3
12	6 by 3

Besides the formation of the end of a purlin, attempted by Price, Langley also notices the bevels of the jack-rafters. We now come to the description of his diagrams.

"The *Figures* 1 and 2, *Plate* 9, are examples of floors made of short lengths, which I have given for the diversion of the curious."

These floors are of a similar construction with those shown in the works of Dr. Wallis. Godfrey Richards, our first author, has also inserted two kinds of floors of this nature, one constructed of hexagons and triangles, the other consisting of squares laid diagonally in respect of the plan, with a hexagon in the middle. These examples were executed at the old Somerset House, and were at that time a novelty in England. This species of naked flooring may be seen in the works of Serlio. It had its origin in Italy, and was thence transported to this country. Though from the principles of construction, the timbers mutually support each other, this species of joisting has not been found advantageous, either in saving of expense, or with respect to strength, but the contrary; it has therefore in modern works been discontinued.



Drawn by P. Nicholson.

Eng^d by R. Thew.

Figure 3, "represents the section of a girder; *b b*, &c., parts of two binding-joists, tenoned into the girder; *a a*, &c., the ends of bridging-joists; *e e*, boarding on the bridgings; *d d*, &c., mortises in the binding-joists to receive the tenons of the ceiling-joists; as also the mortises *b c*, *b c*, &c., but these last are those which are called *pulley-mortises*, into which the ceiling-joists are slid. To understand this more plainly, (see *Figure* 4,) the figures *f f f f* are added, which represent the sections of so many binding-joists; *g g*, &c., the sections of small joists between them; *x x*, a side view of a bridging-joist; *h h h*, ceiling-joists tenoned into the binding-joists, flush with their bottoms, as aforesaid, to receive the lath and plaster."

Figures 5 and 6 are parts of *Figures* 3 and 4, enlarged.

The joists *g g*, in *Figure* 4, add considerable expense, without being of adequate service.

Figures 7, 8, 9, 10, are scarfings shown in plate 50, of his work; but he takes no notice of them in the text, and indeed they are not deserving of it; we have already noticed those in Smith's work, to which these of Langley's have a near affinity.

Figure 11, represented in plate 53 of his work, is not noticed in the text, but the following words are written over the top of the figure: "A new method for trussing-beams, girders, &c., by Batty Langley."

The showing of such ridiculous constructions in carpentry, has certainly lessened the credit of this author, as permitting fancy to take the place of judgment, in cases where strength alone was the object.

Figure 12 is his method of laying roofs in ledgement; he only differs from Price in this particular, that he lays all the rafter feet next to the wall-plates, whereas Price lays them the contrary way. Price's disposition is more convenient in practice, but Langley's more natural for building up.

Figures 13 and 14 are his methods of tracing angle-brackets, and are the same in principle as that shown by Halfpenny, which was an example for a right angle. But Langley, always profuse in his figures, and pompous in his text, has not only shown the description of angle-brackets for right angles, but also for obtuse and acute angles, likewise for ovolos, cavettos, cimarectas, and cima-reversas, as if the same principle did not apply to all forms alike.

In *Figure* 15, his description is as follows: "The curvatures of hip-rafters to polygonal roofs, that is, those whose plans are polygons, are also found by transposing the ordinates of a principal rafter (which must be given) upon the base of a hip-rafter.

"Suppose in" (*Figure* 15) "*a d* to be the base, over which the cavetto principal rafter *c d*, is to stand: and let *a e* be the base of a hip-rafter: divide *a d* into equal parts, and draw the ordinates 2, 1; 4, 3, &c., on the line *a d*; divide *a e* in the same manner as *a d*, and on the line *a e* draw the ordinates 1, 2; 3, 4; 5, 6, &c., and from the point *b*, through the points 2, 4, 6, 8, &c., trace the curve of the hip-rafter, as required."

This disposition of confining the parts into one connected diagram is more obvious to learners than Mr. Price's, but even this of Langley's is not shown to the utmost advantage; for why divide the bases into equal parts, as this equality causes the curvature of the ribs and the curving sides of the covering to be divided unequally? Though the covering is shown in the figure, he has given no description of it in the text.

Figure 16, shows his method of covering niches or domes, explained as follows: "Let *a f c* be the plan of the head of a semi-circular niche, and complete the circle *a f c d*. Draw the diameters *a b c* and *d b f* continued out towards *e* at pleasure. Make *f r* and *f s* each equal to one-fourth of *a f*; then *r s* will be equal to half *a f*, and draw the lines *r b* and *s b*, divide *b d* into any number of equal parts, and draw the ordinates 1, 8; 2, 9; 3, 10, &c., and on the points where those ordinates cut the semi-diameter *b d*, with the radius of each semi-ordinate, describe semi-circles, as the dotted semi-circles in the figure. Make *e f* equal to the curve *a f*; make *f p* equal to *a* 1; *f o* equal to *a* 2; *f n* equal to *a* 3; *f m* equal to *a* 4; *f l* equal to *a* 5; *f k* equal to *a* 6; and *f g* equal to *a* 7. On the point *e* describe the arches 13, 14; 11, 12; 9, 10; &c. Bisect the half part of each of the dotted semi-circles, as *f c* in one; 1, 8, in two; 3, 9, in four; 5, 10, in six; 7, 11, in eight; 9, 12, in ten; 11, 13, in twelve; and 13, 14, in fourteen; make *f h* and *f g* each equal to half the arch *f i*; *p* 1 and *p* 2 each equal to half the arch 1, 2; *o* 3, *o* 4, each equal to half the arch 3, 4; and so, in like manner, *n* 5 and *n* 6, to the half arch 5, 6, &c. From the point *e*, through the points 12, 11, 9, 7, &c., and 14, 12, 10, &c., trace the curves *e h* and *e g*; then four such pieces as *e g h* will cover the head of the niche, as required."

This is certainly a very tiresome method, as each of the semi-circles must be divided into equal parts; but why divide each quadrant into two, which he has directed? as the more the parts, the truer the covering will be. If the arches *a d* and *c d* had been divided into equal parts, the covering could have been traced with more exactness, as there is a very long space beginning with the point *e*, without any guide, and is as much as the three lower spaces taken together: an equality of the parts in *a d* and *c d* would have been productive of the parts *c g*, *g k*, *k l*, &c., also equal to each other, and consequently the distances of the points in the curves *e h* and *e g*, though not exactly equal, would have been nearly so.

The description given by Mr. Price for the covering of domes, is defective; but his aim was at a much more convenient method than this of Langley's, which requires ample space, and is very troublesome and tedious in practice, without obtaining any greater accuracy. The reader must observe, that in strictness of principle, no flat surface, however thin, can be made to comply with a spheric surface; yet if comparatively a very small portion of the flat surface be taken, it may be made so nearly to coincide with the spheric, as not to be detected by the eye, which is as near as we ever need in practice; and thus the narrower the board, the more nearly will its surface comply with the spheric surface; but as we shall have occasion to speak of this in another place, we shall leave it for the present, and proceed to show his methods of finding the coverings of solids.

Figure 17, "represents the manner of covering the outside of a cone; the arch *e a* being made equal to the circumference *e*, which is equal to the base of the cone: this figure is exhibited here to show, that the soffits of a semi-circular headed window, whose splay is continued all round, is no more than the lower superfices of a semi-cone; for if the splay were continued, it would meet in a point."

In this respect he is right; but no covering can be more easy to conceive, except that of a right cylinder. The method of covering an oblique cylinder he never could obtain, as the edges which should coincide with the elliptic sections are all exhibited in straight lines. See Plate 74, at the end of his *Builder's Complete Assistant*; neither has he ever been able to obtain the covering of the ungula of a right cone, or of its complement when cut to produce an elliptic section, so that the edge of his covering may coincide with the said elliptic section, and its surface with the curved surface of the cone.

Figure 18. "The superficies of these frustrums are laid out as follows." "On *a* describe the arch *c m l*, &c. *e* equal to the circumference of the base of the cone, which divide into eight equal parts, at the points *m*, *l*, *k*, *i*, &c. and draw the lines *a m*, *a l*, *a k*, &c. Draw *b* 1, parallel to *d c*, and divide *i c* into four equal parts. Make *a* 5, *a* 11, each equal to *a* 4; make *a* 6, *a* 10, each equal to *a* 3; make *a* 7, *a* 9, each equal to *a* 2; make *a* 8 equal to *a* 1. Through the points 11, 10, 9, 8, and 7, 6, 5, trace the curves *e* 8 and 8 *c;* then the figure *c* 8 *e i c* is the superficies of the side."

What has the division of the line *i c* to do with the principle? This equality is not founded upon any part of the construction of the solid, and consequently the method can never obtain a true cover or envelope; indeed, it is so void of science as not to deserve any farther notice. In the next place, he attempts to find the envelope of a part of a semi-cuneoid, contained between two concentric cylindric surfaces, or of the covering or lining of the soffit of a window turned upon a centre, which has either an elliptic or circular section, everywhere parallel to its end, and to coincide with the superficies of a circular wall, or the head of an aperture splaying on the sides, and level at the crown. But are we now to expect that this will be accomplished, unless by accident, when he has already failed in obtaining methods for the description of much more simple envelopes, viz. for cylinders and cones cut obliquely? The reader will, however, attend to his description, which is as follows, and then judge for himself.

The descriptions of the following diagrams are equally deficient in method, and void of principle: his diagrams, also, are full of redundant lines. He begins the text without announcing the purpose of the operation, so that the reader must be kept in the dark till the conclusion.

Plate X. *Figure* 1. "*Of straight, circular, and elliptical arches in circular walls.*—The first work to be done, is the making of the centres, to turn these kinds of arches upon, which may be thus performed: Let G H I K be the plan of a circular building, and at *Figure* 6, it is required to make a centre for a semi-circular arch to the window, whose diameter without is *a d*, and within *n m*. Bisect *a d* in *f*, and describe the semi-circle *a p d*. Divide *a d* into any number of equal parts at the points 6, 4, 2, &c. and draw the ordinates 6 6; 4, 4; 2, 2, &c. Divide *n m* into the same number of equal parts, and make the ordinates 6, 5; 4, 3; 2, 1, &c. equal to the ordinates 6, 6; 4, 4; 2, 2, &c. and through the points 5, 3, 1, *k*, &c. trace the curve *n k m*, then *a p d* and *n k m* will be the two ribs for the centre: this being done, place the ribs perpendicular over the lines *a d* and *n m*, and cover them, as centres usually are, and then, applying the edge of a plumb-rule to the divers parts of the inside and outside of the window's bottom, the top of the rule will give the several points at which the inside and outside of the covering is to be cut off, so as to stand exactly over the inside and outside of the building, and then the centre will be completed as required."

It is hardly possible to conceive anything so unscientific as this description. In describing and forming the centre for the head of the required aperture, he is accurate; but when we are told to apply "the edge of a plumb-rule to the divers parts of the inside and outside of the window's bottom," and that "the top of the rule will give the several points at which the inside and outside of the covering are to be cut off, so as to stand exactly over the inside and outside of the building; and" that "the centre will be completed as required," he is altogether intolerable; for besides being tedious to an extreme, it is no more than every mechanic could have easily conceived. In forming the centre, it would be better to form the inside curve with a trammel, which would obviate the tedious work of dividing the base of each curve into equal parts, as well as the transferring of the ordinates of the semicircle to those of the ellipses, and then, at last, either tracing the elliptic curve by hand, or bending a thin slip of wood round pins or nails stuck in the points. At all events, even in the operation of tracing, the dividing of the bases into equal parts is a very bad practice, as it always leaves so large and so quick a portion of the curve at each extremity to be guessed at; but here it is admissible, on account of the following diagrams connected therewith.

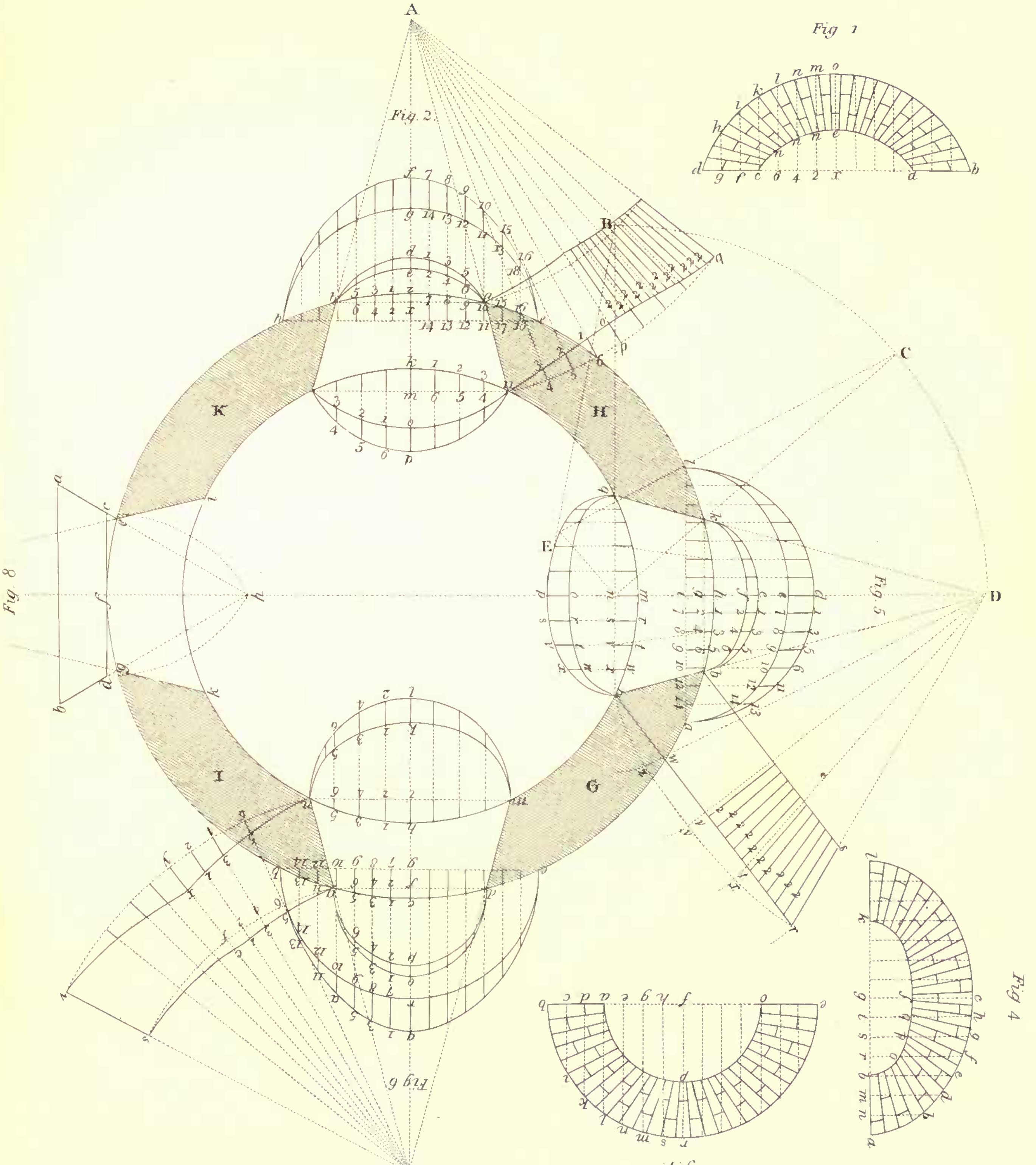
"*To divide the courses in the arch of this window.*—On a flat panel, &c. draw a line, as *b e*, in *Figure* 7, make *a f o* equal to the curve *a c d*, also make *a b* and *o e* each equal to the intended height of the brick arch. Make *f p*, in *Figure* 7, equal to *f p*, in *Figure* 6; also make *a b* and *o e*, in *Figure* 7, each equal to *b a*, in *Figure* 6; then the points *b* and *e* will be the extremes of the arch. Make *p r*, in *Figure* 7, equal to *b a*, the given height of the arch, and through the points *b r e* and *a p o* describe two semi-ellipses, which divide into courses as before taught, and which will be the face of the arch required."

This operation produces nothing, as he does not show its application to practice, in the formation of the stones or bricks to their proper shapes.

"*To find the angles or bevels of the under part of each course.*—Continue the splay backs of the window *m d* and *n a* until they meet in F. On F, with the radius F *n* and F *a*, describe the arches *n y v* and *a f s*, making *n y v* equal to the girt of the arch *n k m*. Make *n* 6, *n* 4, *n* 2, *n y*, &c. on the arch *n y v*, equal to *n* 6, *n* 4, *n* 2, *n y*, &c. on the curve *n k m*, and draw the lines 6 F, 4 F, 2 F, *y* F, &c. Make the ordinates 6, 5; 4, 3; 2, 1; *y x*, &c. on the lines 6 F, 4 F, &c. equal to the ordinates 5, 6; 3, 4; 1, 2; *h i*, &c. on the line *n m* and through the points 5, 3, 1, *x*, &c. trace the curve *v x n*. In the same manner transfer the ordinates 5, 6; 3, 4; 1, 2; *c f*, &c. on the line *a d* to the arch *s f a*, as from 5 to 6, from 4 to 3, &c. and trace the curve *s c a;* and then will the figure *n x v s c a* be the soffito of the window laid out, and which being divided into the same number of equal parts, as the under part of the arch *a p o*, *Figure* 7, and lines drawn to the centre F, as is done in *Figure* 2, to the centre A, by the line 2, 2, 2, &c. those lines will give the bevel of every course in soffito, as required."

Here is an attempt to find the lining or envelope of a cuneoid or cono-cuneus, in a circular wall, for the soffits of the stones or bricks; and had he succeeded, his endeavours would have been so far right: but the method which he follows has no relation to the construction of the centre itself, and is therefore extremely erroneous. Nor can the same method be applied to the covering of a cone, though the affinity or relation is much nearer in the latter solid than in the former, and, consequently, the envelope here found would cover a cone more nearly than the surface of a cuneoid. But, indeed, though very near approaches have been made to the cuneoidal surface, its determinate figure has never been exactly shown on a plane: however, the geometrical construction may be laid out on the surface of the solid itself, and all curves, corresponding to given ones on the plan, found with the utmost accuracy. The other parts of *Figure* 7, are not described in the text, but seem to contain lines without meaning. The following is all that is said of *Figures* 1, 2, 4, and 5:

Figure 5 "is another example of a semi-elliptical arch, whose front is *Figure* 2. Also *Figure* 4, is a third example of a scheme arch, whose front is *Figure* 8. And *Figure* 1, is a fourth example of a straight arch, which, in general, are performed by the aforesaid rule."



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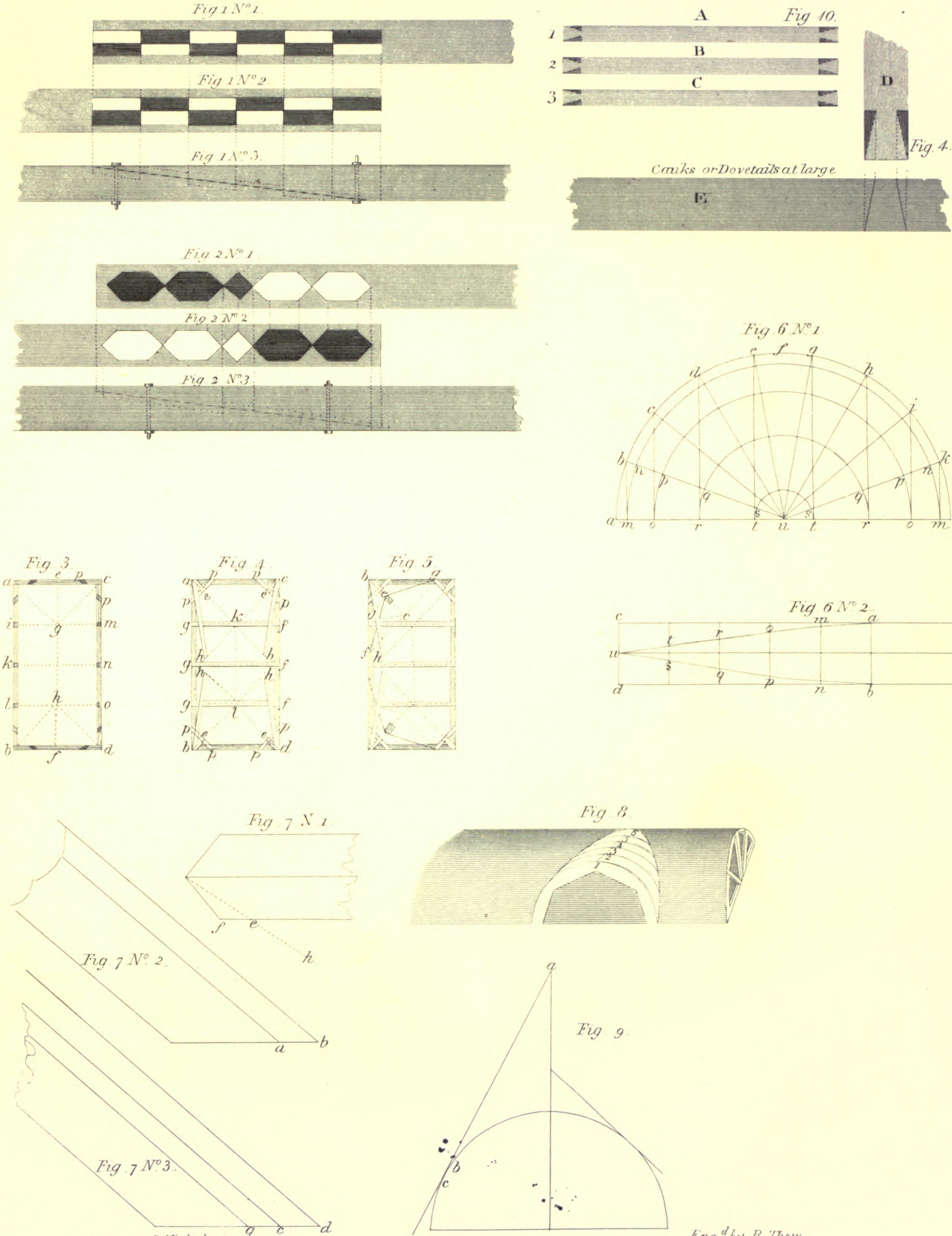
CARPENTRY

PLATE XI

The Splicing or Lengthening of Beams explained.



Drawn by P. Nicholson.

Eng.d by R. Thew.

Here the text is unintelligible, and the discovery of the principles, by inspection, still more so.

Passing from the *The Builder's Complete Assistant*, we come next to *The Builder's and Workman's Treasury of Designs*, by the same Author. The portion of this work which treats of carpentry, is contained in an appendix at the end, consisting of fourteen plates.

In *Plate* XI. *Figures* 1 and 2, Nos. 1, 2, 3, of each Figure, are shown two methods of lengthening beams: but there is no other description than what is exhibited at the top of the plate, viz., "The splicing or lengthening of beams explained."

The two pieces are tabled together, by a very different method to what any former author has exhibited. The tables are concealed, showing on the outside, when bolted together, as in No. 3 of each Figure, an oblique continued joint. The construction is ingenious, as it prevents their separation without breaking the tables by a longitudinal strain; but the difficulty of fitting them together with accuracy, and the tedious process, renders them unfit for practice.

Langley's *Geometrical Principles of Roofing* are similar to those of the preceding author; but for the sake of showing the terms applicable to different purposes, and his method of treating the subject, we shall extract a few of his descriptions: "*a b c d* (*Figure* 3) plan of the raising; *e f* the central line; *i m*, *l o*, base lines of the outward principals, *a g*, *g c*, *b h*, *h d*, base lines of the hips; *g h* base of the ridge; *k n* base line of the middle pair of principals; *e g*, *h f*, base lines of the single principals, which meet the hips in the points *g h*; *i k l*, *m n o*, dovetail mortises in the raising, to receive the *dovetails* or *cauks* 1, 2, 3, of the beams A B C; (*Figure* 10) *p p*, dovetail mortises to receive the *angle-braces*, as *p*, *p*. *Figure* 4. D, a cauk or dovetail at large; E, the dovetail-mortises in the raising, to receive the dovetail or cauk D."

Figure 4. "*a b c d*, plan of the raising; *f g*, *f g*, *f g*, beams *cauked* down on the raising; *p p*, *p p*, &c., *angle-braces cauked* down in like manner; *a e*, *b e*, *c e*, *d e*, *dragon-pieces* to receive the feet of the hip-rafters; *a h*, *b h*, *c h*, *d h*, hip-rafters; *a h k*, the angle at the top; and *h a k* the angle of the foot of the hip *a h*."

Figure 5. "*To find the angle of a hip in any regular or irregular building.*—RULE. On any part of its base line, as *c*, draw a right line at right angles, as *f g*; set up the hip, as *h b*, and from *c* draw *c d* perpendicular to the hip *h b*; make *c e* equal to *c d*, and draw the lines *f e*, *e g*; then the angle *f e g* is the angle of the back required."

These descriptions are tolerably clear; the technical terms used by him, are *raising*, *base-line*, *hips*, *back of the hip*, *principals*, *dovetail-mortises*, *cauks*, *angle-braces*, and *dragon-pieces*. *Raising* is used by Moxon, in his *Mechanical Exercises*, but is vaguely defined by that author; *base-lines*, *hips*, *back of the hip*, and *principal rafters*, are used by Godfrey Richards, in his *Constructions of Roofs*, in finding the lengths and backings of hip-rafters. This last-mentioned author names the diagonal beams under the hips, *dragon-beams*; Langley calls them *dragon-pieces*. What Langley spells *cauks*, Price spells *cocks*. *Angle-braces* are not, that we have observed, named by any author before Langley, who also names *jack-rafters*, in Plate 5, of his *Builder's and Workman's Treasury*.

There is a work, not mentioned in the list of authors, by Edward Oakley, Architect, which, in point of priority, ought to have stood even before Smith's *Carpenter's Companion*, it being dated in the title-page 1730: another work was likewise published by Edward Hoppus, Surveyor, the second edition of which, as appears from the title-page, was published in 1738; when the first edition was published we do not know, but probably about the same time as Oakley's, or before. With respect to carpentry, these two works are nearly alike, as to the number of the problems, their order, the method of treating them, and the end intended; one seems to have been copied from the other, and the first of the two to have been taken from Halfpenny's *Art of Sound Building*, with the exception of a problem, which is exhibited in a plate, and explained in each of these authors, for covering of the head of a niche or dome, with boards, to bend with their joints in vertical planes, passing through its axis. This problem is thus explained by Oakley:

Figure 6. "*To make a niche or globe, with thin boards; or to cover them with paper or pasteboard.*—Admit *a f l* (No. 1) to be the plan of a semi-circular niche; *c e f d* (No. 2) to be the board, paper, or pasteboard, of a given width, *c d* or *e f*. Divide the semi-circle *a f l* into equal divisions, according to the breadth of (No. 2) as *a b*, *b c*, *c d*, *d e*, *e g*, *g h*, *h i*, *i k*, and *k l*; draw the lines, *b u*, *c u*, *d u*, *e u*, *g u*, *h u*, *i u*, *k u*, and let fall perpendiculars on the line *a l*, from the points *b*, *c*, *d*, *e*, *g*, *h*, *i*, *k*. Upon the centre *u*, with the intervals, *m*, *o*, *r*, and *t*, describe semi-circles; set the girt of the arch *a f* or *f l*, on the board, *g c*, (No. 2) as *c a* and *d b*, which divide into so many equal parts as there are semi-circles, as in (No. 2.) Divide (No. 2) in the midst, as by the line *u w*; take the arch *a b*, and set it equally on each side of the line *u w*, as at *a b*; set the arch *m n*, in like manner, on *u w*, as at *m n*, and so on to *t s*; then by sticking in small tacks at the points *a*, *m*, *o*, *r*, *t*, and *u*, on the one side of *u w*, and at the points *b*, *n*, *p*, *q*, and *s*, on the other side of *u w*, by applying a thin ruler from *a* to *u*, and *b* to *u*, the curve lines on each side will be given, which may be described by a pencil, &c., which is the true mould for every piece in a globe or niche, which was required."

Here it must be observed, that the division of the semi-circle (No. 1) is erroneous; for if the quadrant *a f* or *f l* be considered as a vertical section of the dome, it is evident it should have been divided into the same number of parts as the length of the board (No. 2;) and the several lengths of the one equal to those of the other; but *a f* or *f l* is only divided into $4\frac{1}{2}$ equal parts, while the board is divided into 5; which inequality causes the board to be too narrow towards the top, and to swell out too much at the bottom, as shown in the following figure.

In *The London Art of Building*, written by Salmon, there is nothing new in construction. His geometrical principles of roofing are like those by Godfrey Richards; besides which, he treats of no other subject, except a few designs of roofs.

The British Architect, the production of Mr. Abraham Swan, is not very abundant in curious constructions of carpentry, yet there are some ideas worthy of notice.

Figure 7, No. 1, "Shows the backing of the hip." "Divide the thickness of the hip into two equal parts; then having found the pitch of your hip, as is shown in (No. 2) set one of these parts upon the base line, from *b* to *a*, and it shows what wood is to be taken off.

"If the side of the building comes in with a bevel, as the dotted line *h*, in (No. 1) then transfer half the thickness of the hip, from *d* to *c*, in (No. 3) and take the distance *f e*, in (No. 1) and set it from *c* to *g*, in (No. 3.) This will show how much is to be taken off the hip, when the building bevels."

It is strange that this author should have departed so far from Pope's scientific method, as first shown by Godfrey Richards, in order to adopt one so mechanical, more liable to inaccuracy, and less expeditious.

With respect to groins, all that Swan has said on this subject, is contained in the following words:

Figure 8, "exhibits an arch boarded over, wherein the several figures 1, 2, 3, &c., represent so many ribs, or jack-rafters, set upon the circular body of the arch, in order for another arch to intersect it, where those boarded over the groins are formed." We learn nothing from this, but the manner of placing the jack-ribs on the body of the arch. Price describes the method of placing these low ribs upon the boarding, and calls them *small centres;* but his diagram is different, and not near so clear.

In the boarding of domes with the joints in horizontal planes, Swan has shown the first ideas of the subject: *Figure* 9, "represents a circular body. *To find the curve of any lath or margin to be bent round this body, parallel to its base.*

"Let the points *b* and *c* represent the margin which you intend to bend round; then draw a right line through these points, to meet the perpendicular or diameter produced, as in *a*, and it gives the length *a b* the shorter, and *a c* the longer radius for striking the curve required."

This author has nothing more of novelty in the art of carpentry.

Our next author is Mr. William Pain. In his *British Palladio*, he shows the methods of his bracketing for coves, and plaster cornices, as follows: *Plate* XII. *Figure* 1, "D is an angle-bracket for an internal angle, which are (is) traced by ordinates." *Figure* 2, "E is an angle-bracket for a plaster cornice, at an internal angle; F, an external angle, allowing one inch for lath and plaster." The formation of angle-brackets is so easy, that a very little reflection, on inspecting the figure, will show the method adopted, without description: but still something more might have been said on the practical part.

From *The Builder's Golden Rule*, the following diagrams, with their descriptions, are taken. "*The backing of curve-line hips, and tracing them.—Figure* 3, (No. 1) is the rib of a dome, and (No. 2) is the hip traced from it. Divide the given rib (No. 1) into five parts, on the base line, and draw the ordinates 1, 1, 2, 2, 3, 3, 4, 4, 5, 5; then divide the base line of the hip into the same number of parts; take them from (No. 1) and set them on (No. 2); then tack in nails at the points 1, 2, 3, 4, 5; bend a thin slip round, and mark as that curve directs, which gives the hip-mould. To back the hip, take from (No. 3) the plan of the hip, 1, 2, and set it on the hip at the bottom 1, 2; then shift the hip-mould to 2, and out to the top: mark it by, and that will be the wood to come off for the backing of the hip." The practice of dividing the base of the given rib, and the base of the required rib into equal parts, was first shown by Halfpenny, and now by our present author, Pain; and though the principle is true, the practice is bad, as it leaves so great a portion of the curve to be traced by the eye, where it rises from the base; and though it is not necessary that each base should be divided into equal parts, or into any series of parts which shall have a given proportion to each other, yet it would be better to divide the curve of the given rib into equal parts, then divide the base of the required rib in the same proportion; and the arcs of the required rib terminated by the upper extremities of each two ordinates, will be very nearly, if not quite, proportional; that is, the distance between the tracing points will be nearer where the curve is quickest, and where the greater number of points are most required.

Figure 4, shows "the backing for a straight hip. You are to observe that the piece of wood be of the same thickness as the hips, and form of the curve, for the little part you want; then cut it to the pitch of the hip at foot, set it on the plan, and mark it by that, which will give the backing exactly; and so for any other. Or, if you draw a line parallel with the base line, and take off 1, 2, on the plan (No. 2) and set it on the said lines 1, 2, all the way up, and mark by the mould, it will give the backing in any case required, straight or curved."

This general and correct principle was first noticed by Price.

Figure 5. "*The method of coving the angles, when there is a circle or oval in the centre of the ceiling.*—Draw the centre part, touching the sides and ends; then draw another to the extreme of the angles, parallel with the centre; then draw the semicircular arch A, and from that trace the side arches B, B, and the rib C, C, C, C, which is a mould to cut all the brackets for the angles; as is plain to inspection by the lines on the plan."

This principle is erroneous, and the description deficient. There is no respect paid to the elliptic base; but the brackets are traced upon the principle of angle-brackets. The sections of any body must depend upon the construction of that body, or upon its properties; thus, if a body is intended to have this property, that all parallel sections are to be similar figures, and if the method of forming it is not founded upon this principle, the body is not what it was intended to be, but something else; the construction will therefore be erroneous. All sections of a body must be found by describing the seats of the curves of as many parallel sections as may be thought sufficient, on one of the largest of them; then having a given or transverse section, that will cut all the parallel sections of the body, all other sections whatever may be found: but our author, Mr. Pain, forms the section of all bodies like those of prisms, without attending to the properties of the body required, as is the case in the example before us.

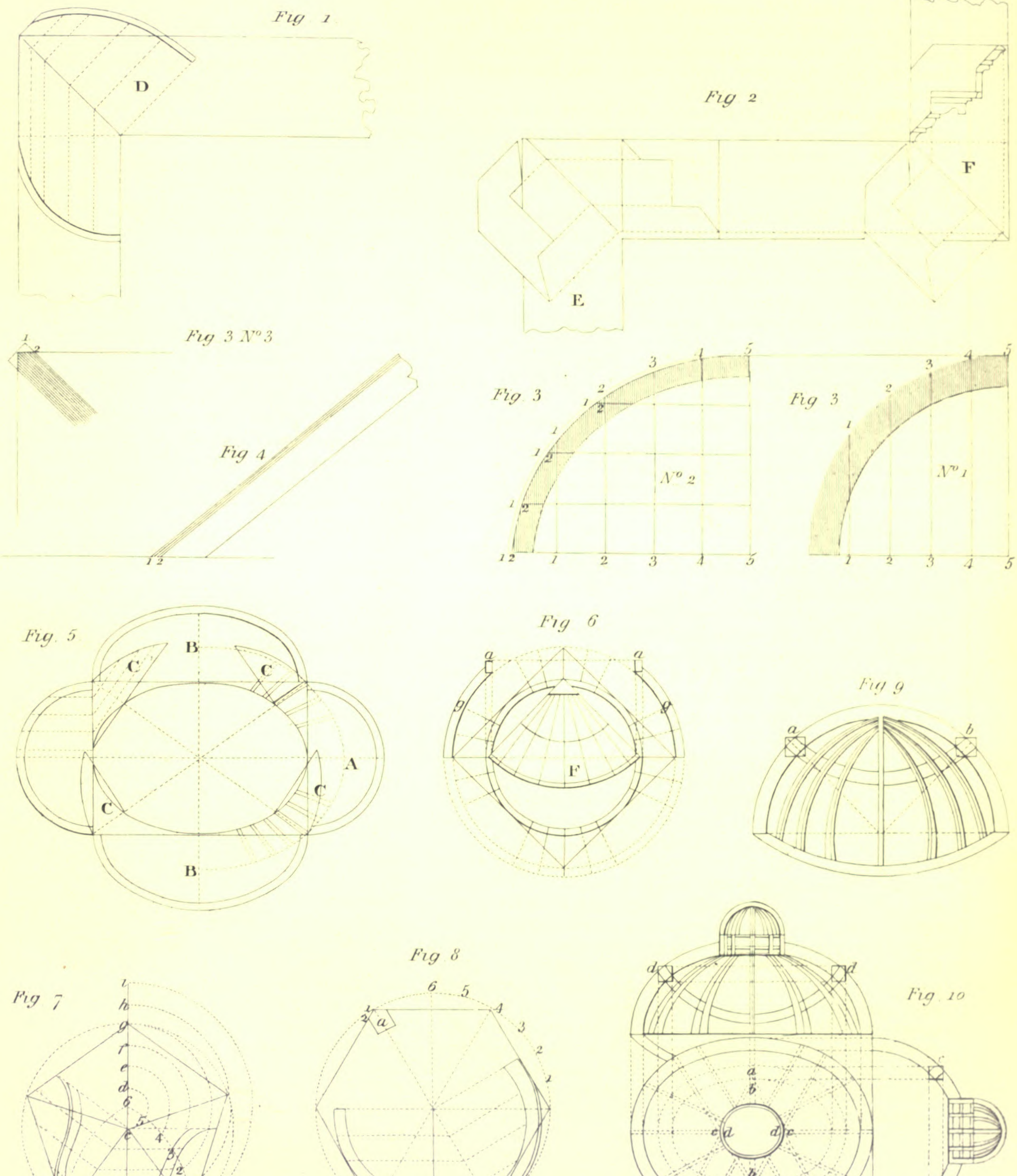
In the first edition of his *Practical House Carpenter*, he has presented the diagram of an interior circular dome, formed into pendentives by bracketing the spandrels above, and traced according to the same erroneous principle: but after the publication of the *Carpenter's New Guide*, by the author of this Work, the error was corrected, in the second edition of the said *Practical House Carpenter*, so as to correspond with the legitimate principle, first published in the *Carpenter's New Guide:* his description, which is very short, is partly contained in the text, and partly on the plate: in the text, he says, *Figure* 6, "is a conical skylight, showing how to bracket the angles of the ceiling under the kirb, the hip-mould *g* at the angle is traced from the rib *b*, and that mould would do to cut all the ribs at the angles, as shown at the angle *a*."

What is here said, refers to the diagrams in the first edition; but the text stands in the sixth edition, as in the first, though the diagram is altered in the second and succeeding editions. There is no rib *b*, nor angle *a*, shown on the improved diagram. On the plate he writes thus: "F dome with a skylight on the top. *g*, *g*, moulds for the ribs of the dome; *a*, *a*, the kirb of the light." This latter description refers to the diagram as it now stands.

The skylight on the top is exhibited in a very erroneous manner, being inconsistent with the principles of any kind of projection that we are acquainted with. The plan of the bracketing, and the ribs of the domical part, are shown by a common ichnographical projection, while the skylight is exhibited in a kind of false perspective, and being without any connection with the kirb on which it is placed, it has the appearance of being raised upon its edge, resting upon two points in the kirb.

Figure 7, "is an ogee roof, whose plan is a pentagon, and shows the method of drawing the polygon figure to any given side; make a radius of that side, and draw the arches 2, 6; divide one of these arches into six parts, and turn them to the centre line, as shown by the letters and figures 5 *d*, 4 *e*, &c.; the centre *c* will draw a circle to receive the side 5 times,

PLATE XII.



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6 is the centre to receive the side 6 times, *d* seven times, and so on to *i*, which is the centre to draw the circle to receive the side twelve times."

This problem should have been classed in practical geometry, as it has no reference whatever to carpentry. It is only true in the hexagon and dodecagon, and is very incorrect for the description of polygons upon a given straight line, which have fewer sides than six. In his diagram, he shows the method of describing the hip from the common rib being given; but the text contains no description of it.

Figure 8, "is a dome, whose plan is a hexagon, and shows how to divide a circle into any number of parts: divide one-fourth of the circle into the number of parts you would have the circle, as, 1, 2, 3, 4, 5, 6, and always take four of them. To find the backing of the curve-line hips, lay down the plan of the hip at the angle, as *a;* then take the distance 1, 2, at bottom, tack in a nail, then shift the hip-mould, and marking by it, as 1 2, 3 4, 5 6, 7 8, 9, 10, will show the wood to come off." In this description, Mr. Pain proposes to find the division of a circle into any number of parts; but as he does not mention any fixed ratio of these parts, they may be taken at pleasure, without rule; but allowing that he had neglected to name this condition, under which the circle was to be divided, and suppose that he meant the parts to be equal, and to be found by a general method; there is no regular rule of performing this problem but by an approximation. If we allow that the quadrant can be divided into equal parts, we must also allow that the whole circle will contain four times that number of parts; but the division of the quadrant into equal parts is equally impossible with that of the whole circle; the rule is therefore absurd, and consequently it is only accomplishing one absurdity by another, and wasting the reader's time to no purpose. In this problem, as in the last, he has also neglected to inform his reader how the hip is found, though it is sufficiently clear on the plate to present the idea of forming it to any intelligent person.

Figure 9, "is a dome on a circular plan; *a* and *b* show the section of the horizontal rib."

Figure 10, "is a dome on an elliptic plan; the centres for the mould of the horizontal ribs *d d*, are *a a*, *b b*, *c c*, *d d;* the place of that rib on the plan is found by dropping dot lines from the sections *d d: c c* on the top, is designed for a skylight." These descriptions are unintelligible.

Plate XIII. *Figure* 1, "shows the method for cutting the boards to cover the dome; divide the dome into as many parts as you think it will take boards, and draw lines to cut the edges of each board, and where they meet the centre line, that is the centre for the edge of each board. This is drawn one inch to a foot." This has already been shown and described by Swan, but he is deficient in not representing the boards as Pain has done; the description of the former, however, though short, is much clearer than that of the latter.

Figure 2, is taken from the *Practical House Carpenter*, but the description is to be found neither in the text nor on the plate. It must therefore be left to the sagacity of the reader to find it out. We suppose the diagram to represent the method of covering a dome by bending the boards with the joints on vertical planes passing through the axis. This method has already been shown by several of the preceding authors, of whom Price and Langley are the most accurate, and differ most as to the mode of ascertaining the form of the board, but come to the same result at last.

Oakley, Hoppus, and Price, perform the operation by straight ordinates, whereas Langley and Pain do it by curved ordinates: one method ascertains the form with as much accuracy as the other, but the operation with straight ordinates requires much less trouble than the other. Pain even shows many more lines than are sufficient, which superabundance makes his diagram much less intelligible to the understanding of his reader. The concentric arcs, which he has used as ordinates, are erroneous in principle, though the use of them does not affect the practice, as we shall here show.

Figure 3. "Let A D C be half the section of a dome passing through its vertical axis; divide the curve A B into as many equal parts as the number of boards of which the covering is to consist; through each point in the circumference draw a line to the centre C; and through each of the same points draw another line at right angles to the respective radii, and produce them upwards, as also the axis C D, so as to cut each of the tangents from the several points in the curve; then each of these tangents, so limited, are the radii of the successive ordinates; the tangent at the bottom is of infinite length, the next is limited, and the succeeding ones become gradually shorter and shorter, till the tangent and the arc become nearly of one length. So that the ordinates of the board exhibited in *Figure* 4, are arcs of radii, respectively equal to the tangents; consequently, the bottom ordinate of the board is a straight line, the next is the arc of a circle of a very flat curvature, the next is an arc of greater curvature, and so each arc becoming quicker and quicker in its curvature, till they reach the summit of the board, which is the last centre."

The most eligible method in practice, founded upon evident principles, is to suppose the dome to become an equilateral and equiangular polygon, and suppose the axal section A B C, *Figure* 5, perpendicular to one of the sides of the dome to be given, and the curve A B to be divided into equal parts, and suppose the parts to be extended upon B C produced; then, if lines be drawn through the divisions of the curve, and through the points of division in C B, produced perpendicular to the said B C; and if B D be drawn perpendicular to B C, equal to half the width of a board, and D C joined, and the ordinates produced so to meet D C; then, if the lines parallel to B D, contained within the triangle B D C be successively taken towards C, and applied on the perpendiculars from and on each side of C D produced; then if curves be drawn through the points at the extremities, they will terminate the edges of a board, which will accurately cover a side of the polygonal dome.

Let us now suppose the number of sides of this dome to be very great, then the sides will vary only in a very small degree, either from the inscribing or circumscribing sphere, and this variation will decrease as the number of sides is increased, and the excess or defect would become insensible; and if we suppose the sides to be infinite, the board which covers the side of the polygonal dome will accurately cover the inscribing or circumscribing spherical dome. This latter method is founded upon principle, but that of forming the bottom ends of the boards into curves is totally destitute of it.

Figure 6, from Pain's *British Palladio*, which he says, "is a pentagon to be covered with a domical roof. To find the curve of the boarding, divide the girth or curve of the rib on the back into as many parts as you please, as here into four, and draw them to the base-line of the rib *e a*, as 7, 8, 9; stretch out *a b*, the middle of the side, and 9 9, 8 8, 7 7, parallel thereto; then take one of the divisions on the girth of the rib, and set off from *e* to 7, 8, 9, *b*, and where that cuts the lines 7 7, 8 8, 9 9, *b*, there tack in nails, and bend a thin slip to the nails, and mark from *e* to *b*, as that curve directs; this will be one edge of the covering: prick these marks on the other side of the line *a b*, and proceed as before; then will the covering or boarding be complete. The covering or boarding of (*Figure* 7) is found in the same manner, which is very plain to inspection; the girth of" the "rib being stretched out, and the parts set on as above directed."

When he says, "stretch out *a b*, the middle of the side, and 9 9, 8 8, 7 7, parallel thereto," he is not intelligible; however, if we understand that *a b* is drawn at right angles to the side *e d* of the polygon, and 9 9, 8 8, 7 7, drawn parallel thereto, the method which he uses will be found to be correct, and, we believe, original.

Figure 8, "shows the method for getting out the veneer, or cover for an elliptical dome or niche. Divide the circumference of one quarter of the plan into any number of parts, as here into 8, and draw them to the centre 4; let the first line from the transverse diameter be the edge of the veneer; the second line will be the middle of the next veneer; the third will be the other edge of it, and so on: continue this line out at pleasure: consider this line as a base, and draw thereon a section of the dome, as No. 1; then divide the circumference into four parts, draw them to the base-line at right angles, and transfer those distances to the corresponding line on the plan; then take the four parts on the girth, and run them on the line stretched out, 1, 2, 3, 4, this will be the length of the veneer; set the compasses on the plan, and strike a curve-line of this radius; then continue the middle line of the veneer, and where it intersects, that curve-line will be the point of veneer next the top of the dome; from this point set off the divisions 1, 2, 3, on the circumference by curve-lines; then take the width of the divisions 1, 2, 3, from the middle line of the plan, and set them on the same line stretched out to cut them at their respective distances, the points of intersection will be the breadth of that side of the veneer; connect them by a curve-line from the plan to the point, and you have one edge complete. For the veneer on the transverse diameter, this edge will serve as a mould; or you may set the half of the veneer to the other side of the plan, and draw a chord-line from these points; set this off that distance of the arch (the little curve) to be outside, and draw a line parallel to the chord-line, on which set off the breadth of the veneer on both sides, then with the whole length of the other veneer in the compasses, set one foot on that breadth, and strike a curve-line to cut the middle line on the transverse diameter; or repeat the curve from the other side, and where they cross will be the point of that veneer, from whence set off the divisions, and proceed as before. But as the radii of an oval are of different lengths, to get the other edge of the veneer, make a section as before, (see No. 2,) and set off, as before, the divisions on the base and plan, and strike the divisions on the girth, from the point of the veneer stretched out, intersect them from the plan, and those points connected will give the other side of that veneer, which will be a mould for the next adjoining; proceed again for every veneer by transferring that length from the plan, and the shortest length from the point; repeat the same operation for every veneer required.

Note. "The conjugate and transverse diameters will have the two sides of the veneer equal. Observe, only four parts are used, to prevent confusion in the figure; but the greater number of parts, the truer the line. Again, if your boards will suit, divide the plan to their number, and proceed as before for every board respectively."

This method is so absurd in every particular, that the coverings obtained are erroneous in the greatest degree; indeed, it leaves no room for argument, and we shall only observe, that in the true form of the boards, between the extremities of the greater and less axis, in any one of the four quarters, one side of the board would be concave and the other convex, where the dome has a considerable difference in its axis; and the greater this eccentricity or difference, the greater will be the degree of curvature of the concavity and convexity of the sides of these boards.

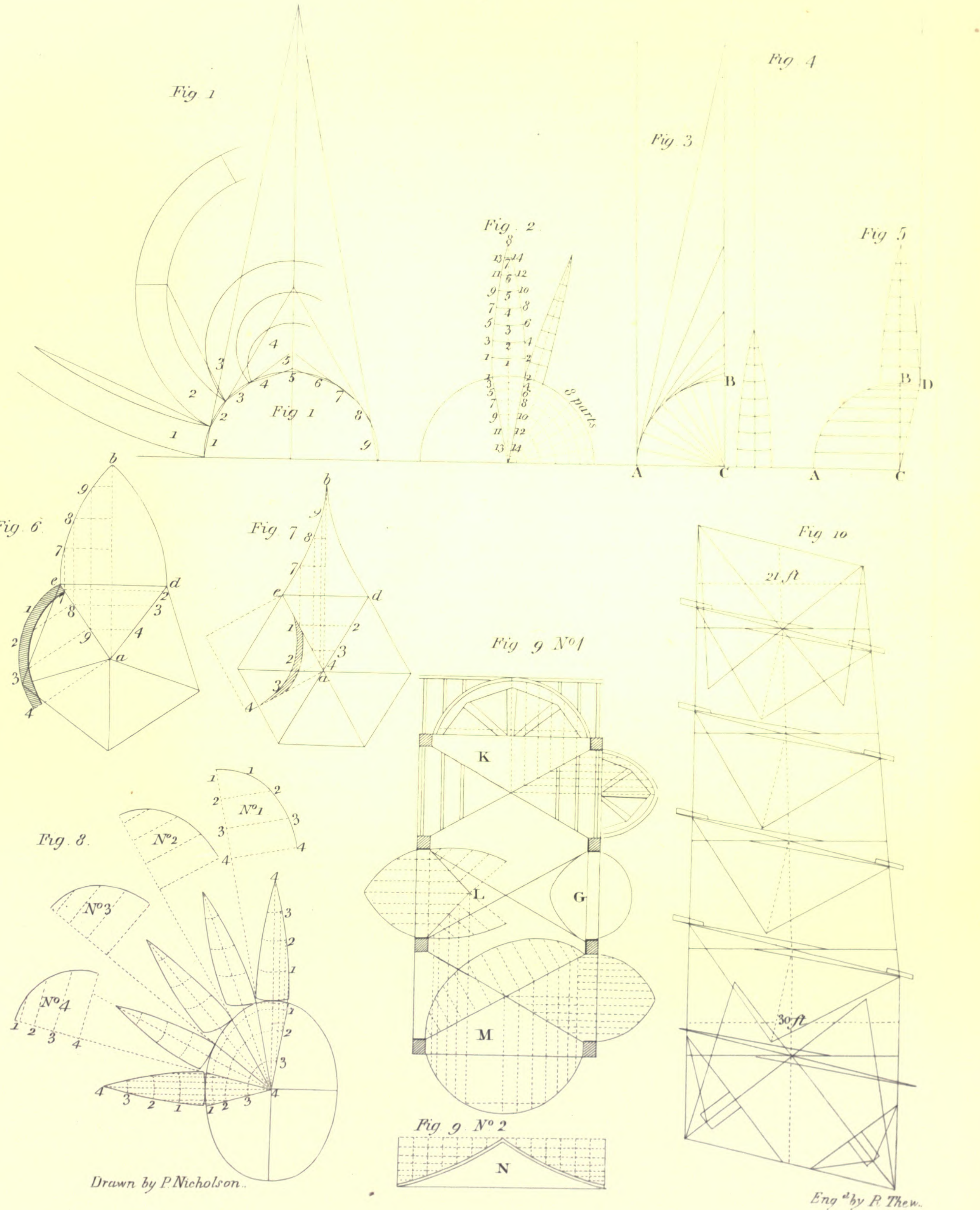
Figure 9, No. 1, shows groins and arches, of different descriptions, from the *Practical House Carpenter*. Pain divides this figure into several others, and distinguishes them by letters of the alphabet. He only gives the following description on the plate: "K centering for groins. L is a half groin cutting under pitch, for a door or window. G a Welsh groin cutting under pitch. M is the method of tracing the ribs and hips for a groin ceiling." *Figure* 9, No. 2, "N is a mould to bend over the body range; K to get the lines to set the jack-ribs by." The reader who has not already acquired a competent knowledge of geometrical lines, will profit but little from this description. The showing of the jack-ribs upon the diagram is an improvement. Swan has shown them perspectively, but the geometrical method of representing them is more serviceable to the workman, as it shows the lengths of the ribs distinctly. He observes that "G is a Welsh groin cutting under pitch," but he does not show how the crooked line, which he has exhibited, is obtained; and even if he had shown it, the method of constructing the rib would still have been wanting. In the mould N, for groin-centering, in order to find the place, or curve-lines, on the boarding, for fixing the jack-ribs, he has given no description, either in the text or on the plate, except that he writes, "the arch line *a* stretched out," and "half the base-line *b*," upon the respective sides; and, consequently, we have no other instructions to inform us how the mould N is found, than by inspecting the figure itself, and tracing out the operation by the connection of the lines; and even then we are left in the dark as to its application. The moulds for groin-centering upon this principle, were first shown by Price, as well for finding the angles of the jack-ribs, as the form of the boarding.

Figure 10, from the *Practical House Carpenter*, "is a bevel roof; the sides are parallel on one part of the plan, the other bevels. To frame this roof in ledgement, the principal rafters must be framed to a level base; that is, the ends of the beams all of one height from the face of the plate; when you come to lay them the other way, to frame in the purlins, there must be winding sticks held to the bases of the rafters, which winding sticks must be all out of winding; and as the width of the building diminishes, the backs of the rafters will lie in winding, as they will when in their places; and mind that they are backed according to the bevel of the plan, for turning them up to tumble in the purlins; by this method the business may be well completed." Allowing that the heels of the rafters are cut to their proper bevels with the backs, the application of winding sticks to such short distances will never make the sides fall accurately into their proper winding. This is altogether a mechanical operation; but it would have been no difficult task to have shown an operation strictly geometrical.

The foregoing remarks will be found to contain a fair and impartial statement of the geometrical improvements and errors of the several writers on Carpentry, at least as far as they have come to our knowledge: we shall now, in conclusion, draw a general result from the whole of their theories, and endeavour to trace the progress of the art towards its present state of comparative perfection.

The method of bracketing hip-rafters, which is said to be the invention of a Mr. Pope, of London, was originally presented to the public by Godfrey Richards, who also first represented roof in ledgements, in order to ascertain the several lengths and angles which the rafters make with each other.

The use of the trammel in common cases; the description



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of a curve through points, by bending a lath, or slip of wood; cove-bracketing, and the construction of ribs in groined ceilings, disposed in vertical planes, were first shown by Halfpenny. In the latter, however, he divides the bases into equal parts, in order to place the ordinates, which is inconvenient; for the equi-distance of the ordinates leaves a very large portion of the curves at each extremity, where they are quickest, to be traced only by the eye. This writer also first described the formation of spherical and spheroidal niches, upon semi-circular and semi-elliptic plans, with semi-circular and semi-elliptic faces, under the names of *semi-circular* and *elliptic niches.*

To Price we owe the mode of framing roofs in ledgement, with all the beams and rafters laid out on a plane; though it must be remembered that the general outline had been previously described by Godfrey Richards. The squaring of the purlin of a circular dome, and of a conic roof or skylight; the backing of angle-brackets (and consequently of ribs in general) by shifting the mould of the rib; the ordinary construction of groin-centering, and moulds for drawing the diagonal lines at the feet of the jack-ribs; the covering of domes, by bending the boards from the base to the vertex; and the stretching out of the surfaces of coved ceilings, were also first described by this writer.

To the writings of Batty Langley we are indebted for the extension of the superficies of polygonal roofs with curvilinear rafters; and likewise the covering of the frustum of a semicone for a soffit in a straight wall, with the axis of the cone at right angles to the plane of the wall.

The principle of forming boards to cover a dome, with the joints running in horizontal planes, or on the surface of a cone with a vertical axis, was laid down by Swan.

That of extending the superficies of a semi-cylinder on a plane, for the soffit of an aperture in a circular wall, with the axis of the cylinder at right angles to the surface of such wall, so as to cover the surface of the cylinder contained between the two walls and each spring of the aperture, was first exhibited by Pain; as was likewise the principle of squaring purlins for an elliptic dome, though very imperfectly.

The sum total of the geometrical constructions by these writers, may be comprised as follows: the use of the trammel; drawing curved lines through points; ascertaining the lengths of rafters, and the backing of hips for both straight and curvilinear rafters; framing of roofs in ledgement, whether rectangular or bevel on the plan; squaring purlins for circular or elliptic domes and cones; the construction of curvilinear ribs for angle-brackets, polygonal roofs, and plaster groins; centerings of groins; forming a conic soffit in a straight wall, with the axis of the cone at right angles to its surface; forming a cylindric soffit in a circular wall, with an horizontal axis; and the covering of polygonal roofs or domes with boards, whose joints fall either in horizontal or vertical planes.

These inventions, however, are far from being laid down in the most happy manner. The text of these authors is frequently obscure, and their diagrams, which have little connection with it, are badly projected, and little calculated to inform: they have likewise so far neglected the requisite arrangement, that their subjects are thrown together in a promiscuous jumble, without either attention to the affinity of their principles, or their order of succession in practice.

Of the several works quoted, Price's alone can justly claim the title of a treatise on carpentry.

Langley is in general tolerably intelligent; he has treated on all that has been done by his predecessors, and has attempted many things of his own; but his labours have not been successful.

In the diagrams of Pain, we find some useful practical hints; but his errors are numerous, and his inventions few. His text, also, is more unintelligible than that of any writer who preceded him in this art.

The inventions and discoveries of the writers quoted, may be reduced to the following: Sections of prisms at right angles to one side or plane of the prism; coverings of prismatic and conic surfaces, in the most simple cases; and the method of ascertaining the lengths and backings of hips. To these principles, the Author of the Architectural Dictionary has added those of the intersection of one plane with another, the latter resting on three lines perpendicular to the former; the geometrical construction of all cases in spherical trigonometry, by solid angles; sections of a prism, cone, or cuneoid, through any three given points; the section of a prism making a given angle with a given parallelogrammatic section of such prism, and passing through any given line on the said section; the section of a cone passing through any line on a given axal or vertical section, and making a given angle with that section; the section through any three given points on the surface of a body, of such property that all sections parallel to a certain plane will be similar figures, having the seats and heights of the points upon one of the similar planes, and another section of the body in a given position to that plan, cutting all the said similar sections; the sections of various other bodies, whose properties are defined; the formation of the edge of a thin pliable surface, which, when bent upon the surface of a prism, may coincide in its edge with a section passing through any three given points on the surface of the said prism; the formation of the edge of a surface, to fit a conic section, passing through any three given points on the surface of the cone, while such surface and that of the cone coincide; the formation of the edge of a thin pliable surface to fit the section of a body cut by any prismatic surface, while the pliable surface coincides with that of the section made by the prismatic surface; the properties of the body being such, that all sections parallel to a certain plane will be similar figures, given a section of the body parallel to one of these sections, and another cutting all the said similar sections in a given position, and the intersections of the given planes on each other.

These subjects include the finding of the sections of cylinders and cones, spheres and spheroids, and the coverings of these bodies, under the circumstances already stated. To these, the author has added the following inventions or discoveries, viz., the method of extending the surface of a cylinder or cylindroid, being the centre of an arched aperture in an oblique wall, terminated by the faces of the said wall; and the covering of the surface of a part of a semi-cone, being the centre of an aperture, with its axis oblique to the surface of the wall which terminates such covering. In ascending groins, he has likewise shown the centering for brickwork, and ribbing for plastering; the construction of polygonal and annular groins, both level and ascending in a spiral, whether for centering or ribbing; cylindro-cylindric arches, or what are commonly, but improperly, denominated Welsh arches; spherical niches, both for straight and circular walls, under any circumstances: the true methods of constructing pendentive or spandrel ceilings, either spherical or spheroidal; the bevels of purlins in all positions to the common rafters; the formation of boards for covering spherical domes, without laying down either plan or section of the dome, entirely within the boards themselves; the forming of the lower boards, without centres, in the covering of a dome, with the joints in horizontal planes; the formation of boards to cover a spheroidal dome, with the joints of the boards in vertical planes; the covering of an elliptic dome with one mould only; the covering of a spheroidal dome with boards having their joints in parallel vertical planes; the construction of a dome with horizontal ribs, without taking the trouble to square them by horizontal and vertical faces; the method of cutting purlins and jack-rafters to fit the hips, without laying the roof in ledgement; principles for the equilibrium of polygonal roofs without ties, so that the rafters may obtain a given ratio among themselves, provided the abutments be sufficient; a principle for preventing rafters without intermediate ties, from having any lateral pressure;—these two latter inventions have been several years before the public, in the architectural plates of Rees's *Cyclopædia*. To these might be added various other principles of less importance, which it is not necessary to recapitulate in this place. In most of the subjects above alluded to, he has given more than one method of operation, and in some instances he has multiplied his examples to five or six different modes of practice. One or two of the inventions in the foregoing list, he acknowledges, are only his own by their new application, the principles being known prior to his time; but he has adapted them to subjects to which they were never before applied; and he conceives that it requires at least as much ingenuity, and is frequently attended with more utility, to be able to apply an old or well-known principle to an useful object, as to discover a principle destitute of practical application: he has, therefore, not scrupled to include them in the list of his discoveries. Nor has he, while thus claiming credit for himself, denied it to others; as may be seen in his remarks on Pain's lining of a cylindric soffit in a circular wall, the principle of which was previously laid down by Price, in his centerings of groins. The inventions which the author has thus appropriated to himself, are the following: the application of the principle of covering the surface of the frustum of a cone to a spheroidal dome, with the joints in vertical planes; the application of the principle of covering an oblong spheroidal dome by one mould only; and the application of the principle shown by Price, in his centering of groins, to a cylindric soffit for an aperture in a straight wall, with its axis oblique to the surface of such wall; which latter was likewise attempted by Pain, but without success.

The author has not been able fully to satisfy himself as to the extension of the surface for the head of an aperture, splaying in the sides and level on the crown, so that the aperture shall form a semi-circle on one side of the wall, and a semi-ellipsis on the other; or a semi-ellipsis on each side, but of different horizontal dimensions, though of the same height. He is, however, convinced, that though the form be not geometrically true, it is much more correct than anything attempted by Langley or Pain; and on it, he has accordingly founded the principle by which alone the nature of the solid itself can be understood. And though unsuccessful in his attempts to extend the surface exactly, he has had the satisfaction of laying down such lines as will apply to the surface of the solid with far greater accuracy and dispatch, than could be obtained by the mechanical operation of plumbing the lines from the plan; by applying the distances on the plan upon their respective level lines on the surface of the solid, all drawn from one vertical line resting on the point where the two sides of the splay come in contact. By this means the line of every wall may be found correctly on the surface, whether the wall be straight or curved, or whether the axis of the solid stand oblique or at right angles to its surface; which cannot be done by any other method hitherto attempted.

In conclusion, it may be observed, that writers on carpentry have frequently been unsuccessful, for want of grounding their schemes upon the simple principles of the bodies they wished to construct; by losing sight of which, they have fallen into puerile operations, and drawn erroneous inferences.

In the course of this work, we shall treat of the several branches of the building art, and each article of those branches, in a manner similar to this on Carpentry; and all inventions, as well useful as otherwise, with every unsuccessful attempt at geometrical construction, will be noticed under their respective heads.

It is now only necessary to observe, briefly, that as the arrangement and classification of the subjects, as well as the mode of conceiving and presenting them in the diagrams, are altogether different from those adopted by the writers who have preceded us in this department, so it is believed, that this method will display the art of carpentry in a novel point of view, and reduce it to that pure scientific form it has never hitherto acquired. But notwithstanding all that has been done, and the great advances made in the art since the publication of the various works we have been examining, it is evident that the subject is not exhausted, but is still susceptible of many improvements. Such improvements will doubtless be effected, in time, by the labours of abler men who will carry to perfection the science and practice of an art so important and so interesting as that of Carpentry.

CARPION, a Grecian architect, who wrote a treatise on the Temple of Minerva, in the citadel of Athens.

CARRIAGE of a Wooden Stair, the frame of timber-work which supports the steps.

The carriage of a flight of steps, supported on one side by a wall, generally consists of two pieces of timber, inclined to the pitch of the stair. These pieces are called *rough-strings*, or *carriages*.

When a geometrical stair consists of two alternate flights, with a half pace between, the carriage of the half pace consists of a beam parallel to the risers of the steps, and several joists framed into the beam, for the support of the boarding. The beam which sustains the joists, is called the *apron-piece*, and that which sustains the rough strings at the upper end is called a *pitching-piece*. The joists of the half pace are sometimes tenoned into the pitching-piece, and sometimes bridge over it; but the steps of both flights are supported by string-pieces, as before. The upper ends of the string-pieces at the landing, rest upon an horizontal piece of timber, denominated an *apron-piece*.

If the steps wind round a circular newel, the carriage of the circular part consists of uprights and bearers, the latter of which are wedged into the wall; though it will answer the purpose as well, to frame them into a string placed against the wall. The uprights and bearers are either framed with mortises and tenons, or are dovetailed together.

When the staircase is of the dog-leg kind, with winders and a close newel, the carriage is formed of bearers let into the wall, and fixed to the newel post. For more information, see Stair-Casing and Hand-Railing.

CARTELLI. *See* Cartouches.

CARTON, or Cartoon (a French term, signifying *thick paper*, or *pasteboard*), in painting, a design on strong paper, to be afterwards chalked through, and transferred on a newly-plastered wall, which is to be painted in fresco. The word is also used for a coloured design, that is to be wrought into mosaic or tapestry.

CARTOUCHES, or Cartoozes (French, from the Italian *Cartoccio*), a kind of blocks or modillions, used in the cornices of wainscoted apartments; differing from modillions in being confined to the interior, whereas modillions are applied both externally and internally.

Cartouches, are ornaments representing a scroll of paper, usually in the form of a tablet, with wavings, whereon is some inscription or device.

They are sometimes drawn on paper, as in the titles of maps, &c., and are sometimes made of stone, brick, plaster, wood, &c., for buildings.

Norden uses this term to signify the winged globe, usually placed over the middle aperture of Egyptian buildings.

CARVED WORK, all those mouldings, planes, or other surfaces which are cut into ornaments, representing, in relief or in recession, foliages, animals, utensils, historical events, &c.

Mouldings are generally carved with leaves, honeysuckles, lions' heads, beads, egg and tongue, egg and dart, guilloches, reeds, flutes, &c. Tori are carved with guilloches, reeds, and flutes. Astragals are carved with beads, of various forms, strung together.

Ovolos, with egg and tongue, and at the corners with honeysuckles, as in Grecian architecture; or with egg and dart, and sometimes with leaves, as in Roman architecture.

Sima-rectas, with honeysuckles, of various forms, connected with scrolls and lions' heads at certain intervals, as in Grecian architecture; or with leaves of various kinds, as in Roman architecture. Sima-inversas, with leaves, stalks, &c., enclosed in borders.

Facias and large surfaces, with foliage interwoven or winding, or with historical subjects from the heathen mythology, and sometimes with flutes, fillets, &c.

But of all carved work none is so beautiful as that left us by the Gothic architects. Of the styles comprised, under this denomination, carving is one principal feature, and it is surprising to what perfection the art arrived; during this period of the dark ages, as they are called, it advanced gradually, and passed through many stages ere it arrived at its full maturity, from the simple and somewhat barbaric mouldings of the Normans, to the luxuriant foliage of the Decorated, or the elaborate richness of the Florid styles; and yet even the carving of the earlier periods is by no means to be despised; the specimens belonging to the Early English style, although somewhat stiff and harsh, possessed a simplicity and chasteness which was never afterwards surpassed. The Decorated style lays claim to the highest rank in carved enrichment, it approaches nearest to nature; indeed, it is almost nature herself, only changed in substance; everything connected with this period is full of grace and elegance. In the next, or Perpendicular style, the flowing lines of the preceding period were deserted for the straight; or if curved lines were introduced, they were of a character purely geometrical; the method adopted was rather artificial than natural, and we see but few examples of foliage such as is found in the previous styles; there was, however, an elaborateness and exuberance at this period never before attempted; in some instances, to such an extent was carved enrichment employed, that scarcely any portion of the plane surface was discernible. This is very conspicuous in the fan-work, as it is termed, which was introduced into the vaulted roofs; we would especially cite, as an example, the roof of Henry the Seventh's Chapel, Westminster, than which, we suppose, there exists not a more elaborate specimen of carving, at least in a work of such magnitude. The light and beautiful pendents of this chapel afford a magnificent specimen of the most enriched and delicate sculpture. Other examples of the same kind, are St. George's Chapel, Windsor, and the Chapel of King's College, Cambridge. Equally beautiful specimens of carving, sometimes even of a more minute description, may be seen in works of a smaller kind, such as fonts, altar-screens, &c., more especially in the latter, in some of which the elaboration is carried to so great an extent, that nothing less than a close and diligent inspection will suffice to unfold its beauties.

CARVEL-BUILT, in ship-building, when the edges of the planks join each other, the vessel is said to be *carvel built*. This term is used in contradistinction to *clinker-built*, which is when the edges of the planks are lapped upon each other.

CARVER, an artist employed in the carving of wood.

CARVING, in general, is the art of cutting a body by recession, in order to form upon it various fanciful representations, as foliages, flowers, fruit, animals, landscapes, or historical events, either in relief, or recessed within a general surface. In this sense, carving comprehends both statuary and engraving, the latter upon either wood, stone, metal, or any other material.

In a more particular sense, carving is the art of cutting wood, as in the above definition. *See* Carved Work.

CARYATIC, whatever relates to the ancient country of the Carians.

Caryatic Order, an order of architecture, whose entablature is supported by female figures instead of columns: the figures themselves are called *Caryatidæ*, *Caryales*, or *Carians*.

The Caryatic order differs from the Persian in having the entablature supported by females, whereas in the latter it is supported by males. *See* Persian Order.

The history of these orders, as related by Vitruvius, is as follows:

"Caria, a city of Peloponnesus, having joined with the Persians against the Grecian states, and the Greeks having put an end to the war by a glorious victory, with one consent declared war against the Caryatides. They took the city, destroyed it, slew the men, and led the matrons into captivity, not permitting them to wear the habits and ornaments of their sex: they were not only led in triumph, but were loaded with scorn, and kept in continual servitude, thus suffering for the crimes of their city. The architects, therefore, of those days, introduced their effigies sustaining weights, in the public buildings, that the remembrance of the crime of the Caryatides might be transmitted to posterity. The Lacedæmonians, likewise, under the command of Pausanias, the son of Cleombrotus, having, at the battle of Platea, with a small number, vanquished a numerous army of Persians, solemnized the triumph, by erecting, with the spoils and plunder, the Persian portico, as a trophy, by which to transmit to posterity the remembrance of the valour and honour of the citizens; introducing therein the statues of the captives, adorned with habits in the barbarian manner, supporting the roof."

Whether this account is correct, in any respect, seems doubtful; it is certainly incorrect as far as it relates to the origin of the order, but whether its distinguishing appellation is rightly attributed to the above circumstances, remains a matter for consideration; we think the evidence is decidedly against Vitruvius. In the first place, be it remembered, there is no allusion made to such circumstances by the Greek historians; and in an inscription brought from Athens by Dr. Chandler, containing a description of the temple of Pandrosus, the figures are called κοραι, or damsels, and are thence naturally supposed to represent the maidens engaged in the celebration of the Panathenaic festival. Mr. Gwilt, who was the first to remark upon the incorrectness of the account of Vitruvius, is of opinion, that the figures were named after the goddess Diana, to whom the title Caryatis was given by the Lacedæmonians, from the circumstance of her having made known to them the story of Carya, daughter of Dion, king of Laconia, who was turned into a nut-tree by Bacchus.

With respect to the epithet, Caryatis, we are inclined to think rather that the goddess obtained this surname from being worshipped especially at Carya, near Sparta, where she had a temple, and where also the Lacedæmonian virgins celebrated an annual festival in honour of her; but as regards the main point in question, we think there can be little doubt but that, as is evidenced by an old commentator on Statius, the term Caryatides was applied to the virgins employed in the service of Diana, and that female figures were first employed in the architecture of the Greek temples as representations of the virgins engaged about the service of the deity to whom the temples were dedicated.

That the figures of men and animals were used for the purpose of supports in the place of columns, long before they were so employed by the Greeks, is well known. That they were not uncommon in Egypt, we learn from Diodorus Siculus, who informs us, that the roof of the hall in the sepulchre of King Osymandyas, was supported by animals instead of pillars, each composed of a single stone, and twenty-four feet in height. Psammeticus also employed colossal statues twelve cubits in height in the propylæum which he erected on the east side of the temple at Memphis.

In Denon's *Travels in Egypt*, we find, among other fragments, representations of five insulated pilasters or pillars, bearing an entablature; the fronts of which are decorated with priests or divinities.

We find several instances of a similar application of men and animals, in one case of elephants, in the temples of India, as in the temple of Elephanta, that near Vellore, and several others.

The molten sea, spoken of in Holy Writ, was supported by twelve bulls; and in the *Odyssey* of Homer, book vii. verse 118, we find the effigies of animals, both rational and irrational, employed as decorations. We do not learn, however, that these latter representations were employed as columns to support an entablature; and there is reason to believe that they were nothing more than ornamental sculptures. In Stewart's *Antiquities of Athens*, we find a most beautiful specimen of Caryatic figures supporting an entablature, consisting of an architrave cornice of a very elegant profile.

The examples to be found amongst the Greeks are those in the temple of Pandrosus, and five specimens out of six previously existing, supporting an entablature adjacent to the temple of Erectheus. In this case there is no frieze, but the entablature is carried to an extraordinary height.

Various fragments of male figures are also met with among the Roman antiquities, which, from their attitudes and ornaments, appear to have supported the entablatures of buildings.

Besides Caryatides and Persians, it is sometimes customary to support the entablatures with figures, of which the upper part represents the head and breast of the human body, and the lower part an inverted frustrum of a square pyramid, with the feet sometimes projecting out below, as if the body had been partly cased: figures of this form are called *Termini;* and had their origin in stones used by the ancients for marking out the limits of property belonging to individuals. Numa Pompilius, in order to render these boundaries sacred, converted the Terminus into a deity, and built a temple, dedicated to him, on the Tarpeian Mount, wherein he was represented by a stone, which in the course of time was sculptured into the form of a human head and shoulders, with the lower parts as we have just described. On particular occasions, this idol was adorned with garlands.

Persian figures are generally charged with a Doric entablature; the Caryatides, with an Ionic or Corinthian architrave cornice; and the Termini, with an entablature of any of the three Grecian orders, according as they were themselves decorated.

Male figures may be introduced with propriety, in arsenals, or galleries of armour, in guard-rooms, and other places devoted to military affairs; they may either represent the figures of captives, or of martial virtues; such as Strength, Valour, Wisdom, Prudence, Fortitude, &c.

As these figures should be of a striking character, they may be of any colossal size that will agree with the architecture of other parts of the building.

In composing Caryatides, the most graceful attitudes and pleasant features should be chosen; and, to prevent an appearance of stiffness, the drapery and features should be varied in the different figures of the range; at the same time, a general uniformity of shape should be preserved throughout. They should always be of a moderate size, or they will appear monstrous, and destroy those sensations, which representations of the fair sex ought to inspire.

Le Clerc says they may be advantageously employed for sustaining the canopy of a throne: in which case, they should be represented under the figures and symbols of heroic virtues. In banqueting-rooms, ball-rooms, or other apartments of recreation, they must bear such characteristics as are calculated to inspire mirth and promote festivity.

As Termini are susceptible of a variety of decorations, they may be employed as embellishments for gardens and fields; where they may represent Jupiter, the protector of boundaries; or some of the rural deities, as Pan, Flora, Pomona, Vertumnus, Ceres, Priapus, Faunus, Sylvanus, Nymphs, and Satyrs. They are also much employed in chimney-pieces and other interior compositions.

CASE (from the French, *caisse*,) an outside covering, envelope, box, or sheath; applied generally to such coverings as completely surround the object enclosed. In building, it means the shell or carcase of a house.

Case-Bays, in naked flooring, the joists framed between a pair of girders. Flooring-joists framed with one of their ends let into a girder, and their other ends inserted in the wall, are called *tail-boys.* The case-bays of floors and roofs should not exceed ten feet.

Case of a Door, a wooden frame, in which the door is hung; door-cases are either constructed of architraves and linings, or wrought framed, rebated, and beaded; in the latter case they are called door-frames.

Case of a Stair, a name given to a wall by which a staircase is surrounded.

CASED, a term in masonry, indicating that the outside of a building is covered or faced with materials of better quality than those of the backing or inside of the walls. Thus brick walls are frequently cased with stone, or with the best kind of bricks. *See* Wall.

Cased Sash-Frames, have their vertical sides hollow, to conceal the weights for hanging the sashes. *See* Sash-Frame.

CASEMATE, a cove, or hollow cylindrical moulding, the section of which is from one-sixth to one-fourth part of a circle.

CASEMENTS, sashes or glass frames, opening on hinges, and revolving upon one of their vertical edges. When a casement fills the whole aperture, it is called *a single casement;* and when two are used, they are called *double casements, folding casements*, or *French sashes.*

Casements are more liable to admit rain, wind, or snow, in stormy weather, than vertical sliding sashes, particularly at the bottom, when they open from the inside.

CASING of Timber-Work is when the outside of a timber building is plastered all over with mortar; after which it is made to resemble stone-work, by striking it, while wet.

with the edge of a trowel, or other implement, guided by a rule. This operation is best performed on heart laths, because the mortar is apt to cause a rapid decay in sap laths. The coating is commonly laid in two thicknesses, the second being applied before the first is dry.

CAST (from the Danish, *kaster*, to throw), in plastering, a piece of insulated plaster, originally formed in a cavity, the bottom of which is the reverse of the face of the cast.

The operation is thus performed: a small quantity of plaster of Paris is mixed with water in a bason, or pan, and stirred up with a spatula, till thoroughly incorporated; more plaster is then added by degrees, till the mixture assumes a moderate consistency, such as to flow on all sides when poured on a horizontal surface; the mould being slightly oiled or greased, to prevent adhesion, the liquid plaster is poured in, so as to fill the mould, or something more. When stiffened in a small degree, the superfluous parts are scraped off to the middle, or in several parts at the edges; when it begins to heat, which happens in a few minutes, it will be sufficiently hard: then, if the mould be made of wax, it may be removed by bending it away from the cast, gently at the edges, quite round, using the parts left on the surface as handles; and proceeding gradually towards the centre, till the cast is quite relieved; but if the material of the mould be brimstone, a slight knock on the back will relieve it. As this operation can only be performed in the direction of a straight line, no part of the cast near the bottom of the mould must project from this line to a greater distance than any part more remote, otherwise it cannot be drawn out without breaking such projections. If more relief is required, than what can be given by the mould, the cast must be undercut with a knife.

If the impression can be relieved of the mould, the cast may be of one piece; otherwise it must be made in several segments, and in such manner as may best conceal the joinings.

Plaster casts are sometimes used for mouldings, instead of working them by hand, in situations where they cannot be conveniently run with a mould.

An exact representation of an original piece of sculpture, or even of a living animal, may be taken, whether generally concave or convex, by using the original as a mould; on which, having first oiled or greased the parts in a slight degree, pour the plaster, as just directed; and this impression is in its turn to be used as a mould, and will give a fac-simile of the original.

Pliny mentions the casting of faces from nature, as being early in practice among the Greeks.

This useful art supplies the painter and sculptor with exact representations from nature, whether of men, brute animals, draperies, or plants; it multiplies models of all kinds, and is now brought to such perfection, that casts of antique statues are made perfectly similar to their prototypes, except only with respect to colour and materials.

The introduction of plaster in architectural decorations, dates from the prevalence of the style called by us the Elizabethan, but its influence is more conspicuous during the succeeding or Italian style. It was first employed in carved and paneled wainscoting, and in the enrichment of the highly-decorated ceilings, which were a prominent feature in buildings of the period. At the first onset, however, the plaster was not cast, but each individual ornament moulded by hand, fixed in the situation which it was intended afterwards to occupy; it was indeed merely the substitution of plaster for wood, and the only advantage consisted in the facility with which the former could be carved, whereas the execution of the latter was difficult. This advantage was further extended at the commencement of the eighteenth century, by casting the plaster ornaments in moulds previously prepared for the purpose, so that from a single mould might be produced a number of casts, thus reducing the expense considerably. Soon afterwards, another material was employed in similar decorations; this was the pulp of paper, which was very generally used, though not so extensively as plaster; through the poverty of the designs in this material, as well as the imperfection in the machinery of those days, it fell into disuse, and was at last entirely superseded by plaster. The latter material, however, could not produce the desired ultimatum, it answered very well so long as the Greek style of ornamentation prevailed; but when this was superseded by the French, Flemish, and Elizabethan, its defects were seriously felt: it was by no means calculated to express the fantastic forms of the latter, or the luxuriant richness of the former styles, especially when, as was frequently the case, the design was marked by bold projection and deep undercutting. This difficulty led to a new trial of the carton pierre, or papier maché as it is now called, which, by the aid of improved machinery, and a greater knowledge of chemical and general science, has been advanced to a high state of excellence, and is in every respect superior to plaster casts previously employed. One invaluable advantage it possesses, is, that it preserves the indents and undercutting of the original or mould, however much recessed; in fact, it can readily be made to assume any form, however intricate. Add to this its hardness and durability, its adaptation to external ornaments, for it is known to have remained uninjured for many years, though exposed to the vicissitudes of the weather; its indestructibility by vermin, its lightness, and its sharpness, and truth of outline, and its superiority to plaster, will not be for a moment questioned. In many of the above particulars, it is superior even to wood, to which it is in some respects similar, for it may be cut with a saw or chisel, bent by heat or steam, and even planed and smoothed with sand-paper. Further, its lightness will allow it to be fixed in any situation, without fear of displacement, and it requires but nails or screws, and even in some cases only needle-points, to secure it firmly in its position. It holds pre-eminence over plaster, in as much as it will receive colour very readily, and gilding much more so than the generality of materials to which such enrichment is applied.

Another article which has of late been introduced as a substitute for the above materials, is embossed leather, which in some instances is superior to either of them. It can be made to assume any degree of relief short of the complete round, and it preserves all the sharpness and fineness of outline possessed by the mould from which it is cast. The moulds in this process are of metal, into which the leather previously prepared by steaming, is forced by a combination of hydraulic and pneumatic pressure, by which extraordinary power the finest lines on the mould are repeated with the greatest accuracy on the copy. It might be supposed from the nature of the material, that this delicacy of outline would be deteriorated by time, or that the cast might be altogether destroyed by damp; but there is really no ground for apprehensions of this nature, as the casts are found under all circumstances to preserve, undiminished in the minutest details, the form transferred to them from the original mould, and to be improved and hardened rather than injured by age. This material has an advantage in the facility with which it can be made to imitate old carved work; indeed, when introduced in the restoration of such works, it is difficult to distinguish the original from the imitation; it may be coloured or gilded as desired. It is applicable to all kinds of interior decorations, such as cornices, friezes, &c., and has been employed even in the entire paneling of rooms.

Another material which, until very recently, was entirely unknown to us, but which, since its first introduction, has come into extensive use, threatens to prove a formidable rival to the above-mentioned articles—we allude to Gutta Percha. This substance has not been tested sufficiently to allow us to speak decidedly as to its applicability to the purposes we are considering; it is moulded into cornices, panels, and other forms of architectural decoration, and is on many accounts eligible for such uses; it can be moulded, cast, stamped, or embossed, into any form however elaborate, and is susceptible of colour; it has, however, disadvantages which for the present must preclude its employment; for, although it promises considerable hardness, it is readily injured by contact with any sharp body; besides this, it is liable to soften and liquify when exposed to an elevated temperature. This last defect has been modified by a process to which the material is subjected in its manufacture, which is termed metallo-thionising, but still it has not been entirely removed. The properties of this production, however, have not yet been sufficiently developed to decide upon its capabilities; many improvements will doubtless be introduced into its manufacture, as its nature becomes more fully understood.

Cast, among plumbers, a little brazen funnel at one end of a mould, for casting pipes without soldering, through which the melted metal is poured into the mould.

Cast, *Rough.* *See* Rough Cast.

CASTELLA, or Castles, in British antiquity, one of the three kinds of fortifications built along the line of the wall of Severus, the other two sorts being denominated *stations* and *towers*. The Castella were neither so large nor strong as the stations, but much more numerous, there being in this wall no fewer than 81. The figure of the castellum was cubical, 66 feet in each dimension, fortified on every side by thick and lofty walls, but without any ditch, except on the north side, where also the wall was raised much above its general height, and with the adjoining ditch formed the fortification.

The castella were placed in the intervals between the stations, generally at the distance of about seven furlongs from each other, and guards were constantly kept in them, consisting of a certain number of men, detached from the nearest stations. *See* Castle.

Castella, in Roman antiquity, also denoted the reservoirs, in which the waters from the aqueducts were collected, whence the city was supplied by leaden pipes.

CASTELLATED HOUSES, those mansions which succeeded the castles and fortified residences of the feudal barons; they still preserved the appearance of strength, although in reality incapable of defence against a regular force. These buildings were provided with battlements and turrets, rather for ornament, however, than for practical purposes.

The windows are generally closed horizontally with labels, over them; the apertures are sometimes divided by mullions, consisting of one or more munnions in the breadth, and one or two transoms in the height, by which the great opening is divided into several smaller apertures, sometimes arched under the lintels, and sometimes also under the transoms. One of the most remarkable of these edifices is Haddon-Hall, Derbyshire.

CASTING, the act of taking the impression of any surface, whether plain or sculptured, by pouring a liquid matter on that surface. *See* Cast.

Casting, in joinery and carpentry, is said of a piece of timber, when its sides are bent or twisted from their original surfaces, by the fibres being unequally heated, dried, or moistened; or by being naturally disposed in different directions; or the twist may, perhaps, arise from different degrees of hardness in the body, occasioned by knots, &c. This effect is otherwise called *warping*.

Casting of Brick or Stone Walls. *See* Rough Cast.

Casting of Bronzes, is thus performed: The figure to be cast from must have a mould made on it, consisting of a mixture of plaster-of-paris and brick-dust, in the proportion of not more than one-third of the former, to two-thirds of the latter. The thickness of this mould must be according to its length and breadth, in order to be sufficiently strong. Little channels, tending upwards, should be cut in various parts of the joints, to give vent to the air forced out by the metal as it runs into the mould. After the mould is made, a thin layer of clay is spread smoothly and uniformly over its inner surface, of the intended thickness of the bronze; the mould is then closed, and its cavity filled with a composition of two-thirds brick-dust and one-third plaster, mixed with water, to form the core; previous to which, should the work be of any magnitude, it will be necessary to insert strong irons bars within the mould, to secure it from accidents, and to facilitate the removal of the core. The mould being then opened, and the clay removed, is with the core thoroughly dried; to effect which more perfectly, they are exposed to the action of a charcoal fire or lighted straw; great attention is required to this part of the process, for should the least moisture be suffered to remain, the mould will burst, and the cast be blown to pieces, to the great danger of the lives or limbs of the workmen. When the mould is finally closed, the cord must be supported in its place by short bars of bronze, running from the mould into the core. The whole then is bound round with iron bars, proportioned in strength to the weight of the cast, and laid in a proper situation for receiving the metal, supported by dry materials, as sand-stones, &c., to prevents accidents. In placing the mould, due care must be taken to connect its mouth with the reservoirs, by means of a channel on an inclined plane, that the liquid metal may run freely. The form of the furnace, and mode of running, are similar to those practised in bell-founding.

Casting of Lead. *See* Plumbing.

CASTLE (from the Latin, *castellum*, a diminutive of *castrum*), in ancient writers, a town or village surrounded with a ditch, and wall furnished with towers at intervals, and guarded by a body of troops.

Castellum originally seems to have signified a smaller fort, for a little garrison. Though Suetonius uses the word where the fortification was large enough to contain a cohort.

According to Vegetius, the *castella* were often, like towns, built on the borders of the empire, where there were constant guards, and fences against the enemy.

Horsley takes them for much the same with what were otherwise denominated *stations*. *See* Castella.

Castle, in a modern sense, is a place fortified either by nature or by art, in a city or country, to keep the people in their duty, or to resist an enemy. In the more extensive interpretation of the word, it includes the various methods of encampment, but in its stricter meaning, it is usually applied to buildings walled with stone, and intended for residence as well as for defence. Few branches of historical research have been so little attended to, as that which relates to military architecture. Castles, indeed, such as we now see them, were of late introduction to the world. Whether we may rank them with the accommodations of life brought by the crusaders from the East, is doubtful: but this much seems tolerably certain, that it was in France, England, Germany, Switzerland, and Savoy, that the system of castellation first prevailed. In Italy, till the Normans got possession of Naples and Sicily, castles were comparatively few. We may at least date their general adoption in Europe with the feudal system.

Castle of Chillon

MY HAIR IS GRAY, BUT NOT WITH YEARS,
NOR GREW IT WHITE IN A SINGLE NIGHT,
AS MEN'S HAVE GROWN WITH SUDDEN FEARS.

The early British fortifications seem to have been little more than mere entrenchments of earth. Cæsar, however, penetrated not far enough to know the true nature of the British fortresses; and in his work, *De Bello Gallico* (lib. v. section 17), has given only the description of a lowland camp. In all parts of England, there is a vast number of strong entrenchments of a very peculiar kind, situated chiefly on the tops of natural hills, and which can be attributed to none of the different people who have ever dwelt in the adjacent country, but the ancient Britons. That they may have been used at different times, and occupied upon emergencies, by the subsequent inhabitants of the island, is no more than probable; but there are many, and undoubted reasons, for deeming them the strong posts and fastnesses of the aboriginal settlers, where they lodged their wives, formed their garrisons, and made their stand. That the Britons were accustomed to fortify such places, we have the authority of Tacitus, who, describing the strongholds formed and resorted to by Caractacus, says, "*Tunc montibus arduis, et si qua clementer accedi poterant, in modum valli saxa præstruit.*"—Annal. lib. xii. sect. 33. One of these entrenchments still makes a formidable appearance on a mountain hanging over the vale of Nannerch, in Flintshire, called Moel-Arthur. But their situation being so high that they could have no supply of water except from the clouds, they were often liable to be untenable for a considerable time together.

One of the most important of these fastnesses in our own country, is the Herefordshire Beacon, situated on a spot that could not but be an object of the utmost attention to the original inhabitants of those territories, which afterwards were deemed distinctly England and Wales, from the very division here formed. It is on the summit of one of the highest of the Malvern hills, and is known by the name just mentioned. It has been by turns attributed to the Romans, the Saxons, and the Danes, but its construction as a stronghold shows it was designed as a security for the whole adjacent country on any emergency. Another of these fortresses is at Bruff, in Staffordshire, which has been described by Mr. Pennant, in his *Journey from Chester*, p. 47, and exactly answers the account of Tacitus. It is placed on the summit of a hill, surrounded by two deep ditches, and has a rampart formed of stone. Other instances are adduced by Mr. Pennant, in his *Tour in Wales*, and by Mr. King, in the first volume of the *Munimenta Antiqua:* but a stronger instance than all, perhaps, is given by Mr. Gough, in the *Additions to Camden*, vol. ii. p. 404, where he shows that the true Caer Caradoc, the very fortress alluded to in the sentence we have quoted, which, if not the royal seat of Caractacus, seems to have been at least his stronghold, was in Shropshire, two miles south of Clun, and three from Coxal, being a large camp, three times as long as it is broad, on the point of a hill, accessible only one way, and defended on the north side by very deep double ditches, in the solid rock; whilst on the east, the steepness of the ground renders it impregnable. On the south it has only one ditch, for the same reason: and the principal entrance is on the west side, fenced with double works; whilst to the south-west it is even fenced with triple works. The most extraordinary, however, of all these kinds of fortresses, is situated in Caernarvonshire, called *Tre'r Caeri*, or *The Town of Fortresses.* The plan and elevation of this ancient stronghold and abode is given by Mr. Pennant, in his *Tour in Wales*, vol. ii. p. 206. On the accessible side it was defended by three rude walls of stone; the upper ones being lofty, about fifteen feet high, and sixteen broad; exhibiting a grand and extensive front. The space on the top is an irregular area; but the whole is filled with cells, some round, and some oval, and some also oblong or square. Several of the round ones were fifteen feet in diameter; which brings to mind the houses of the ancient Gauls, described by Strabo; and of those that were oblong, there was at least one even thirty feet in length. Of the same kind of fortresses were Penmaen Mawr, in Caernarvonshire; Warton Cragg, in Lancashire; Old Oswestry, in Shropshire; the irregular encampment of Maiden Castle, near Dorchester: and probably Old Sarum, whose character was new-modelled by the Romans. Mr. King, in the *Munimenta Antiqua*, vol. i. p. 63, considers the dens in the mountains and the thickets, of Scripture, as strongholds or hill-fortresses of the kind described. When Samson had made a great slaughter of the Philistines, we are told he went and dwelt in the top of the rock Elam; where we find, afterwards, three thousand men of Judah went up to confer with him. That hill-fortresses were used in the earliest ages, there can be little doubt. The Israelites, when their land was invaded by Jabin, the king of Canaan, in consequence of an exhortation from Deborah the prophetess, assembled to make their stand upon Mount Tabor. Among the Indians of South America, strongholds, of a similar nature to those of Britain, have been frequently discovered. Ulloa's *Voyage to South America*, vol. i. p. 503–504. And a very curious instance of the attack and surrender of one in Sogdiana, in Asia, in the time of Alexander the Great, is related by Quintus Curtius, lib. vii. chap. xi. The anecdote is worth the reference of the reader.

The British mode of warfare appears to have received but little alteration from the introduction of Roman tactics. Till finally subdued, their princes showed abilities both in the command of armies and in the conduct of war; they chose their ground judiciously; formed able plans of active operations; and availed themselves of all the advantages of local knowledge: but to the fortresses described, if we may rely on the testimonies of our ancient writers, they did not very frequently retire. Their deficiencies both in the attack, the construction, and the defence of such places, must have been very obvious even to themselves; and as they delighted to live, so they usually chose to fight, in open plains. Their impatient courage, and their aversion from labour, made them unable to endure the delays and fatigues of defending or besieging the castles of their time; and they often reproached the Romans with cowardice, for raising such solid works about their camps and stations. See Boadicea's famous speech to her army, in *Xiphilin, ex Dione in Nerone.*

Of the Roman military works in this country, they were for the greater part temporary; many, however, were stationary posts; and some few, to the retention of which the greatest importance was attached, became walled *castra.*

Cæsar, in the work already quoted, *De Bell. Gall.* lib. vii. describes one of his camps as fortified very much in the manner of a walled city. A few of the Roman stations in our own country assist in throwing light on the description; and, in short, such as were so surrounded, appear to have been the link of connection between the British earth-work and the feudal castle.

Richborough, Portchester, and Pevensey, are the three greatest fortresses the Romans have left us. Richborough, the very earliest in order of time, is supposed to have been begun in the year 43, in the reign of Claudius; but not to have been completed till 205, under the direction of emperor Severus. There are in this distinguished fortress, says Mr. King, (*Munimenta Antiqua*, vol. ii. p. 8) still plainly to be traced all the principal parts of one of the very greatest and most perfect of the stationary camps. The upper division for the general and chief officers, and the lower division for the legion. In the former, the prætorium with its parade, and the sacellum, or small temple, for depositing the ensigns. In the walls too are the traces of the four great gates; the decuman, the prætorian, and the two posterns. The great courses of stone, with which the wall is formed, are separated from each other by alternate layers, composed entirely of a double course of bricks each; as in the walls of Verulam, Silchester, and other of our Roman towns.

The Roman remains at Portchester are not perhaps so clearly to be traced; since, having been constantly used as a fortress in succeeding ages, it has received vast and extremely various additions: and presents us with specimens of military architecture in almost every period, from the Normans to the time of Queen Elizabeth.

Similar alterations to those first mentioned, have given so strong a turn to the general character of Pevensey, that its real æra has been sometimes doubted; though portions of the Roman wall, as well as the decuman gate, may be easily and accurately traced.

Here too it may not be irrelevant to observe, that the castle at Colchester, in Essex, has been sometimes taken for a Roman fortress. And this not only because it has many of the same sort of tiles which are found in Roman walls, but because they are laid in the same manner, with bands. Though, if the building be examined with attention, there may be traced, in almost every part, evident marks either of the later Saxon or Norman workmanship: and though many of the tiles which are used in it may have been gathered from the remains of Roman buildings, the greater part appears to have been made on purpose. *See the Archæologia*, vol. iv. p. 33.

That in the Roman times, however, there must have been many other such walled stations as those at Richborough, Portchester, and Pevensey, there can be little doubt. The Saxons, in the course of their long wars with the Britons, may be fairly supposed to have destroyed many of the fortifications which had been thus erected: and after their final settlement, they neglected to repair those which remained, or to build many of their own. By these means the country became open and defenceless; which greatly facilitated the incursions of the Danes, who met with little obstruction from fortified places. That there was, however, something like a castle at Bamborough, in Northumberland, we have the concurrent testimony of historians, as Matthew of Westminster, p. 193, sub ann. 547. *Saxon Chronicle*, p. 19. Roger Hoved. p. 238, b. Bede, lib. iii. chap. vi. p. 12: a castle at Corfe, in Dorsetshire, is said to have existed in the days of Edgar. Gough's *Add. to Camden*, vol. i. p. 49. King's *Munimenta Antiqua*, vol. iii. p. 209. Portchester castle, during this period, probably retained its designation. And Mr. King, *Munimenta Antiqua*, vol. iii. p. 211, has taken considerable pains to prove that the fortress at Castleton, in Derbyshire, is of as high antiquity.

Alfred the Great, however, seems to have been the first of our princes with whom the building of castles became an object of national policy. Though, if Asser's authority may be received, they were not exactly what the reader, at the first mention of their name, might take them for; since they were composed not only of stone, but of wood; Asser *de Reb. gestis Alfredi*, p. 17, 18. Elfleda, too, his daughter, governess of Mercia, who seems to have been the only person in the kingdom who properly complied with the commands, and imitated the example, of her illustrious father, and who inherited more of the wisdom and spirit of Alfred than any of his children, not only followed his steps by fighting many battles with the Danes, but built not less than eight castles in the space of three years, to check their incursions. Hen. Hunt. *Hist.* p. 204. A still more remarkable instance of the knowledge of castle-building at a short period subsequent to this, may be found in William of Malmesbury, chap. vi. when he mentions the rebuilding of Exeter by Athelstan, who died in 941. "*Urbem igitur illam*," says the historian, "*quam contaminatæ gentis repurgio defœcaverat*, turribus munivit, *muro ex quadratis lapidibus cinxit.*" And from the few remains of the fortifications of this period, we find, that the walls precisely answer Malmesbury's description. They were faced with these four-square stones both within and without, and the intermediate space between the facings was filled up with rubble or rough flint-stones, mixed together with a strong and permanent cement. It is to this period too, that the most judicious of our writers have referred the castle at Colchester, which has been already mentioned. Its form is four-square, flanked at the four corners with strong towers, and it is about two hundred and twenty-four yards in circumference on the outside, all projections and windings included; the four sides nearly facing the four cardinal points. Some have even gone so far as to call this venerable ruin British; others, as we have already said, have attributed it, with a greater share of plausibility, to the Romans; but Camden and our better writers ascribe it to Edward the Elder, who repaired the walls and rebuilt the town, in the beginning of the 10th century.

Still, however, the paucity of strong posts in the island during every period of the Anglo-Saxon history, may be constantly observed. And it is more than probable that to this defect we may attribute the defeat of Harold; since it became necessary that all should be risked upon the issue of a single battle. The Conqueror, himself, was evidently sensible that the want of fortified places in England had greatly facilitated his conquest, and might, at any time, also facilitate his expulsion. He therefore made all possible haste to remedy the defect, by building magnificent and strong castles in all the towns within the royal demesnes. "William," says Matthew Paris, "excelled all his predecessors in building castles, and greatly harassed his subjects and vassals with these works." Matthew Paris, *Hist.* p. 8. col. 2. And his earls, barons, and even prelates, imitated his example; and it was the first care of every one who received a grant of an estate from the crown, to build a castle upon it for his defence and residence. The disputes about the succession, in the following reigns, kept up this spirit for building great and strong castles. William Rufus was still a greater builder than his father; and Henry I. was not idle in adding to their number. "William Rufus," says Henry Knyghton, col. 2373, "was much addicted to building royal castles and palaces, as the castles of Dover, Windsor, Norwich, Exeter, the palace of Westminster, and many others, testify; nor was there any king of England before him that erected so many, and such noble edifices." Though of one or two of these, William Rufus was only the improver. But the rage for building castles never prevailed so much in any period of the English history as in the turbulent reign of Stephen, between 1135 and 1154. In this reign, says the writer of the *Saxon Chronicle*, p. 238, every one, who was able, built a castle; so that the poor people were worn out with the toil of these buildings, and the whole kingdom was covered with castles. And this last expression will hardly appear too strong, when we are informed, that, besides all the castles before that time in England, no fewer than eleven hundred and fifteen were raised from the foundation, in the short space of nineteen years. — Rad. *de Diceto*, col. 528. "Stephen," says Holinshed, vol. iii. fol. 50, "began to repent himself, although too late, for that he had granted license to so many of his subjects to build castles within their own grounds."

An art, Dr. Henry observes, (*History of Britain*, vol. vi. p. 188, 8vo.) so much practised as architecture was in this period, must have been much improved. That it really was so, will appear from the following very brief description of the most common form and structure of a royal castle, or of that of a great earl, baron, or prelate, in this period; and as these castles served both for residence and defence, this description will serve both for an account of the domestic and military architecture of those times, which cannot well be separated.

The situation of the castles of the Anglo-Norman kings and barons was most commonly on an eminence, and near a river; a situation on several accounts eligible. The whole site of the castle (which was frequently of great extent and irregular figure) was surrounded by a deep and broad ditch, sometimes filled with water, and sometimes dry, called the *fosse*. Before the great gate was an outwork, called a *barbacan*, or *antemural*, which was a strong and high wall, with turrets upon it, designed for the defence of the gate and drawbridge. On the inside of the ditch stood the wall of the castle, about eight or ten feet thick, and between twenty and thirty feet high, with a parapet, and a kind of embrasures, called *crennels*, on the top. On this wall, at proper distances, square towers, of two or three stories high, were built, which served for lodging some of the principal officers of the proprietor of the castle, and for other purposes; and on the inside were erected lodgings for the common servants or retainers, granaries, storehouses, and other necessary offices. On the top of this wall, and on the flat roofs of these buildings, stood the defenders of the castle, when it was besieged, and from thence discharged arrows, darts, and stones, on the besiegers. The great gate of the castle stood in the course of this wall, and was strongly fortified with a tower on each side, and rooms over the passage, which was closed with thick folding-doors of oak, often plated with iron, and with an iron portcullis, or grate, let down from above. Within this outward wall was a large open space, or court, called, in the largest and most perfect castles, the *outer bayle* or *ballium*, in which stood commonly a church or chapel. On the inside of this outer bayle was another ditch, wall, gate, and towers, enclosing the inner bayle, or court, within which the chief tower, or keep, was built. This was a very large square fabric, four or five stories high, having small windows in prodigious thick walls, which rendered the apartments within it dark and gloomy. This great tower was the palace of the prince, prelate, or baron, to whom the castle belonged, and the residence of the constable or governor. Under ground were dismal dark vaults, for the confinement of prisoners, which made it sometimes be called the dungeon. In this building, also, was the great hall, in which the owner displayed his hospitality, by entertaining his numerous friends and followers. At one end of the great halls of castles, palaces, and monasteries, there was a place raised a little above the rest of the floor, called the *dais*, where the chief table stood, at which persons of the highest rank dined. Though there were unquestionably great variations in the structure of castles and palaces in this period, yet the most perfect and magnificent of them seem to have been constructed on the above plan. Such, to give one example, was the famous castle of Bedford, as appears from the following account of the manner in which it was taken by Henry III. A. D. 1224, from Matthew Paris, *Hist. Angl.* p. 221–2. The castle was taken by four assaults. "In the first was taken the barbacan; in the second, the outer ballia; at the third attack, the wall by the old tower was thrown down by the miners, where, with great danger, they possessed themselves of the inner ballia, through a chink; at the fourth assault, the miners set fire to the tower, so that the smoke burst out, and the tower itself was cloven to that degree, as to show visibly some broad chinks; whereupon the enemy surrendered."

As Britain abounded in this period in fortified towns and castles, much of the art of war, of course, consisted in defending and assaulting strong places; and a knowledge of the application of them in this period may be obtained from the relation of the siege of Exeter castle by king Stephen, in the year 1136. See the *Gesta Regis Stephani*, apud Duchesn, p. 934. It is perhaps the most consummate specimen of the military skill of that age with which we are acquainted. And it may be enough to observe, that after this siege had lasted three months, and king Stephen had expended upon it in machines, arms, and other things, no less than 15,000 marks, equal in efficacy to 150,000 pounds of our money, the besieged were obliged to surrender for want of water. Henry's *Hist. of Britain*, vol. vi. p. 217.

Berkeley, which was originally founded in the reign of Stephen, is one of the best remains we are now possessed of, of an ancient feudal castle. But the changes which almost all these buildings have undergone in subsequent times, may be judged of by those which have taken place at Berkeley. The buildings within the inmost only of the three gates are said to have been the work of Henry II. when duke of Normandy; while the two outermost, with all the buildings belonging to them, except the keep, are referred to the latter end of the reign of Henry II. and to those of the second and third Edwards. The hall and the two chapels are of the latter period; and the great kitchen, adjoining to the keep, was of the work of Henry VII.

Among the castles which Mr. King has endeavoured to appropriate to the early Norman period, are those of Nottingham, Lincoln, and Clifford's tower at York, all erected by the Conqueror: *Archæol.* vol. vi. p. 257. The remains of all these, he observes, fully illustrate the Norman mode of constructing such edifices. Tickhill, in the neighbourhood of Doncaster, appears to have been another of these castles, *ibid.* 267; and Pontefract bespeaks a Norman design, with rude and imperfect alterations. All of these appear to have been erected upon artificial mounts, and nearly cover the whole area of the summit of the respective hills on which they are situated.

Tunbridge castle, in Kent, built by Richard de Clare, about the time of William Rufus, is mentioned by Mr. King, as a specimen of the later Norman structures; and he has been very accurate in his description of it; *ibid.* 270. Gundulph, who directed the building of the Tower of London, in 1078, and the castle at Rochester, he describes to have introduced a great many judicious alterations, and not only to have increased the security, but the magnificence of our military piles; and observes that the castle at Rochester is a complete specimen of all that he effected. Newark, which Mr. King afterwards mentions, is an instance of a prelate's castle in the reign of Stephen: and the keep of Knaresborough, of the time of Henry III., completes the specimens it may be proper to mention of the irregular style of castle-building which prevailed during the interval between the Norman Conquest and the middle of the thirteenth century.

To these succeeded the magnificent piles of Edward I., more convenient and more stately, and containing not only many towers, but great halls, and sometimes even religious houses. The best style of military architecture in this period was displayed in the castles of Caernarvon, Conway, and Caerphilly; and it is singular to observe that many of our more ancient castles were then increased with additions in the same sumptuous style.

After the age of Edward I. we find another kind of castle introduced, approaching nearer to the idea of modern palaces. The first of these was that at Windsor, built by Edward III., who employed William of Wykeham as his architect. This convenient and enlarged style of building was soon imitated, on a lesser scale, by the nobles of the realm; and two remarkable instances, wherein convenience and magnificence were singularly blended at this period, may be found in the castles of Harewood and Spofford, in Yorkshire. The improvements at Kenilworth afford another instance of the great enlargement which our castles, during this age, were accustomed to receive: and Naworth, in Cumberland, is another of the best specimens that can probably be referred to. Caistor, in Norfolk, affords the style of Henry the Sixth's reign. It was built by Sir John Fastolf, who died in 1459.

To these venerable piles succeeded the castellated houses; mansions adorned with turrets, and battlements; but utterly incapable of defence, except against a rude mob, armed with clubs and staves, on whom the gates might be shut; yet still mansions almost quite devoid of all real elegance, or comfortable convenience, and fitted only to entertain a herd of retainers wallowing in licentiousness. At the same time, however, they discover marks of economy and good management, which enabled their hospitable lords to support such rude revels, and to keep up their state even better than many of their more refined successors. Of these buildings one of the most perfect and most curious, now remaining, is Haddon House, in Derbyshire; castellated and embattled, in all the apparent forms of regular defence; but really without the least means of resistance in its original construction. The description Mr. King has given of it, *Archæol.* vol. vi. p. 347, is, however, too long to be extracted, and too curious to be abridged.

After this kind of building, the magnificent quadrangular houses of the reign of Henry VIII. succeeded; of which the most beautiful and genuine models, perhaps, were those of Cowdray, in Sussex, and Penshurst, the seat of the Sidney family, in Kent.

Without referring to the stately buildings of Elizabeth's reign, it may be enough to say, that here ends the history of the English castle. The block-houses of Calshot, Hurst, Sandown, Sandgate, and South Sea, are the last instances of such buildings ever intended for a stand, and seem strongly to mark the revolution which has taken place in our defensive system of war.

The total change in military tactics, brought about by the invention of gunpowder and artillery; the more settled state of the nation, Scotland becoming part of the dominions of the kings of England; the respectable footing of our navy, whose wooden walls secure us from invasions; and the abolition of the feudal system,—all conspired to render castles of little use or consequence, as fortresses: so the great improvement in arts and sciences, and their constant attendant, the increase of luxury, made our nobility and gentry build themselves more pleasant and airy dwellings; relinquishing the ancient dreary mansions of their forefathers, where the enjoyment of light and air was sacrificed to the consideration of strength; and whose best rooms, according to our modern refined notions, have more the appearance of gaols and dungeons for prisoners, than apartments for the reception of a rich and powerful baron.

However, in the reign of Charles I., a little before the breaking out of the civil war, some inquiry into the state of these buildings seems to have taken place; for on the 22nd of January, 1636, a commission was issued, appointing lieutenant-colonel Francis Coningsby, commissionary-general of and for all the castles and fortifications in England and Wales, with an allowance of 13s. 4d. a day, to be paid out of the cheques and defalcations that should be made by him from time to time; or, in default thereof, out of the Treasury. Whether this office was really instituted for the purpose of scrutinizing into the state of these fortresses, as foreseeing the events which afterwards happened; or whether it was only formed to gratify some favourite, does not appear. During the troubles of that reign, some ancient castles were garrisoned and defended, several of which, particularly Corfe castle, in Dorsetshire, were afterwards destroyed, by order of the parliament: since that period, they have been abandoned to the mercy of time, weather, and the more unsparing hands of avaricious men. The last have proved the most destructive; many of these monuments of ancient magnificence having been by them demolished for the sake of the materials: by which the country has been deprived of those remains of antiquity, so essential, in the eyes of foreigners, to the dignity of a nation; and which, if rightly considered, tended to inspire the beholder with a love for the now happy establishment; by leading him to compare the present with those times when such buildings were erected: times when this unhappy kingdom was distracted by intestine wars; when the son was armed against the father, and brother slaughtered brother; when the lives, honour, and property of the wretched inhabitants depended on the nod of an arbitrary king, or were subject to the more tyrannical and capricious wills of lawless and foreign barons.

The few castles existing in the Saxon time, were, probably, on occasion of war, or invasions, garrisoned by the national militia, and, at other times, slightly guarded by the domestics of the princes or great personages who resided in them; but after the Conquest, when all the estates were converted into baronies, held by knight's service, castle-guard, coming under that denomination, was among the duties to which particular tenants were liable. From these services the bishops and abbots, who, till the time of the Normans, had held their lands in frank-almoign, or free alms, were, by this new regulation, not exempted; they were not, indeed. like the laity, obliged to personal service, it being sufficient that they provided fit and able persons to officiate in their stead. This was, however, at first vigorously opposed by Anselm, archbishop of Canterbury; who, being obliged to find some knights to attend King William Rufus in his wars in Wales, complained of it as an innovation and infringement of the rights and immunities of the church.

It was no uncommon thing for the Conqueror, and the kings of those days, to grant estates to men of approved fidelity and valour, on condition that they should perform castle-guard, with a certain number of men, for some specified time; and sometimes they were likewise bound by their tenures to keep in repair some tower or bulwark, as was the case at Dover castle.

In process of time, these services were commuted for annual rents, sometimes styled *ward-penny*, and *wayt-fee*, but commonly *castle-guard rents;* payable on fixed days, under prodigious penalties, called *sur-sizes.* At Rochester, if a man failed in the payment of his rent of castle-guard on the feast of St. Andrew, his debt was doubled every tide, during the time for which the payment was delayed. These were afterwards restrained by an act of parliament, made in the reign of King Henry VIII., and finally annihilated, with the tenures by knight's service, in the time of Charles II. Such castles as were private property, were guarded either by mercenary soldiers, or the tenants of the lord or owner.

Castles which belonged to the crown, or fell to it either by forfeiture or escheat (circumstances that frequently happened in the distracted reigns of the feudal times) were generally committed to the custody of some trusty person who seems to have been indifferently styled *governor* or *constable*. Sometimes also they were put into the possession of the sheriff of the county, who often converted them into prisons. That officer was then accountable to the exchequer, for the farm or produce of the lands belonging to the places entrusted to his care, as well as all other profits: he was likewise, in case of war or invasion, obliged to victual and furnish them with munition out of the issues of his county; to which he was directed by writ of privy seal. Variety of these writs, temp. Edw. III., may be seen in Madox's *History of the Exchequer;* and it appears, from the same authority, that the barons of the exchequer were sometimes appointed to survey these castles, and the state of the buildings and works carrying on therein.—Rees's *Cyclopedia.*

CASTRA, the Latin name for a camp.

CASTS. *See* Cast and Casting.

CATABASION (from *καταβαινω*, *I descend*), in the Greek church, a hollow place under the altar, wherein the relics were kept, and through which was the descent into the vaults beneath.

CATABULUM, a building, or stable, in which the beasts of burden and carriages were kept for the public service. The ancient Christians were sometimes condemned to serve in the catabula.

CATACAUSTIC CURVE. *See* Caustic Curve.

CATACOMB, a grotto or subterraneous place for the interment of the dead.

In Italy, this term is particularly applied to an assemblage of subterraneous sepulchres, three leagues from Rome, in the Via Appia. Each catacomb is three feet wide, and eight or ten feet high, running in the form of an alley or gallery, and communicating with each other. Some authors imagine them to be the cells wherein the primitive Christians hid themselves; and others take them to be the burial-places of the early Romans, before the practice of burning the dead was introduced.

The most celebrated catacombs are those of Egypt, wherein the ancient inhabitants deposited their mummies. The descent into them is through a square aperture with holes in the sides, for the feet, somewhat like an upright ladder. These excavations are hewn out of the solid rock, which consists of free-stone, and the walls are adorned with hieroglyphics, and representations of utensils and implements of war. *See* Pocock, Norden, and Denon.

CATADROME, an engine used in building, for lifting and letting down great weights.

CATAFALCO (from the Italian), a decoration, of architecture, sculpture, or painting, raised on a scaffold, on which to exhibit a coffin or cenotaph, in a funeral solemnity.

CATCH-DRAIN, in the construction of canals, the same as counter-drain; sometimes it also implies the feeders of a reservoir.

CATENARIA, a mechanical curve, which a heavy flexible body, of uniform thickness, would form itself into, if hung freely from its two extremities. The famous Galileo first investigated the nature of this curve, and supposed it to be a parabola. This problem, after being proposed by Mons. J. Bernouillé, was first solved by Dr. D. Gregory, who also affirmed, that the inverted catenaria was the best figure for the arch of a bridge; the intrados of which, however, must depend entirely upon the curvature of the extrados.

CATHEDRAL, (from the Greek, *καθεδρα, a chair;* derived from *καθεζομαι*, *sedeo*, I sit,) the head church of a diocese, wherein is the see or seat of a bishop.

During the first ages of the church, cathedrals were probably more numerous than other churches, as we know that there was a bishop in every town of importance wherever the Christian religion prevailed. The bishop, the head of the church, was assisted in the services of religion by his priests and deacons, the bishop, however, retaining the more important duties, such as preaching and the administration of the sacraments, which he seldom delegated to the assistant presbyters, unless necessitated so to do. In process of time, as occasion offered, other churches were formed, subject to the mother-church, and to the jurisdiction of its bishop; at this early period, however, it cannot be doubted but that the proportion of bishops to the lower order of the clergy was much greater than at the present day, and consequently the number of cathedrals or bishops' sees must have been more numerous. It is not our intention, however, in this place, to dwell at length upon the general subject; we would confine ourselves more especially to our own country, and will accordingly proceed to investigate the accounts we have left us of the early cathedrals of Great Britain.

No one, probably, would think of controverting the fact of the early introduction of Christianity into this country; it may indeed be questioned whether Saint Paul, or Saint Joseph, or the British king Lucius, be the benefactor to whom we owe its introduction; but its existence here during the first century will scarcely admit of a doubt. We know further that the British church was episcopally governed, for we hear of the presence of British bishops at the council of Arles, as early as the commencement of the fourth century; and we have consequently every reason to conclude that the episcopal form of government was co-existent with the church, and further, that if churches existed at all, some such churches must have been cathedrals.

We cannot speak with any degree of certainty of the date, form, or material of the first cathedrals. Dr. Milner says, that a cathedral was erected by Lucius, at Winchester, of the enormous length of 600 feet, as early as the close of the second century. Whether the dimensions given do not belie the whole statement must be left to the judgment of individuals; but there is good reason to believe that churches did exist at this period, as we hear of their demolition during the Diocletian persecution, which took place A. D. 303.

Upon the success of the Pagan-Saxons, the Christian churches of England were of course destroyed, whilst those in Wales and south-west of England, where the British Christians had retreated, were considerably increased; this was especially the case with monasteries, which served in a measure as places of safety, and in building which the Britains followed the salutary advice of Saint Germain. Upon the conversion of the Saxons by Saint Augustine, churches again made their appearance in Kent, as we learn that a cathedral was erected by that missionary-bishop at Canterbury, and dedicated under the title of Christ Church. At a not much later period we hear of the foundation of the cathedral churches of Saints Paul and Andrew, the one at London and the other at Rochester. Shortly after Augustine's mission in the south, the wonderful success of Paulinus in the northern parts of the island, in converting the king, Edwin, and his pagan subjects, gave rise to the cathedral of York. It is stated that Edwin first erected a church of timber in this city, but afterwards built a larger church of stone, in which the timber one was enclosed. Paulinus, again successful at Lincoln, caused to be erected a church of stone, of "admirable workmanship," as Bede tells us.

Stephen Eddy, a writer older than Bede, informs us that Wilfrid, bishop of York, finding, upon taking possession of his see, that the old church built by Edwin and Oswald was in a dilapidated condition, set about repairing it—"skilfully roofing it with lead, and preventing the entrance of birds and rain by putting glass into the windows, yet such glass as allowed the light to shine within;" and our author goes on to state that the same Wilfrid built a new church at Ripon, of polished stone, "with columns variously ornamented, and porches." The account of the dedication of this church is given in full, and is the earliest description of the kind extant.

A curious and somewhat detailed account is given by the Monk of Ramsey, of the construction of the church at Ramsey existing previously to the one dedicated in his time. He says, "it was raised on a solid foundation, driven in by the battering-ram, and had two towers above the roofs: the lesser was in front at the west end; the greater, at the intersection of the four parts of the building, rested on four columns, connected together by arches carried from one to the other." He further adds, that this church was obliged to be pulled down, and a new one erected in its stead, in consequence of a settlement in the central tower, which rendered the entire building unsafe.—That this church was of stone can scarcely be doubted, after perusing the above narrative; but we have direct and explicit mention of the fact, for the same author, in describing the labours of the workmen, says: "Some brought the stones, others made the cement, while others attended to the machines for raising the stones; so that in a short time was seen the sacred edifice with its two towers, where previously there had been but a barren waste."

A curious representation of an Anglo-Saxon church is to be seen in an Illuminated Pontifical in the Public Library at Rouen, containing the order for the dedication and consecration of churches; the date of which is ascribed by some to the eighth, and by others to the tenth, century; that the manuscript is of English origin has never been doubted. This miniature in black outline represents the ceremony of dedication. The form of the church is remarkably similar to that of our existing cathedrals, which is more especially noticeable in the form of the towers and spires, the symbolical cock on the steeple, and the ornamental hinges of the door.

We are here naturally led into some inquiry respecting the materials, form, and disposition of these early cathedrals. The materials employed by the Anglo-Saxons seem to have been wood and stone, but during what time either material was used cannot easily be determined; whether they were both used at the same period, under different circumstances, or whether at any point of time the one was superseded by the other, we are unable to learn. It has been supposed, and with some plausibility, that wooden churches were erected by the Scotch and Irish missionaries, and the more substantial fabrics by those from Rome, and this idea seems to be borne out by Bede, who states "that Adrian, the first bishop of Lindisfarne, having departed this life, Finan, sent and ordained by the Scots, succeeded him, and built a church in the island after the method of the Scots; which was built not of stone, but of hewn oak, and covered with reeds." This writer adds, that "Eadbert, the seventh bishop, took off the thatch, and covered both the walls and roof with lead." It seems very reasonable likewise that the Roman missionaries, who had been used to the structures of Italy, should not feel satisfied with mere wooden buildings. It is true it seems to be noted as somewhat unusual, that Wilfrid built a church at Ripon of polished stone, yet the novelty may not have consisted in the erection being of stone, but rather in the fact of the stone being smoothed or polished; for it is probable that the first buildings, after the Roman manner, were of rough undressed stone, there being neither time, means, nor workmen to complete a more finished structure. It is very probable that Wilfrid's church was built by Italian workmen, as we know that he had frequented Rome, and was a man too zealous in promoting the temporal splendour of the church, to allow any opportunity of forwarding his object to slip past unimproved. There can be little doubt but that in process of time the employment of stone entirely superseded that of timber.

No inconsiderable notion is afforded us of the form and disposition of the parts of the early cathedrals, from an account already referred to—we allude to that of the church at Ramsey. From this description we gather that the plan of the church was cruciform, with a tower rising from the intersection, and another at the west end of the church.

We learn from Wolstan, that there was a tower at the west end of the old church at Winchester, but that in the new structure the tower was towards the eastern extremity, and of the last it is related that it consisted of five stories, in each of which were four windows looking towards the cardinal points.

Further, in the miniature of the Illuminated Pontifical above described, we notice that the tower is surmounted by a steeple, a fact which, were it not for other considerations, would almost tempt us to refer the manuscript to a much later date, as we know that such additions were not very frequent, even in the Norman period; indeed, the idea of a Saxon cathedral afforded us by these descriptions, approaches very nearly to actual existing specimens of much later date. We must not conclude from these accounts that all churches of this date were cruciform, for we learn the contrary from Bede, who speaks of churches as square; some have supposed that Ramsey was the first instance of a cruciform edifice, but this was not the case, as is evinced by a metrical description of a cathedral, written long before its erection.

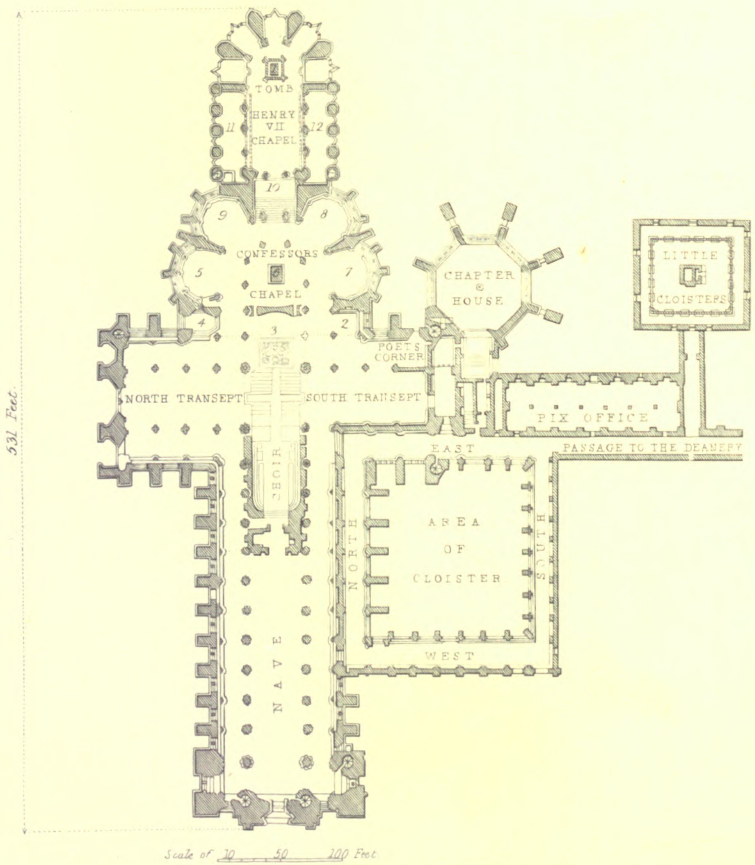
Having thus far considered the nature of the Saxon cathedrals, we arrive at the Norman era, during which a great number were erected; but as we have no lack of existing examples of this period, we do not think it requisite to pursue a detailed inquiry any further: we shall now proceed to some description of the cathedrals of the present day.

The term Cathedral includes generally the whole of the buildings connected with the bishop's see, including the church, chapter-house, chapels, cloisters, dormitories, refectories, residences for those engaged in attendance on the bishop, and in the services of the cathedral, and buildings for a variety of uses; it is applied, however, in a more especial sense, only to the church, and to such application we shall confine ourselves in the following remarks.

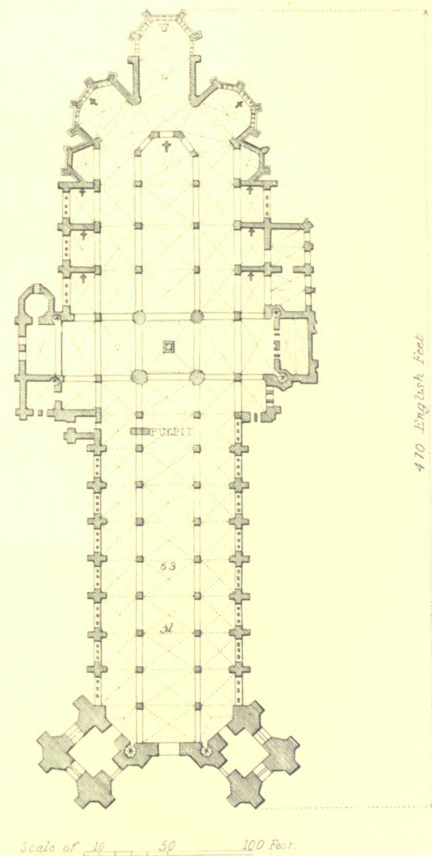
The plan of our old cathedral churches is invariably that of a Latin cross, having the nave in the longest arm, the transepts in the two cross arms, and the choir, comprising the remaining length of the church, to the east of the nave; the English always placing their altar at the east end, which was more frequently square, than either circular or multangular, as in the continental churches. Not unusually the plan was extended further eastward, to provide for an additional chapel, dedicated to our Ladye, and sometimes, though much less frequently, a similar, but smaller projection, was added at the west end: this was the Galilee porch, so named, as we learn from Gervase, from the passage of Scripture—"He goeth before you into Galilee, there ye shall see him,"—this being the place where the monks were allowed to see their female relatives; here was also the station of catechumens, and the resting-place of corpses previous to their interment. In some instances we find a double transept, east and west of each other, as at Canterbury; the additional arm is accounted for symbolically as representing the inscription placed above

PLAN OF AN ENGLISH ABBEY CHURCH.

PLAN OF A FRENCH CATHEDRAL CHURCH.



GENERAL PLAN OF WESTMINSTER ABBEY.



GENERAL PLAN OF ST. OUEN AT ROUEN.

R Brown Archt.

R. Thew sc.

the head of our Lord at his crucifixion, the lower symbolizing the cross-piece on which the arms were extended. It is noticed in some cathedrals that the eastern extremity is not in the same line with the nave, but bent on one side, as it were; this is explained in a similar manner as marking the inclination of the head of our Lord while on the cross. At the west end of the nave, on each side of it, were situated the towers, and another at the intersection of the nave and transepts, all of which were in some cases surmounted with spires; sometimes this addition was restricted to the western towers, but it is frequently omitted altogether, when the towers are usually carried to a greater elevation. At Exeter, we meet with the towers forming the transept, and at Peterborough with one at the northern extremity of the west transept. Internally the nave and choir are divided into three aisles, the central one being carried up above the others. This tripartite division is seldom carried out in the transepts, in which, however, we sometimes find one aisle as at Durham, and sometimes two as at Westminster and Bristol. The aisles are separated from the body of the church by an arcade, immediately above which the vaulting commences; in the body, however, between the arcade and vaulting, are interposed two stories, the lower one consisting of a gallery called triforia, opening into the nave and choir by means of a small arcade, and supposed to have been appropriated to the nuns; and the upper, termed the clere-story, in which were placed the windows for lighting the central avenue of the church. In Bath Cathedral, the triforia are omitted, and their place supplied by a string-course.

An approximation to the proportions of the different measurements of cathedral churches is given by Brown Willis, as follows: — The height is generally equal to the breadth of the nave and aisles; the cross, in which the transepts and intermediate space are contained, is extended half the length of the whole fabric, as is likewise the nave; the side-aisles equal half the breadth and height of the nave, and the spires and tower have a mean proportion between the length of the nave and that of the transept.

The above description will give a general idea of the construction of our cathedrals; but from the exceptions already noticed, it will be understood that no rule applies invariably to all buildings of the kind; for although the plans are in all cases similar, and the arrangement of the parts of the edifice systematic, yet we find not one cathedral in any respect a copy of another.

We now proceed to give some account of the edifices of this rank preserved to us in the present day, of which we have 21 in England, and 4 in Wales. There were also 13 in Scotland, and 22 in Ireland. In addition to the number already mentioned, we have in England one modern cathedral, Saint Paul's, London; besides which the collegiate church at Manchester has recently been elevated to the dignity of a bishop's see; but as the latter was never constructed for such a purpose, we do not think it can be correctly included with the others as an architectural example.

The following is an account of the erection of cathedral churches in England, and additions made to them, arranged in chronological order: —

To the period of the Anglo-Normans, or between 1066 and 1170, including the reigns of William I. and II., Henry I., Stephen, and the first sixteen years of Henry II., we may attribute the western front and nave of Rochester cathedral; the nave, north aisle, and the chapels round the choir of that at Gloucester; the original substructure of Exeter cathedral, with its transepts and towers; the central tower and transept of Winton cathedral; the nave of that at Chichester; the north transept of that at Ely; the choir of Peterborough cathedral; the oldest part of the western front and central tower of that at Lincoln; the central church of Durham, excepting the additional transept on the east; the nave and tower of Norwich; and many arches of Worcester cathedral.

In the period between 1170 and 1220, including the latter part of the reign of Henry II., and the reigns of Richard I. and John, the older Ladye chapel and chapter-house of Bristol were erected; as were likewise the choir and round tower (called Becket's Crown) at Canterbury; the nave and chapter-house at Oxford; the nave and choir of Norwich cathedral; the western towers at Ely; the transepts of Peterborough; the presbytery, Chichester; the transept, tower, and choir of that at Hereford; the nave and choir of Wells cathedral (begun); and the chapter-house of Chester.

In the period between 1220 and 1300, including the reigns of Henry III. and part of Edward I., were erected the nave and arches beyond the transept of Lincoln cathedral; the north and south transepts of York minster; the choir and transept, Rochester; an additional transept to the cathedral of Durham; the tower and whole western front of that of Wells; the choir at Carlisle; the presbytery and south transept at Ely; the transept and choir at Worcester; and the whole of Salisbury cathedral.

In the period between 1300 and 1400, including the latter part of the reign of Edward I, and the reigns of Edward II. and III. and Richard II., the nave and choir of Exeter cathedral were erected; and that at Lichfield was built uniformly; additions were made to the central tower at Lincoln: the nave of Worcester cathedral was built, as were the nave, choir, and western front of York minster; also the transepts at Canterbury and Gloucester; the spire and tower at Norwich; the spire and additions to Salisbury cathedral; the cloisters were begun at Gloucester: the nave and choir were erected at Bristol, as well as the spire and choir at Chichester; our Lady's chapel at Ely; and the chapter-house and cloisters (now destroyed) at Hereford.

In the period between 1400 and 1460, including the reigns of Henry IV., V., and VI., were erected the choir of Gloucester cathedral; the nave of that of Canterbury; Bishop Beckington's addition to Wells cathedral; and that of Lincoln, from the upper transept to the great east window.

In the period between 1460 to 1547, viz., from the reign of Edward IV. to the end of that of Henry VIII., were erected our Lady's chapel at Gloucester; the roof of the choir of Oxford cathedral; the choir of that of Chester; Alcocke's chapel at Ely; the Ladye chapel, Peterborough; the north porch, Hereford; and the exterior of the choir at Winchester.

The following particulars respecting the English Cathedrals are extracted principally from the works of Britton and Dallaway: —

PECULIARITIES.

Bath — The unusual height of the clere-story.

Bristol — Had no nave, the present choir being formed out of the Ladye chapel.

Canterbury — The grand entrance is under the south tower. The marble columns of the choir with Romanesque capitals, and the octangular chapel called Becket's Crown.

Chester — Extraordinary size of the south transept.

Chichester — Double aisles to nave, and detached campanile at its north-west angle.

Durham — The chapel of our Ladye placed at the east end as a second transept; the Galilee placed before, and distinct from the façade.

Ely — A single western tower connected with the nave; — the octangular tower; —the Ladye chapel detached from choir, and a Galilee in a perfect state.

Exeter — The skreen before the west front, and towers at either end of the transept. This cathedral was completed according to the original plan.

Lincoln — The arches in the west front, the work of Remigius; the Galilee and double transept.

Lichfield — The three stone spires.

Norwich — The roof of the nave, and the west end, with the Erpingham gateway.

Peterborough — The triple arcade before the west front eighty-two feet high; the double towers with spires at the western angles; tower at the southern extremity of the north-west transept, and the Galilee.

Rochester — The choir longer than the nave.

Salisbury — The complete uniformity of style; the height of the central spire, and the double elliptic inverted arch under the tower, as at Wells.

Winchester — The longest nave.

York — The double aisles to the transept; the largest window; the square louvre, and the absence of cloisters.

Remarkable Parts.

Bath — The tower has four turrets, without pinnacles, and is oblong in plan, which is owing to the narrowness of the transept; the aisles are very low, and there is no triforium in the nave, but merely a plain string-course. There is an alto-relievo of Jacob's ladder at the west end.

Bristol — Has no external flying buttresses, the walls of the nave being supported by the roofs of the aisles, which are formed of complicated open arches; the aisles and nave are of equal height, only forty-three feet.

Canterbury — The crypt, which is of greater extent, and more lofty than any other in England; the central tower and the apsidal form of the east end.

Chester — The unequal dimensions of the north and south transepts, the latter being wider, and nearly as long as the nave, with aisles on each side, while the former is unusually short, and of the same width as the central tower; the aisles of the choir also extend beyond it eastward, and form the aisles of the Ladye chapel.

Chichester — Has the earliest specimen of a vaulted roof; its spire greatly resembles that of Salisbury.

Durham — Pillars of nave curiously striated; the Galilee measures 50 feet by 78 feet.

Exeter — Possesses almost the only example of a group in sculpture, which is in the triforia of the transept, and represents a concert of musical instruments.

Ely — The octangular lantern, which is 71 feet in diameter, and 142 feet from the ground, supplied the place of a lofty central tower which fell down a short time previous to the erection of the lantern. There exists one of the earliest specimens of the pointed arch in the tower and transept.

Gloucester — The eastern termination is apsidal; and the cloisters, the most perfect and beautiful in England, unusually situate on the north side of the church.

Lincoln — Old west front; the large and beautiful south porch, and east façade; the Galilee. The central tower had a spire higher than Salisbury, which was blown down A. D. 1547. This church is remarkable for its sculpture, and has a curious bas-relief of the Deluge over the west door, and of the Last Judgment over the south porch.

Lichfield — Is nearly uniform, and was completed throughout on the original plan. The east end is apsidal in plan.

Norwich — The end of the choir is octangular, and the cloisters are very spacious.

Peterborough — The grand façade and portico, remarkable for their fine proportions; the Galilee and aspidal termination, also the west transept, which is placed at the west end.

Rochester — The west façade is one of the most perfect specimens of Norman; the choir is longer than the nave.

Salisbury — Is the most uniform cathedral in England, and has a lofty and beautiful spire, only seven inches thick.

Wells — The west front is noted as bearing a resemblance to the façades of Continental cathedrals; it is filled with statues; the central tower is supported on an inverted arch as at Salisbury.

Winchester — Is remarkable for its fine nave; the choir is under the central tower.

Worcester — The style and proportions of the nave are considered beautiful.

York — The aisles surrounding the whole church are of the same dimensions throughout; the rose window, which is 22 feet 6 inches in diameter, is the finest in England; the choir is under the tower, as at Winchester.

The subjoined Tables may be found useful; the former, from the works of Dallaway, gives the dates of the principal portions of the English Cathedrals; the latter, compiled principally from Britton's Antiquities, shows their dimensions. It will be noticed that Mr. Dallaway's dates do not agree in every case with those above given.

Dates of the Principal Portions of the English Cathedrals.

Cathedrals.	Nave.	Choir.	Aisles.	Transept.	Tower.	Cathedrals.	Nave.	Choir.	Aisles.	Transept.	Tower.
Bath..........	1532	1500	1532 na. 1570 ch.	1500 1532	1500	Lichfield	1295	1295	1295	1295	1295 W. 1430 Cent.
Bristol	1332	1332		1311 S. 1463 N.	1463	Lincoln	1200	1200	1200	1300 W. 1306 E.	1254 Cent. 1279 W.
Canterbury	1420	1174	1174	1174 up. 1379 lwr.	1070 N.W. 1400 S.W. 1500 Cent.	Norwich.......	1171	1195	1171 na. 1160 ch.	1195	1096
Carlisle	1150	1363	1150 na. 1363 ch.	1353	1400	Oxford	1120	1120	1120	1122	1222
Chester	1485		1485	1320 N.	1508	Peterborough...	1175	1160	1175 na. 1160 ch.	1272 W.	
Chichester	1125	1217	1125 na. 1217 ch.	1217 N. 1329 S.	1217 W. 1282 Cent.	Rochester......	1080	1227	1080 na. 1227 ch.	1080	
Durham	1093	1233		1230	1230 W. 1295 Cent.	Salisbury	1217	1230	1217 na. 1230 ch.	1274	1217
Ely...........	1174	1235		1133 N.	1174 W. 1328 Cent.	Wells.........	1239	1239	1239	1239	1450 W. 1465 Cent.
Exeter	1307	1318	1307 na. 1318 ch.	1280	1128	Winchester	1394	1493	1394 na. 1493 ch.	1070	1070
Gloucester	1089	1357	1089 na. 1310 ch.	1330 S. 1375 N.	1457	Worcester	1218	1218	1218	1218 lwr. 1380 up.	1372
Hereford	1095	1115	1095	1095 up. 1148 lwr.	1216 W.	York	1291	1361	1291 na. 1361 ch.	1227	1361 W. 1420 Cent.

Admeasurements of the principal parts of the most remarkable Cathedral Churches of Great Britain, given in English feet. A large portion of this Table is extracted from Britton's Works.

Cathedrals.	Extreme Length.		Extreme Breadth.		Nave.				Choir.			Transept.			Centre Tower.	West Towers	West Front.	
	Exterior.	Interior.	Exterior.	Interior.	Length.	Breadth.	Breadth with aisles.	Height.	Length.	Breadth with aisles.	Height.	Length.	Breadth.	Height.	Height in Pinnacles.	Height.	Breadth at Ground.	Height.
[a] Canterbury	545	516	170	158	188	27	73	80	132	86	76	158	40	75[1]	230	153[3]	93	107
												128	34	79[2]				
York	518	480	241	220	210	43	110	93	130	100	100	220	98	93	200	196	140	137
Bristol	203	174	127	113	...	..	...	...	76	69	54	174	29	50	133			
Carlisle	242	210	130	116	...	..	...	...	107	72	...	116	18					
Chester	375	312	112	100	120	41	84	...	80	84	...	100	44		...	...		
[b] Chichester	410	386	151	131	146	26	100	65	68	60	65	131	34	65	300[5]	95[6]		
Durham	507	476	194	170	203	37	82	70	93	79	70	170	59	...	210	143	117	105
[c] Ely	535	517	190	179	203	30	74	...	101	74	70	179	78	...	170[7]	215	142	112
Exeter	408	382	155	140	96	31	72	66	123	72	66	140	30	72	153	...	113	100
Gloucester	427	406	154	142	160	33	35	68	110	83	85	142	35	70	223	...	95	88
[d] Hereford	350	326	174	145	125	28	70	63	76	72	60	145	53[8]	60	160	...	95	
												106	35[9]					
[e] Litchfield	403	379	177	149	143	26	66	58	145	69	57	149	45	57	252[11]	200[12]	100	93
[f] Lincoln	505	440	242	218	176	37	78	81	118	80	75	218	61	74	264	209	175	132
												165	37[13]					
[g] Norwich	415	384	200	180	205	28	70	75	130	72	85	180	28	72	309[14]	...	83	93
[h] Oxford	168	156	116	102	61	22	53	45	54	52	45	102	21	45	145[15]	...		
[i] Peterborough	480	427	198	184	234	35	79	73	90	79	...	183	58	73	143	150	153	115
																155[16]		
[k] Rochester	383	362	170	144	140	32	73	55	145	85	55	122	32	55	156	95	93	
												90	58	55[17]				
[l] Salisbury	474	450	230	206	196	32	78	81	152	78	81	206	57	81	404[20]	...	112	115
												145	44	81[19]				
Wells	415	385	155	130	164	32	70	68	82	32	73	130	68	68	165	125	148	115
Winchester	556	520	230	208	240	32	88	78	113	88	67	208	81	80	148	...	128	130
[m] Worcester	425	386	145	127	174	30	78	67	90	73	61	127	31	66	193	...		
												121	24	66[21]				
[n] St. Paul's	512	462	283	228	170	39	102	90	97	102	90	228	97	90	360[22]	210	177	138
[o] Old St. Paul's	...	690	...	...	...	..	130	102	165	42[24]	88	248	..	...	534[23]			
Westminster Abbey Church	530	475	215	195	154	30	68	105	136	72	105	195	73	105	...	225	110	141
St. Asaph	...	179	...	...	119	..	68	60	60	32	60	108	..	...	93			
Bangor	...	214	...	...	141	..	60	34	53	...	...	96	32	...	...	60		
St. David	...	307	...	...	124	..	76	46	80	...	...	148	..	...	...	127		
[p] Llandaff	...	270	...	...	...	..	80	...	...	...	...	...	..	...	...	90		
[q] Man	...	113	...	...	...	22	...	...	...	...	...	66						
[r] St. Patrick	...	300	...	...	...	..	...	...	...	...	...	157	..	...	223[25]			
Dunblane	...	216	...	...	...	..	...	...	...	...	...	76	..	...	...	120		
[s] Elgin	...	264	...	...	...	35	...	...	...	...	...	114	..	...	198[26]	84[27]		
[t] Glasgow	370	339	...	...	155	30	62	90	97	62	90	...	..	...	220[28]	120[29]		
Iona	...	160	...	...	...	..	...	...	...	...	...	70	..	...	75			
[u] Kirkwall	...	256	...	...	...	..	...	70	...	...	...	...	..	...	133[30]			

[a] Has two transepts: [1] East transept; [2] West transept; [3] South-west tower.
[b] [5] Including spire; [6] South-west tower.
[c] [7] Octagonal lantern; there is a projection or transept at the west end, forming a galilee.
[d] [8] North end with aisle; there are two transepts; [9] East transept.
[e] [11] and [12] With spires.
[f] Has two transepts: [13] East transept.
[g] [14] With spire.
[b] [15] With spire.
[i] Has projection or transept at the western extremity; [16] tower over north-west transept.
[k] Has two transepts; [17] East transept.
[l] Has two transepts; [19] East transept.
[m] Has two transepts; [21] East transept.
[n] [22] Top of cross over dome.
[o] [23] To top of spire; [24] without aisles.
[p] Has two western towers.
[q] No side aisles.
[r] [25] With spire.
[s] [26] With spire; [27] Without spire; length of ladye chapel eastward 28 feet, extending the whole width of the cathedral.
[t] [28] To the extremity of the spire; [29] At north-west angle.
[u] [30] With spire.

Many cathedrals of architecture similar to our own, are to be seen on the Continent, of the more noted of which we shall give a short description. One of the great points of distinction between the English and foreign cathedrals, is the superior magnitude of the latter, which is evidenced more in the height than in any other dimension:—a circumstance which will be apparent, when it is told that the west front of York Minster could be placed beneath the choir-roofs of Beauvais or Amiens cathedrals; the length of the continental buildings, however, does not bear so great a proportion to their breadth as in England, so that they lose that perspective effect afforded by the long vista of arcades which forms so beautiful a feature in our cathedrals. Another distinguishing characteristic in the foreign churches is afforded in the magnificence of the grand façades, of which full one moiety is occupied by the portal. In our works the entrance is of small dimensions, and is subservient to the window above it, but in theirs it forms the principal object, being splayed from the door to the exterior surface of the wall, and the space thus formed, occupied with columns, niches, statues, and other embellishments; the upper part of this splay is of course of an arched form, and the tympanum over the door-head is frequently filled with large groups of sculpture. The upper half of the façade is occupied by a circular or rose window of great magnitude. This arrangement is frequently carried out in the ends of the transepts. Further we have to notice the apsidal forms of the east end, the numerous chapels surrounding the choir, and the great height of the roof, which in France is in a great measure concealed by lofty parapets, but in Germany, where it is even more lofty, is left exposed. Internally, the foreign structures are remarkable for the great height of the body and aisles, and simplicity of the vaulting; for the apsidal termination with its vaulted roof, and the size of the rose windows of the nave and transepts. The body of the building is frequently divided laterally into five parts, having a central nave with a double aisle on each side of it.

The following cathedrals are remarkable for their—

Entrance Porches—Rheims, Strasburg, and Rouen.

Rose windows—Strasburg, Notre Dame, S. Ouen, Rouen, and Rheims.

Towers and spires—Strasburg, Mechlin, Antwerp, Ulm, Cologne, Friburg, Louvain, and Vienna. The height of that of Strasburg is 550 feet; that of Louvain (now fallen) 533 feet; and that of Vienna, 465 feet. Strasburg, Friburg, and Constance, are noted for their spires of open work or pierced tracery.

The cathedrals of Freidburgh and Frankenburgh have the nave and aisles of the same height, and that of Freidburgh has the side aisles nearly as wide as the nave. St. Lorenzo, Nuremburgh, has a choir loftier than the nave, and the cathedral at Worms is celebrated for its two choirs.

S. Peter's, Rome, is the most spacious cathedral, after which follow those of Cologne and Milan, of which the former has never been completed; it was commenced in the middle of the thirteenth century, but the choir is the only portion that was finished, the nave is carried up only half its intended height. This building, if entire, would be perhaps the most magnificent cathedral in existence, but there seems but a remote probability of its completion: it is said to be adorned with 4,973 pinnacles, 576 statues, 128 windows, 160 flying buttresses, 104 pillars, and 9 entrances, while Milan boasts of 4,400 statues, and 160 columns of white marble.

Admeasurements of some of the more remarkable Continental Cathedrals, given in English feet.

Name of Cathedral.	Total length.	Nave.			Choir.			Aisles.		Transept.		Breadth of façade.	Breadth of nave with aisles.	Height of central tower.	Height of west tower.
		Length.	Breadth.	Height.	Length.	Breadth.	Height.	Breadth.	Height.	Length.	Breadth.				
[a] Amiens	415	220	42	132	130	42	129	18	..	180	42	150	...	...	210
[b] Bayeux	296	140	48	76	118	36	...	17	..	113	..	...	...	224	230
[c] Chartres	376	222	46	108	114	46	...	21	..	195	40	...	103	...	378[1]
[d] Notre Dame	492	244	42	...	157	38	...	..	..	...	..	...	...	...	221
[e] Rheims	439	...	38	116	...	..	...	22	..	150	93	140	93	...	253
[f] Rouen	408	...	..	90	...	..	...	..	..	164	..	...	93	532[2]	...
[g] S. Ouen	416	244	34	100	102	..	...	..	..	130	..	...	...	240	...
[h] Antwerp	500	...	..	...	...	..	...	..	..	230	..	...	...	466	360
[i] Cologne	532	...	..	160	...	..	160	..	80	250	..	...	...	432	532
Friburg	399	...	..	86	...	..	...	..	..	...	..	...	...	...	372
Ulm	416	...	..	140	...	..	...	..	..	...	..	166	...	...	490
[k] Florence	491	132	..	139	...	..	...	..	..	294	..	...	...	463	..
Milan	493	279	..	...	...	..	...	32	..	283	..	197	...	356	...
Rome—S. Peter	669	...	..	...	...	..	...	..	..	442	..	396	...	432	...

[a] Has two western towers.
[b] Has two western towers, and a central one.
[c] [1] With spire. Has double aisles round choir.
[d] Has double aisles of equal dimensions, with galleries over them. The south rose window is 45 feet 6 inches in diameter.
[e] Has two western towers.
[f] [2] With spire.
[g] Ladye chapel 62 feet long.
[h] With spires.
[i] Has double aisles continued all round the church.
[k] Exterior dome.

CATHERINE WHEEL, a large ornament in the upper compartment of the windows of Gothic structures; of a circular outline, filled interiorly with a rosette, or radiating divisions, and beautifully variegated.

Catherine-wheel windows are supposed to have been borrowed from our continental neighbours, in the 14th century. In foreign cathedrals, such windows are of enormous magnitude, and of frequent occurrence; as they are commonly met with, not only in the end walls of the transept, as with us, but also in the western façade immediately above the entrance. There is a very fine one in the cathedral of Rheims; and in the great church of St. Oüen, at Rouen, are two; one of which, of great diameter, is called *la rose.* Winchester cathedral has likewise a very large one; but it is still exceeded by one at Cheltenham, in Gloucestershire. In St. Peter's church, Westminster, there is one in each transept.

CATHETUS, a line falling perpendicularly upon another line or surface.

CATHETUS, in architecture, according to Vitruvius, is a right line drawn perpendicularly from the under arris, or line of the sima-inversa at each flank of the Ionic capital, to the centre of the eye of each volute. It must, however, be remarked, that the cathetus drawn in this manner, does not apply to all ancient examples of this order.

CATTLE SHED, or CATTLE HOUSE, in rural economy, an erection for the purpose of containing cattle while feeding, or otherwise. In order to make the feeding of cattle advantageous, it is most important that the cattle sheds should be placed in the most convenient situations with respect to the fields from which the food is to be brought. In large farms, moveable sheds with temporary yards may be erected according as different fields are in grass or roots, and a great saving of carriage thereby effected, both in the bringing the food to the cattle, and carting the dung unto the land; a clay bottom should be selected, in a high and dry spot, if possible, and it should ever be borne in mind, that, with cattle, as with human beings, cleanliness, free ventilation, and perfect drainage are indispensable to perfect health and a sound condition of the body.

Cattle sheds are most cheaply constructed when placed against walls or other buildings. If they are to be erected in an isolated situation, the expense of the double shed will be much less than that of the single one, to contain the same number of cattle.

Every building of this description should be capable of being well aired, by a free ventilation; and so constructed as to require the least possible labour in giving the food and clearing away the dung; the stalls should be so placed as to keep the cattle dry and clean, with sufficient drains to carry away, and reservoirs to receive the ordure. The greater number of the air-holes should be in the roof; and if the building have gables, there should be a window in each, as high as possible, with moveable boards, or air flights, as in granary windows, which may be easily opened or shut, by means of a small rope. These precautions will not only conduce to the health of the cattle, but tend to preserve the timbers, which, from the alternate wetting by the breath, and drying, would otherwise soon go to decay.

In single sheds, the cattle are, in many parts of the country, fastened to stakes about three feet distant from each other, ranged in a line parallel to the wall, at the distance of about 18 or 20 inches from it, thus leaving sufficient space for laying down the food; but this plan is inconvenient, as it obliges the feeder to pass between the cattle when he feeds them, and is consequently attended with loss of time, and is sometimes dangerous.

The best construction is that which admits a sufficient space for a passage before the cattle, for the feeder to pass along with a wheel-barrow, when he distributes their food. In single sheds, three feet will be sufficient for the width of this passage; and in double sheds, the heads of the cattle should face each other, and the breadth of the passage need not be increased beyond four feet.

Where cattle are fed from the outside, through holes left for the purpose, many inconveniences may arise from wet weather, a severe frost, or a heavy fall of snow; but when fed within, no change of weather can have any influence on their feeding; particularly if due care be taken to keep the provender dry and under cover.

In single sheds, it would be convenient to have a provender-loft above the cattle, for holding, occasionally, hay and straw; a loft of this kind might be provided with flaps in the flooring, furnished with hinges, which, when opened, would afford an easy access for putting in the fodder from the cart, and enable the feeder to throw it into the racks when required. In this case the roof may be supported by posts or pillars, about three or four feet high, on the top of the wall, and eight or ten feet distant from each other; the flaps may be lifted by rings, and be made stationary in any required position, by a catch.

In many places, cows and oxen are bound to stakes, without any stalls, or divisions between them. In some parts, cows are bound in pairs, with a slight division between them; in others, they are not bound, but every cow or ox has a separate stall, divided from the rest by wooden rails, so that they cannot get out, and so narrow that they cannot turn round. Many feeders think the cattle thrive better in stalls of this description, than when they are bound. At each stake there should be a trough for holding provender, and between these two troughs there should be another for water, common to the cattle on both sides; this water-trough, which, as well as the others, may be of stone, and of one piece, may be supplied by a pipe from a cistern or reservoir; and over them should be a perpendicular rack for straw or hay. But though the double stalls, here recommended, are much used for milch cows in different parts of England, they have, in general, only one provender-trough for each cow, and none for water.

In paving stalls for cattle, the declivity is in general too great, which occasions them to stand uneasy. The best mode is similar to that of paving stables. Wood has lately been used with advantage for paving stalls.

In many places, it is the practice to fasten the heads of the cattle between two stakes; by which they can neither lie down in comfort, nor dislodge or destroy those tormenting vermin, which frequently prey upon them. No animal can thrive when confined in this manner.

As the dung of cows and oxen is of a liquid nature, it may perhaps be carried off by means of an iron grating, placed behind each animal, as nearly as can be, in the spot where it usually drops, and immediately over the stall drain, or over a wooden spout, which being continued in a sufficient slope, to a pit or reservoir without, will, with the assistance of water occasionally thrown down, empty itself therein. Should any obstruction occur, the aid of a rake or a hoe, fitted to the drain, may be easily applied; especially if the drain be only covered with a strong plank, which may be taken up when necessary. The greater part of the dung being thus carried away, the remainder will be easily removed. Such a contrivance would save much labour, and facilitate the keeping of cattle clean; it would also be the means of saving a great deal of litter, when scarce or dear. On this part of the subject it may be observed, that the waste of urine and dung, too often seen in even well-conducted farms, is much to be deprecated and lamented—everything of the kind is valuable, and should be conducted to proper reservoirs judiciously constructed and arranged for the purpose, to be afterwards used on the land.

Where a great number of cattle are kept, the erection of sheds or feeding houses on a circular plan, proves very economical, and saves much labour, though a little more expensive in the first cost. In this form of building, the animals stand all round with their tails towards the external wall, leaving a sufficient passage or gangway behind, for them to pass to and from their stalls; proper openings are also to be left in the wall, for discharging the dung, which may fall into covered pits on the outside. The openings should be so contrived, as to be capable of being shut up in severe weather. The area, or space in the middle, is converted to the use of feeding and attendance; and, to render the plan complete, there should be a room above, to store up tho different sorts of food that the cattle may require.

The oblong plan likewise admits of much room and convenience, and is a form in which many cattle houses have been lately erected. In this kind of shed, the length of fifty or sixty feet affords room for a great number of cattle. The roof is made shelving, 14 feet in the highest part, and six or seven in the lowest. The place for the reception of the cattle is separated from that wherein the dung is to be deposited, by a wall, or other convenient division, and may be about 18 or 20 feet within, to afford good room. The stalls are twelve feet long, and from 4 feet to 4 feet 6 inches wide; leaving gang ways at the heads and behind the cattle, 3 feet or 3½ feet in breadth. Each stall has two doors, the one for admission of the cattle, the other for the persons who attend them; and when the buildings are of great length, it may be convenient to have additional doors at each end. There should likewise be a water-trough in each stall, and where a stream can be made to run through the whole range, it is productive of great advantage. The boxes, or mangers, for particular sorts of food, as well as racks for hay, are also necessary to render these buildings complete. The bottom of the stalls may be formed of strong planking, laid so as to have a very slight descent, and perforated with holes for the passage of the urine into the reservoir. There should also be openings in the wall, behind the cattle, between every two stalls, of about two feet square, for discharging the dung, with proper shutters fitted to them. Each stall should likewise have a wooden window, of about the same size, for the admission of light and for free ventilation, placed as high as the house or shed will admit. The reservoir for the dung or urine should extend the whole length of the building. For further particulars on this subject, *see* Cow-House.

CAUKING, or Cocking, the mode of fixing the tie-beams of a roof, or the binding-joists of a floor, down to the wall-plates. This was formerly done by dovetailing, in the following manner:—a small part of the depth of the beam at the end of the under side was cut in the form of a dovetail, and a corresponding notch, to receive it, was formed on the upper side of the wall-plate, across its breadth; making, of course, the wide part of the dovetail towards the exterior part of the wall, so that the beams, when laid in their notches, and the roof finished, would tend greatly to prevent the walls from separating, though strained by inward pressure, or even if having a tendency to spread through accidents or bad workmanship. But beams fixed according to this mode, having been found liable to be drawn to a certain degree out of the notches in the wall-plates, from the shrinking of the timber; a more secure mode has succeeded, which prevents all possibility of one being drawn out of the other, however unseasoned the stuff may be, or however affected by changes of weather. *See* Cocking.

CAULICOLES (from *caulis*, a stalk or stem), in the Corinthian capital, eight stalks between each two of the upper row of leaves, ramifying upwards, each into two foliated branches, and seeming to support the volutes under the abacus; each branch supporting one of the sixteen volutes, or helices, two of which are placed at each angle, and two in the middle of each face of the abacus.

CAULKING, in ship-building, the operation of driving a quantity of oakum, or old untwisted ropes, into the seams of the planks in the sides or decks of a ship, to secure the interior from water. After the oakum is driven very hard into the seams, it is covered with hot melted pitch, or rosin, to prevent the water from rotting it.

Caulking Irons, chisels for driving the oakum into the seams; in caulking, these chisels are some broad, some round, and others grooved.

CAUSEWAY, in the most usual sense, denotes a common hard raised way, maintained and repaired with stones and rubbish.

It also signifies a massive construction of stone, stakes, and fascines; or an elevation of fat viscous earth, well beaten; serving either as a road across wet marshy places, or as a mole to retain the waters of a pond, or prevent a river from overflowing low lands.

CAUSTIC CURVE, in the higher geometry, a curve formed by the concourse of the rays of light reflected from some other curve. It is not of much use in building, as this reflection only forms one of the known curves, which are all specified under their respective heads.

CAVÆDIUM (from the Latin, *cava* and *ædium*), a vacant space within the body of a building; in a Roman house, it was what we now call a *court*. According to Vitruvius, there were five kinds of cavædia, denominated *Tuscan*, *Corinthian*, *tetrastyle*, *displuvinated*, and *testudinated*.

The Tuscan cavædium had a roof projecting from each wall, leaving an aperture in the middle; it was suspended on the walls without the intervention of any support from pillars or columns.

The Corinthian cavædium was similar to the Tuscan, except that the roof was supported by columns.

The tetrastyle, as its name implies, had one column at each of the four angles of the roof, for its support.

The displuvinated, being without any roof, admitted a free access of the light to the windows of the surrounding rooms, and was therefore calculated for winter apartments.

The testudinated, which was covered with a vault or concave ceiling, rising from the walls, was used when the span or impetus was not very great; the space above being used for various kinds of apartments. The latter, however, can hardly be deemed a court, though it comes under the general denomination of cavædium.

CAVAZION, Cavasion, or Cavation, an excavation made in the ground for the foundation of a building.

CAVE, a subterraneous hollow place, or the space dug out for cellarage and other purposes below the basement rooms of a house. A common allowance for this is one-sixth of the height of the building. Caves, without doubt, were among the first habitations of men, before they became acquainted with the method of rearing a covering for shelter. They were also used in the early ages as receptacles for the dead.

CAVEA, in the ancient amphitheatres, properly signified the place where the wild beasts were kept; but the word was also applied to the middle part, called the *arena*, and frequently denoted the whole of the interior of the amphitheatres, as well as of the theatres.

CAVETTO (Italian, a diminutive of the Latin, *cavus*, hollow), a concave moulding or cove, the curvature of whose section does not exceed the quarter of a circle; its projection may be equal to its altitude, and should never be less than two-thirds of it. The cavetto, which is the reverse of the ovolo, or quarter-round, is sometimes used in the bed and crowning mouldings of cornices; and forms the upper member of the architrave of some of the most beautiful Grecian Ionics. The hollow moulding used in the bases between the tori, &c., is also called a *cavetto*.

CEILING (from the Latin, *cœlum* the sky, or *celare*, to cover), the inside of the roof, or top of an apartment, opposed to the surface of the floor. Ceilings may be either flat, or coved, or both. Coved ceilings are sometimes concave round the margin and flat in the middle, or otherwise they are vaulted. *See* Vault. The former occupy from one-fifth to one-fourth of the height of the room. The principal sections of vaulted ceilings may be of various segments, equal to, or less than semicircles as may be most suitable to the height of the room.

Flat ceilings are adorned with large compartments, or foliages and other ornaments, or with both.

Compartment ceilings are either formed by raising mouldings on the surface, or by depressing the panels within a moulded enclosure, which may be partly raised upon, and partly recessed within the framing, or entirely recessed. The figures of the panels may be either polygonal, circular, or elliptical. The ceilings of the porticos, and of the interior of ancient temples, were comparted, and the panels deeply recessed; the prominent parts between them representing, it is said, the ancient manner of framing the beams of wood which composed the floors. The mouldings on the sides of the panels are sunk in one, two, or several degrees, like inverted steps; and the bottoms of panels are most frequently decorated with roses. The figures of these compartments are mostly equilateral and equiangular. Triangles were seldom used; but we find squares, hexagons, and octagons in great abundance. The framing around the panels, in Grecian and Roman examples, is constantly parallel, or of equal breadth; therefore, when squares are introduced, there is no other variety; but hexagons will join in contiguity with one another, or form the interstices into lozenges, or equilateral triangles. Octagons naturally form two varieties, viz., that of its own figure, and squares in the interstices; this kind of compartment is called *coffering*, and the recessed parts *coffers*, which are used not only in plain ceilings, but also in cylindrical vaults.

The borders of the coffering are generally terminated with belts, charged most frequently with foliage; and sometimes, again, the foliage is bordered with guilloches, as in the Temple of Peace, at Rome.

In the ceiling of the entire temple at Balbec, coffers are disposed around the cylindrical vault in one row, rising over each intercolumn, and between every row of coffers is a projecting belt, ornamented with a guilloche, corresponding with two semi-attached columns, in the same vertical plane; one column supporting each springing of the belt.

The ceilings of the ancients were commonly relieved by colour and gilding in various designs, which must have greatly added to the effect of the whole edifice; this practice has been adopted in the new entrance-hall of the British Museum with very great success.

The moderns follow the practice of the ancients in their cupolas and cylindrical vaults, ornamenting them with coffers and belts; and the belts again with frets, guilloches, or foliages. Small panels are ornamented with roses, and large ones with foliage or historical subjects. The grounds may be gilt, and the ornaments white, partly coloured, or streaked with gold; or the ornaments may be gilt, and the grounds white, pearl, straw-colour, light-blue, or any tint that may agree best with the ornaments.

Some ceilings are painted, either wholly or in various compartments only. When a ceiling is painted to represent the sky, it ought to be upon a plane or spheric surface, without being coved at the edges.

Ceilings plane and coved are much employed in modern apartments; they seem to be a kind of medium between the horizontal and the various arched forms practised by the ancients: they do not require so much height as the latter; but they are neither so graceful nor yet so grand.

Vaulted ceilings are more expensive than plane ones; but they are also susceptible of a greater variety of embellishments.

When a ceiling is made on the under side of the rafters of a roof, it is said to be *camp-ceiled*, or *tent-ceiled*.

The timbers of ceilings in Gothic edifices are seldom plastered, although examples are occasionally found, as at Rochester Cathedral, of the Decorated period, which is divided by moulded ribs of wood. The timber ceilings are either flat, concave, circular, or ranging with the principal timbers of the roof; sometimes, however, we have vaulted ceilings of timber, as at Winchester Cathedral. When flat, the ceilings are divided into panels by moulded ribs, which at their intersection are enriched with bosses, pendants, or such like ornaments; sometimes large panels are subdivided by mouldings of a smaller section. The concave ceilings, which present the form of a barrel vault, have most frequently only a single rib running along the top; when others are introduced, it is but sparingly. In all cases, ceilings were enriched with gilding and colours of the most brilliant kind, examples of which are constantly being brought to light during the restoration of old churches.

Plaster was very much used in the ceilings of Elizabeth's time and the succeeding reigns, in which period the ceilings were generally flat, divided into panels by ribs, which, as well as the panels themselves, were often adorned with an exuberance of decoration moulded in the plaster, of which we have many beautiful specimens.

Soffit amounts to nearly the same thing as a *ceiling*, except that the former is applied to the under sides of apertures and cornices, and the latter to a more extended space, as the top or side of an apartment opposite to the floor. The under surface of an arch is also called the *soffit*, or *intrados*, whether it be the head of an aperture, or extended over an apartment.

Arched ceilings are described under the article VAULT.

CEILING, is also understood to be the lath and plaster at the top of a room, or on the under side of common or ceiling joists.

CEILING, in carpentry, the joisting, ribbing, or bracketing for supporting the lath and plaster of the upper surface, or ceiling of a room. There are various kinds of ceilings, as plane ceilings, cove ceilings, and plane and cove ceilings. Under cove ceilings may be classed several other kinds, as waggon-headed, or cylindrical ceilings, dome ceilings, groin ceilings, and spandrel ceilings. For bracketing these different figures, see the words BRACKETING and RIBBING; for the definition of arch ceiling, see VAULT.

CEILING-FLOOR, the joisting and ceiling supported by the beams of the roof.

CEILING-JOISTS, small beams, which are either mortised into the sides of the binding-joists with pulley-mortises, or notched upon, and nailed up to the under sides of the said joists. This last mode takes away from the height of the room; but it is easier to execute, and is thought to be less liable to break the plaster, than when the ends of the ceiling-joists are inserted in pulley-mortises. When girders are introduced in the floor, the under sides of the girders must be furred, to correspond with the level of the under edges of the ceiling-joists.

CELL, in carpentry. *See* SILL.

CELLA, in Roman antiquity, was variously applied. It denoted, in temples, the interior or most retired place, called by the Greeks, *naos;* and in baths, various apartments, as the *frigidaria*, *tepidaria*, *caldaria*, &c. It was also used to denote the apartments of prostitutes, and the bed-chambers of domestics.

CELLA, was likewise applied to monasteries, to denote a lesser one, subordinate to a greater; and was even applied, *vice versa*, to rich monasteries not dependent on any.

CELLAR, in ancient writers, a conservatory for provisions, whether to eat or drink. The term comes from the Latin *celarium*, and is of the same import with *cella*.

CELLAR, as now used, is generally applied to an apartment in which liquors are deposited. Cellars are commonly placed in the lower story of the dwelling-house, sunk beneath the surface of the ground; sometimes they are placed under ground, and are entered from the area before the building; they are sometimes also placed in out-houses. When they are placed within the dwelling-house, or contiguous to an out-building, they should have a north exposure. Cellars should be kept cool, and consequently remote from any place that would communicate heat, and care should be taken to preserve them of as uniform temperature as possible; for this purpose they should be constructed with double walls and double vaults, leaving a hollow space all round.

Cellars, and other places vaulted under ground, were called by the Greeks *hypogæa*.

CELLARAGE, the number of cellars which a dwelling-house requires, whether one or many.

CELTIC, or Druidical Architecture. A term applied to a class of structures composed of rough unhewn stones of great size, the erection of which is generally attributed to that family of mankind classed under the name of Celts, more especially to the Druids.

These erections are of various descriptions, some consisting of a single stone, others comprising many hundreds; their arrangement also differs very greatly, yet at the same time there is a general similarity which readily marks their relation. The remains are more numerous in this country than in any other, but they are by no means confined to it, similar erections being found not only in the neighbouring islands, in France, Germany, the Netherlands, Portugal, Sweden, and Denmark, but also in Phœnicia, Palestine, India, Malabar, Persia and China, and even in the western continent.

To account for the existence of these works in such remote regions, their construction has been attributed to the Celtæ. These Celts, or Gauls, as they were termed by the Romans, are supposed to be descendants of Gomer, the son of Japhet, whose posterity were called after his name, Gomerians, a title which is identical with the Cimmerians of the Greeks, and the Cimbri of the Latins. That the Celtæ were a branch of the same stock as the Cimmerians, is generally allowed, and it would seem, that they followed in their migrations a south-westerly course, while the Cimmerians pursued a northern, and afterwards a westerly direction. When and where the great family separated is not so universally agreed upon, some writers asserting that they divided before they took their departure from the East, others maintaining that the separation did not take place before they had advanced some distance into Europe. The latter class of writers, who rest mainly on the authority of Herodotus, suppose that the two branches of the one family travelled together until they were overtaken and harassed by the Scythians, when a large number, the Celtæ, moved southward, and spread westward from Asia Minor to Italy, and afterwards to Spain and Britain. It is certain that the Cimmerians were closely followed by the succeeding horde of emigrants, the Scythians, and were by them continually pressed further westwards; it is also generally allowed, that Great Britain was peopled principally by the northern hordes who passed through Denmark and Gaul. If we follow the theory of those who place the separation at the later period on this side the Sea of Azoph, we shall have to account in some other manner for the existence of Celtic remains in Syria and Phœnicia, as well as in India. This difficulty is obviated by attributing the introduction of such a mode of building into this country to the Phœnicians; but then we are left to account for the appearance of the same in the north. The supporters of this opinion quote the statement of Cæsar, that Druidism originated in Britain, and was carried thence to Gaul; and from whom, say they, are the Britons likely to have learned it, but from the Phœnicians, with whom we know they carried on a trade in tin, and who, on account of the advantages obtained from that traffic, were very jealous of their knowledge of the island being extended to other nations; it is allowed, that the structures we are considering were closely allied to Druidism. But this theory, as we said before, raises the difficulty about the existence of similar works in the north, unless it be admitted indeed that the Phœnicians and the northern tribes are of the same family, and if so, we allow its early separation, which is the fact for which the opposite party contend; the only difference being this, that in one case, we need only account for one separation; while in the other, we must necessarily suppose a second. The fact of the identity of the Phœnicians with the northern tribes of the Cimmerians does not rest solely on historic evidence, it is also demonstrable from other facts, such as the common origin of their languages, and the similarity of their customs and religious observances. As far as the former is concerned, there seems to be sufficient evidence to show that the Hebrew, Phœnician, Sanscrit, Irish, and Manx languages, are derived from the same source; and as regards the latter, Dr. Borlase, in his attempt to controvert the opinion, admits that the customs and ceremonies of Asia and of Northern Europe were known and practised by the British Druids, although he maintains that the Britons had several observances which were peculiar to themselves. It would indeed seem that Druidism appeared in a more matured and systematic form in these islands, than elsewhere, and this is but reasonable, for, as was before remarked, the Cimbrians were a nomadic race, and were constantly being driven forward by the Scythians; until, as a last resource, they crossed the German ocean into Britain: here defended on all sides by the sea, they had but little to fear from their aggressors, and were precluded from making further movements westward; here therefore they permanently settled, and betook themselves to the arts of peace, and thus was their religion elaborated and reduced to a system; and as, in the case of Numa, and the early Romans, religion established peace, so in this instance did peace establish and extend religion.

From the above observations, we think, may reasonably be drawn the following conclusions, namely, that the erection of all structures of this kind is to be attributed to one race of people, and their appearance in such different and distant quarters to the fact of that race being migratory or nomadic.

The monuments erected by the Celts may be divided and classed as follows:—Lithoi, composed severally of one, two, and three stones, to the first of which is applied the distinguishing appellation monolithon, and to the last, that of trilithon. They have all the common name of Cromlehs. After these come the kist-vaens, or chests, composed of four stones, and lastly, circles comprising a large number of stones. Further, we have logan, or rocking-stones, tolmen stones, cheese-rings, and cairns.

The most simple of these structures are the monolithoi, or single stones, of which we find a great number in various parts of the British Islands. The first mention of such stones we find, is of that set up by Jacob after his dream, which he named Bethel; the next is that set up by Joshua under an oak by the sanctuary, as a witness unto the Israelites, lest they denied their God. Another stone is spoken of at a later period, called the stone of Abel, upon which the ark was rested; and another, which was placed by Samuel between Mizpeh and Shen as a memorial of the Divine assistance. We read also of the stone Ezel, and the great stone in Gibeon. Many such stones are seen in Palestine at the present day, but not in the places mentioned in the Old Testament. The same kind of stones are almost universal in India, few, if any, of the temples being without them; there are two also in Tyre. It is suggested, that the pillars of Hercules were of this class, and with some probability, as Arrian says, that "Gades was built by the Phœnicians; the sacrifices and ceremonies there performed are all after the Phœnician manner;" and Strabo adds, that there were here two pillars dedicated to Hercules. Plato mentions a pillar connected in some way with the

Amazons, and similar lithoi were to be seen at Megara, at Cheronæa, in Thessaly, Ionia and Mauritania, one also within the walls of Athens. Cyrus erected obelisks over the grave of Abradates, king of Susa, and over those of his wife and officers. Further north we find such stones in Denmark, Sweden, Scotland, Ireland, and in our own country.

As these stones are of necessity much alike in all cases, we need only give a description of one, to afford a general idea of the whole of them; we select that of Rudstone, in the East Riding of Yorkshire. It stands about four yards from the north-east corner of Rudstone Church, and rises above the ground twenty-four feet; if, as is stated, it measures the same below ground, its total length will be forty-eight feet; its breadth is six feet, and thickness two feet; all four sides are slightly convex. The stone is of a very hard quality, and its weight is calculated at above forty tons.

The uses of the monolithoi seem to have been various. That some were used as sepulchral monuments, is allowed by all; and some allow them to have had no other use; such was the pillar set up by Jacob over Rachel's grave, also those erected by Cyrus, as before mentioned. Some were trophies of victories, as that erected by Samuel after his defeat of the Philistines; some were witnesses to covenants, as that set up by Jacob and Laban, and that of Joshua; whilst others are merely boundary stones.

Similar in description are the curious round towers so prevalent in Ireland, which are generally found in the locality of a Christian church, a situation which is accounted for by the supposition that the Christian missionaries were accustomed to rear their edifices near the spot where the pagan temples had stood. It is certain that these towers are very old, as they were considered ancient even in the twelfth century; they vary both in height and construction, but their general appearance is that of a circular obelisk tapering gradually towards the summit, and finishing in a conical roof. *See* ROUND TOWERS.

These obelisks are also termed Cromlehs, a word signifying a stone of adoration; also Bothal, which doubtless is the same as the Hebrew, Bethel, both terms signifying the House of God. Under these names are also included monuments of two or three stones, the former comprising an upright pillar with a cross-piece on the top, and the latter two upright stones, with a third at the top, stretching from one to the other; the latter are named likewise trilithons.

Next to the lithoi, or cromlehs, stand the kist-vaens, or monuments of four stones, consisting of three uprights, and one horizontal stone covering the whole: they are often found in, or near circles, and are frequently accompanied with barrows of various kinds. Kist-vaen is a Welsh term, and signifies stone-chest, but the term quoit is frequently applied to the same structures, more especially in Cornwall, and there is one near Cloyne, in Ireland, named Carig-Croith, which is interpreted Sun's House. Such monuments are found in abundance, and in every quarter of the globe; we select one as a specimen, Kit's Coty House, Kent.

This monument stands near to the village of Aylesford, and is thus described by Stowe:—"It consists of four flat stones, one of them standing upright, between two others, inclosing the edges of the first, and the fourth laid flat upon the other three, and is of such height that men may stand on either side the middle stone in time of storm or tempest, safe from wind and rain, being defended with the breadth of the stones, having one at their backs, one on either side, and the fourth over their heads." "About a coit's cast from this monument, lieth another great stone, a great part thereof in the ground, as fallen down where the same had been affixed." This description answers very well to its appearance at the present day, with the exception that the separate stone last mentioned, is now entirely buried in the ground. The dimensions are given as follows in Grose's Antiquities:—"Upright stone on the north or north-west side, eight feet high, eight feet broad, two feet thick; estimated weight, eight tons and a half. Upright stone on the south or south-east side, eight feet high, seven and a half feet broad, two feet thick; estimated weight, eight tons. Upright stone between these, very irregular; medium dimensions, five feet high, five feet broad, fourteen inches thick; estimated weight, about two tons. Upper stone very irregular; eleven feet long, eight feet broad, two feet thick; estimated weight, about ten tons seven hundred-weight."

Monuments of the same description are to be seen in Palestine, the following account of some of which is given by Captains Irby and Mangles:—"On the banks of the Jordan, at the foot of the mountain, we observed some very singular, interesting, and certainly very ancient tombs, composed of great rough stones, resembling what is called Kit's Coty House, in Kent. They are built of two long side-stones, with one at each end, and a small door in front, mostly facing the north; this door was of stone. All were of rough stones, apparently not hewn, but found in flat fragments, many of which are seen about the spot in huge flakes. Over the whole was laid an immense flat piece, projecting both at the sides and ends. What rendered these tombs more remarkable was, that the interior was not long enough for a body, being only five feet. This is occasioned by both the front and back stones being considerably within the ends of the sides only. There are about twenty-seven of these tombs, very irregularly situated." This description would answer very well for our own erections of the kind, were it not for the second stone and doorway, no traces of which are to be found in these islands. Sir Richard Colt Hoare gives two representations of similar stones in Malabar, but he does not accompany them with any description.

Numerous monuments of this kind are to be found throughout the British Isles, but they occur most frequently in Cornwall and Wales, also in the Isle of Anglesea, the last resort of the Druids, and in Ireland.

What the use of these caves were is not agreed upon, some claiming them as sacrificial altars, others as tombs, and others again as simply sacred constructions answering to the ark or sacred chest of the Jews. The former position is maintained by King, who, after referring to the account given by the Romans of the human sacrifices of the Druids, contends for the peculiar applicability of such erections to that purpose; but his opinions do not seem to be borne out by facts. As a decisive argument in the matter, he cites an instance of a structure of the kind existing in the county of Louth, Ireland, which is called the killing-stone; but if this hold good as a proof, a similar one may be advanced for the second class of opinions, in the case of the Trevethy Stone in Cornwall, the word Trevedi signifying, in the British language, it is said, the Place of Graves; and besides this, Kit's Coty House is transferred into Catigern's house of coits, the term coit being translated large flat stone. This place is so named, it is averred, from the fact of Catigern being buried there, after the battle with Hengist and Horsa, which occurred at Aylesford, and in which he was slain.

We have now arrived at the largest and most interesting class of monuments, the Druidical circles; they consist of one or more circles of upright stones placed at short intervals from each other; the circles are usually concentric, but we have not unfrequently two smaller circles placed side by side within a larger one, and the whole surrounded with a circular ditch and vallum. The stones composing the circles are not always single, but sometimes consist of trilithons, sometimes of kist-vaens. Such erections are found in various localities, although more frequently in this country than elsewhere. Mention is made of them in the Sacred writings in more than one instance: Moses is said to have erected an altar, and twelve pillars, according to the twelve tribes of Israel, ere he ascended the mount to receive the law; he also gives directions to the Israelites at a later period, that upon crossing Jordan they should set up in mount Ebal great stones, and plaster them with plaster, and especially orders that they should be whole stones, and unwrought; we accordingly find Joshua setting up twelve stones in the midst of Jordan, and taking twelve further forward, and pitching them in Gilgal, as a memorial of the passage of the Jordan;—it is worthy of remark, that the word Gilgal signifies a wheel or circle, and doubtless the place was so named from the circle of stones there set up. Such circles are found likewise in Sweden, Norway, Denmark, and Iceland, in which last place they are termed Doom circles; they are spoken of by Clarke as existing in the Troad, and Sir William Ouseley gives views and description of one to be seen in Persia; but what is most remarkable, there exist three in America, one upon a high rock on the bank of the river Winnipigon.

Such structures were unquestionably temples in which the Druidical services were performed, and not only so, but they seem to have been the prototype of all heathen temples, for we gather from authentic sources, that the most ancient heathen fanes were all open to the sky without roof of any kind. It is argued by some, that they were used merely for civil purposes, or that some of them at least were exclusively so employed; that they were all so employed we do not for a moment doubt, but we contend that they were all likewise employed for sacred purposes; indeed, the government of the people was so implicit with their religion, that the Druids were at one and the same time both priests and rulers.

The circles are supposed by some to have been closely connected with astrology, and indeed the agreement of the number and arrangement of the stones with the divisions of the ancient cycles is remarkable, as will be seen by referring to the tables of Dr. Stukeley, which are given in the following page.

The most remarkable of the circular erections in Great Britain are those of Stonehenge and Abury, both of which are situate in the neighbourhood of Salisbury Plain. The former, about seven miles north of Salisbury, is approached by a broad avenue protected on either side by a vallum, or long mound of earth; this avenue leads into a large circular platform three hundred feet in diameter, enclosed from the surrounding plain by means of a vallum fifteen feet in height, with a ditch on either side of it, and, as some suppose, by an inner circle of stones, some few having been found in immediate proximity to the other circle. In the avenue, at a distance of about a hundred feet from the circular ditch, is a large stone inclining towards you as you approach, and a similar one in the ditch at the entrance. Passing onwards in a straight direction you approach a large number of stones composing the temple, more especially so termed, which consists of an outer circle of stones fourteen feet in height, seventeen of which still remain, six scattered in various parts of the circle, but eleven on the north-east side, at equal distances from each other, forming a continuous segment of a circle, thus demonstrating the form and position of the whole. This circle consisted originally of thirty stones, surmounted by a continuous impost of large flat stones, which were fitted on to the uprights by mortise and tenon, and formed a complete and regular circle. Within this enclosure is another of a similar figure, and eighty-three feet in diameter, composed of the same number of stones, which however are of smaller dimensions and without imposts. Within this again were five separate structures, termed trilithons, each consisting of two large stones surmounted with an impost, and having three smaller stones a short distance in advance. These structures were situate, one immediately opposite the avenue, and two on each side of it, leaving an unoccupied space for an entrance. The larger upright stones were more lofty than any of the others, one of them measuring upwards of twenty-one and a half feet in height; thus overtopping all the outer circles. In front of the central trilithon, is placed, by Stukeley, a low flat stone, supposed to be the altar. The avenue noticed at the commencement of this description is continued in a north-easterly direction for a distance of about a third of a mile, where it separates into two branches, the one leading southward between two rows of barrows, the other in the opposite direction for more than a mile and a half to a spot called the cursus, which is a flat tract of land, bounded on each side by banks and ditches, and at its extremities by barrows or tumuli.

The erection at Abury, although of more rude construction than Stonehenge, is of more stupendous dimensions; few of the stones remain at the present day, great numbers having been employed in the erection of the neighbouring town, yet we have accounts of many which existed at a previous period, with the aid of which, and of his own experienced judgment, Dr. Stukeley made out a plan of the original structure entire. It consisted of a large circular enclosure of more than twenty-eight acres, surrounded with a great vallum and ditch, the inner slope of the former measuring eighty feet, its circumference at the apex being four thousand four hundred and forty-two feet. On the inner side of the ditch, and close upon its bank, was a circle thirteen hundred feet in diameter, composed of one hundred immense stones of an average height of seventeen feet, and placed at a distance of about twenty-seven feet from each other. Within this outer circle were two smaller ones, situate side by side on a diameter running from north-west to south-east, of the more northerly of which some stones of great size are still standing. These circles consist of two concentric rows of stone, within which, in the southern circle, was a central obelisk, towards which, it is said, the worshippers used to turn during the celebration of the rites, and in the same position, on the northern circle, a structure termed a cove, consisting of three large stones placed towards each other at an obtuse angle. The distance of the centres of the north and south circles is given at five hundred and eighteen feet, and the distances of their circumferences at eighty-six feet, thus determining the length of the diameters, four hundred and thirty-two feet. These admeasurements, however, must be received with some reserve, as the remains were so scanty at the time they were taken, as to leave the exact position of the circles or their centres a matter of great uncertainty. Of this structure, which it is calculated could originally boast in all of more than six hundred stones, but few portions remain, the rest having been employed either in the erection of the town of the same name, which stands within its boundaries, or in constructing and repairing its roads.

From two entrances on the southern side of the exterior circle, extend two avenues, each formed by a double line of upright stones, and of more than a mile in length. One of them running in a south-easterly direction, the breadth of which averages fifty feet, led to an elliptical piece of ground on the top of a hill called the Hackpen, enclosed within two hundred upright stones, and surrounded on all sides with barrows. The south-western avenue, consisting of about two hundred stones, is nearly a mile and a half in length, and terminates in a single stone. It has to be remarked, that both these avenues run in a curved direction, and are hence by some supposed to represent a serpent, thus connecting the religion of the Druids with the early and prevalent superstition of serpent-worship; the western avenue answers to the tail of the reptile; the larger circle to the body; while the head is represented by the Hackpen, a word which, in some languages, signifies *serpent.* The circles of this portion of the structure are concentric, the outer one containing forty stones, having a diameter of one hundred and fifty feet, and the inner, which is composed of eighteen stones, a diameter of forty-eight feet.

Between the two avenues just mentioned, are three mounds, or hills, one of which, situate at the extreme south, and nearly midway between the extremities of the avenues, is remarkable as being the largest artificial mound in Europe; it is named Silbury Hill. The base of this mound covers a space of five acres and thirty-four perches, and its circumference is two thousand and twenty-seven feet, the length of the slope three hundred and sixteen feet, and the diameter of the platform, at its apex, one hundred and twenty feet. Besides this and other erections connected with Abury, are a variety of Druidical remains scattered in all directions for some distance round the great circle.

The number of stones employed at Abury and Stonehenge, with their distribution, as given by Dr. Stukeley :—

ABURY.	Stones.
The great circle contains	100
North temple, outer circle	30
North temple, inner circle	12
South temple, outer circle	30
South temple, inner circle	12
The cove and altar	4
Obelisk and altar	2
The eastern avenue	200
The western avenue	200
Hackpen, outer circle	40
Hackpen, inner circle	18
Long stone-cove jambs	1
The Ring stone	1
Closing stone of tail	1
Total	652

STONEHENGE.	Stones.
The great-circle uprights	30
The great-circle imposts	30
Inner circle	40
Trilithon uprights	10
Trilithon imposts	5
Inmost stones	19
Altar	1
Stones within the vallum	2
Large table stone	1
Distant pillar	1
Stone at entrance	1
Total	140

Mr. Toland gives the following account of a remarkable structure of this kind. " In the isle of Lewis," he says, " at the village of Classerniss, there is one of these temples very remarkable. The circle consists of twelve obelisks, about seven feet high each, and distant from each other six feet. In the centre stands a stone thirteen feet high, in the perfect shape of the rudder of a ship. Directly south from the circle, there stand four obelisks running out in a line; as also another such line due east, and a third to the west, the number and distances of the stones being in these wings the same; so that this temple, the most entire that can be, is at the same time both round and winged. But to the north, there reach, by way of avenue, two straight ranges of obelisks, of the same bigness and distances with those of the circle; yet the ranges themselves are eight feet distant, and each consisting of nineteen stones, the thirty-ninth being the entrance to the avenue." Dr. Borlase mentions three circles of stone in the parish of St. Clare, Cornwall, called the Hurlers, which are separate and distinct from each other, but whose centres are in one straight line.

Amongst some few of the most important circles besides those already mentioned, may be classed that of Stanton Drew, consisting originally of three circles, of the larger of which five stones remain, and of the smaller, a larger number; the stones are much inferior in point of size to those already described. Rollrich is another circle of stones near Chipping Norton, Oxfordshire, the highest of which is not more than five feet above the ground; they are irregular, and of unequal height. Another is found near Penrith, Cumberland, which consists of seventy-seven stones, each ten feet in height, and before them, at the entrance, stands a single one by itself, fifteen feet high. Similar structures are found in other parts of England, Scotland, and the Isles, but none of them approaching in size those of Abury or Stonehenge.

There exists at Carnac, in Brittany, a monument, which in size approaches nearer to Abury than any other such work, but which, in its form and general character, is perfectly unique; it is of ruder formation than either Abury or Stonehenge, " and consists of eleven rows of unwrought pieces of rock or stone, merely set up on end in the earth, without any pieces crossing them at top. These stones are of great thickness, but not exceeding nine or twelve feet in height; there may be some few fifteen feet. The rows are placed from fifteen to eighteen paces from each other, extending in length —taking rather a semicircular direction—above half a mile, on unequal ground, and towards one end upon a hilly site. When the length of these rows is considered, there must have been nearly three hundred stones in each, and there are eleven rows; this will give some idea of the immensity of the work, and the labour such a construction required. It is said that there are above four thousand stones still remaining." This account is taken from Mrs. Stoddart's Tour in Normandy and Brittany; but a French writer gives the size of some of the stones at twenty-one and twenty-two feet, and he especially alludes to one specimen, which was twenty-two feet high, twelve broad, and six deep; its weight is given at two hundred and fifty-seven thousand pounds.

Logan stones, or rocking-stones, as they are less technically termed, are stones, often of an immense size, poised on others, or on natural rocks, in such a peculiar manner, as to move with the slightest touch. They seem to have been erected at various times and places. They were known to the Greeks, and called by them *λιθοι εμψυχοι*, or live stones, also named Petræ Ambrosiæ, from the ceremony they underwent of being anointed with oil. Pliny takes notice of one erected by Lycippus, at Tarentum, and also of one at Cyzicum, which is said to have been left by the Argonauts; but the most celebrated was the Gygonean stone, near the Pillars of Hercules, of which Ptolemy Hephæstion relates, that it stands near the ocean, and may be moved with the stalk of an asphodel, but cannot be removed by any force. Pliny likewise says of one at Harpava, in Asia, that it is of so strange and wonderful a nature, that if even a finger is laid on it, it will move, but if you thrust it with your whole body, it will not move at all.

These stones are very common in Britain; there are several in Cornwall and Yorkshire, as also in Scotland, where they are called Claca Breath, or stones of judgment; it is known that there existed formerly several in the island of Iona, which have since been destroyed. In some cases the stone rests on two points, in others on one; it is said that the junction was formed in one instance in Scotland, where the stone had been removed, by a protuberant knob in the upper stone fitting into a socket.

A stone of this nature is that near Penzance, Cornwall, named Men-amber; it is eleven feet in length, four feet in depth, and six in width. Its equilibrium was destroyed by Cromwell's soldiers, by breaking off a portion. Another logan stone situate at Land's End, is said to weigh seventy tons; it stands on one of a stupendous group of granite rocks which rise to a prodigious altitude, and overhang the sea; it was thrown down by a ship's crew, but the good sense of the inhabitants obliged them to replace it.

Borlase was the first to notice a structure of a somewhat different character to the last, called Tolmen, or Hole of Stone, consisting of a large stone supported at two points by others, leaving a space between them, through which it is supposed devotees passed for religious purposes. Of a similar opening at the extremity of Malabar Hill, in the island of Bombay, a writer says—"This place is used by the Gentoos as a purification for their sins, which they say is effected by their going in at the opening below, and emerging out of the cavity above." We find stones of this kind in Cornwall and in Ireland; the most noted is that in the parish of Constantine, Cornwall, which is thus described by Dr. Borlase:—"It is one vast egg-like stone, placed on the points of two natural rocks, so that a man may creep under the great one, and between its supporters, through a passage about three feet wide, and as much high. The longest diameter of this stone is thirty-three feet, the depth thirteen feet, and the breadth eighteen feet six inches. I measured one half of the circumference, and found it, according to my computation, forty-eight feet and a half, so that this stone is ninety-seven feet in circumference, about sixty feet across the middle, and by the best information I can get, contains at least seven hundred and fifty tons of stone. Getting up a ladder to view the top of it, we found the whole surface worked like an imperfect or mutilated honey-comb, into basons; one much larger than the rest was at the south end, about seven feet long; another at the north, about five; the rest smaller, seldom more than one foot, often not so much: the sides and shape irregular. Most of these basons discharge into the two principal ones (which lie in the middle of the surface) those only excepted which are near the brim of the stone, and they have little lips or channels which discharge the water they collect over the sides of the Tolmen; and the flat rocks which lie underneath, receive the droppings in basons cut into their surfaces. This stone is no less wonderful for its position than for its size, for although the under part is nearly semicircular, yet it rests on the two large rocks, and so slight and detached does it stand, that it touches the two under stones, but as it were on their points.

Wring-cheeses, so named from their resemblance in form to an ancient cheese-press, consist of large masses of stone placed one upon the other for several tiers, the whole resting on a base of much smaller dimensions than the superincumbent mass. By some it is contended that they are merely the productions of nature, but it seems more reasonable to suppose, that at least some art has been employed in their formation. They are by some termed rock-idols, under the supposition that they were worshipped as gods.

One such monument, situate in the parish of St. Clare, Cornwall, Dr. Borlase thus describes:—"The rock now called Wring-cheese, is a group of rocks that attracts the admiration of all travellers. On the top stone of this, were two regular basons; part of one of which has been broken off. The upper stone was, as I am informed, a logan or rocking-stone, and might, when it was entire, be easily moved with a pole, but now great part of that weight which kept it on poise, is taken away. The whole heap of stones is thirty-two feet high, the great weight of the upper part and the slenderness of the under part make every one wonder how such an ill-grounded pile could resist, for so many ages, the storms of such an exposed situation." Mr. Hayman Rooke mentions one situate on Brimham Craggs, Yorkshire, the circumference of which is forty-six feet, and the pedestal on which it rests, only one foot by two feet seven inches.

Cairns are conical heaps of loose stones frequently found on the top of hills or artificial tumuli; the term is derived by Mr. Roland from two Hebrew words, signifying coped heaps. On these are supposed to have been kindled fires, at which certain religious ceremonies took place, such as that mentioned as being observed by the Israelites in making their children pass through the fire, in imitation of their heathen neighbours; thus connecting the customs of the British Druids with those of Asia and Phœnicia. From these Druidical practices may have arisen perchance the ordeal by fire of later times.

At New Grange, near Drogheda, Ireland, is a curious sepulchral pyramid of stone, formed of pebble stones, the weight of the solid contents of which amounted to no less than one hundred and eighty-nine thousand tons. The plan of this monument is curvilinear, and covers about two acres of ground, and is surrounded by a number of large unhewn stones, rising about seven feet above the ground; the height of the pyramid is calculated at seventy feet. A great number of stones, removed for paving and other purposes, led to the discovery of a passage leading into an interior vaulted apartment. This passage began about forty feet within the body of the work, and is entirely composed of large flag stones; its length is sixty-one feet, the width three feet, and the height varies from two to nine feet. This passage leads into an octangular vaulted apartment, whose diameter is seventeen feet, and its height twenty; the vault or dome is remarkable as being composed of overlapping horizontal stones, the upper ones projecting inwardly beyond the lower, sustained in their position by having a larger portion of each stone upon the one beneath it, than projects towards the interior; this construction is exactly similar to that of the tomb of Agamemnon, or treasury of Atreus at Mycenæ. The side of this irregular octagon immediately opposite the entrance, is formed into a niche, as are also two sides at the right and left, similar to the erections called kist-vaens, the last two containing each a rock-bason. This building is, we believe, the only one of its kind existing in Britain.

We have not included the barrows or tumuli in the list of monuments to be considered, simply because they can scarcely be considered to have any great connection with Architecture, but as they are closely allied to the structures we have been considering, we ought not to pass them by without notice. They are mere mounds of earth, of various shapes, raised, as is supposed, over the graves of men of rank, and are found in great numbers in the neighbourhood of the larger monuments: some of them are of oblong shape, raised like coped tombs, some triangular, some circular and oval, of which again some are convex, some concave. Some are of the shape of bowls, and some of bells, while others are of a conical form; occasionally two are formed together, and are called twin-barrows, but more frequently they are seen separate. Many of them have been opened, and are found to contain not only human remains, but also spear-heads and other implements of war, besides articles of domestic use, such as earthen vessels and the like. Their contents determine as well their use, as the date of their formation.

CEMENT. The word cement may be defined as any glutinous or other substance, capable of uniting bodies in close cohesion, or making them adhere firmly together, so as to form of the whole one solid mass—as mortar, glue, solder, asphaltum, &c. Cements are of various kinds, but, for convenience, may be divided into NATURAL and ARTIFICIAL.

Natural cements are found in Russia, France, and other countries, and indeed the substance so extensively used in England, and very improperly termed Roman cement, is nothing more than a natural cement, resulting from a slight calcination of a calcareous mineral, containing about 31 per cent of ochreous clay, and a few hundredths of carbonate of magnesia and manganese. It may be observed, that when the proportion of clay in calcareous minerals exceeds 27 to 30 per cent, it is seldom converted into lime by calcination, but they then furnish a kind of natural cement, which can be used by pulverizing it, and kneading it with water.

There are some natural cements which do not set in water for many days, but these are now rarely used; those which solidify quickly, being generally preferred. The adhesive power of some cements in the open air, is very remarkable; and we have ourselves seen 33 bricks stuck to one another by Roman cement, and projecting at right angles from the side of a wall.

The argillaceous limestones, and the artificial mixtures of pure lime and clay, in the proportions requisite to constitute hydraulic lime by the ordinary calcination, become natural or artificial cements, when they have been subjected merely to a simple incandescence, kept up for some minutes.

Calcareous cements may be classed according to the three following divisions, namely, *simple calcareous cements*, *water cements*, *maltha*, and *mastics*.

1st, Simple calcareous cements include those kinds of mortar which are employed in land-building, and consist of lime, sand, and fresh water.

Calcareous earths are converted into quick-lime by burning, which being wetted with water falls into an impalpable powder, with great extrication of heat: and if in this state it is beat with sand and water, the mass will concrete and become a stony substance, which will be more or less perfect according to its treatment, or to the quality and quantities of ingredients.

When carbonated lime has been thoroughly burned, it is deprived of its water, and all, or nearly all, of its carbonic acid; much of the water, during the process of calcination, being carried off in the form of steam.

Lime-stone loses about $\frac{4}{9}$ of its weight by burning, and when fully burned, falls freely, and will produce something more than double the quantity of powder, or slacked lime, in measure, that the burnt lime-stone consisted of.

Quick-lime, by being exposed to the air, absorbs carbonic acid with greater or less rapidity, as its texture is less or more hard; and this, by continued exposure, becomes unfit for the composition of mortar; hence it is that quick-lime made of chalk, cannot be kept for the same length of time between the burning and slacking, as that made from stone.

Marble, chalk, and limestone, with respect to their use in cements, may be divided into two kinds—simple lime-stone, or pure carbonate of lime, and argillo-ferruginous lime, which contains from $\frac{1}{20}$ to $\frac{1}{12}$ of clay, and oxide of iron, previous to calcination: there are no external marks by which these can be distinguished from each other, but whatever may have been the colour in the crude state, the former, when calcined, becomes white, and the latter more or less of an ochrey tinge. The white kinds are more abundant, and when made into mortar will admit of a greater portion of sand than the brown, consequently are more generally employed in the composition of mortar; but the brown lime is by far the best for all kinds of cement. If white, brown, and shell lime, recently slacked, be separately beat up with a little water into a stiff paste, it will be found that the white lime, whether made from chalk, lime-stone, or marble, will not acquire any degree of hardness; the brown lime will become considerably indurated; and the shell lime will be concreted into a firm cement, which, though it will fall to pieces in water, is well qualified for interior finishings, where it can be kept dry.

It was the opinion of the ancients, and is still received among our modern builders, that the hardest lime-stone furnishes the best lime for mortar; but the experiments of Dr. Higgins and Mr. Smeaton have proved this to be a mistake, and that the softest chalk lime, if thoroughly burned, is equally durable with the hardest stone lime, or even marble: but though stone and chalk lime are equally good under this condition, there is a very important practical difference between them; as the chalk lime absorbs carbonic acid with much greater avidity; and if it be only partially calcined, will, on the application of water, fall into a coarse powder, which stone lime will not do.

For making mortar, the lime should be immediately used from the kiln; and in slacking it, no more water should be allowed than what is just sufficient: and for this purpose Dr. Higgins recommends lime-water.

The sand made use of should be perfectly clean; if there is any mixture of clay or mud, it should be divested of either, or both, by washing it in running water. Mr. Smeaton has fully shown by experiments, that mortar, though of the best quality, when mixed with a small proportion of unburnt clay, never acquires that hardness, which, without this addition, it speedily would have attained. If sea-sand be used, it requires to be well washed with fresh water, to dissolve the salt with which it is mixed, otherwise the cement into which it enters, never becomes thoroughly dry and hard. The sharper and coarser the sand is, the stronger is the mortar; also a less proportion of lime is necessary. It is therefore more profitable to use the largest proportion of sand, as this ingredient is the cheapest in the composition.

The best proportion of lime and sand in the composition of mortar is yet a desideratum.

It may be affirmed, in general, that no more lime is required to a given quantity of sand, than what is just sufficient to surround the particles, or to use the least lime, so as to preserve the necessary degree of plasticity. Mortar in which sand predominates, requires less water in preparing, and therefore sets sooner: it is harder, and less liable to crack in drying; for this reason, that lime shrinks greatly in drying, while sand retains its original magnitude. We are informed by Vitruvius, lib. ii., chap. v., that the Roman builders allowed three parts of pit sand, or two of river or sea sand, to one of lime; but Pliny, *Hist. Nat.* lib. xxxvi., prescribes four parts of coarse sharp pit sand, and only one of lime. The general proportion given by our London builders, is $1\frac{1}{2}$ cwt., or thirty-seven bushels of lime, and $2\frac{1}{2}$ loads of sand; but if proper care were taken in the burning of the lime, the quality of the sand, and in tempering the materials, a much greater quantity of sand might be admitted.

Mr. Smeaton observes, that there is scarcely any mortar but which, if the lime be well burned, and the composition well beaten in the making, will require two measures of sand to one of unslacked lime; and it is singular, that the more the mortar is wrought or beat, a greater proportion of sand may be admitted. He found that by good beating, the same quantity of lime would take in one measure of terras, and three of clean sand, which seems to be the greatest useful proportion.

Dr. Higgins found that a certain proportion of coarse and fine sand improved the composition of mortar; the best proportion of ingredients, according to experiments made by him, is as follows, by measure: Lime, newly slacked, one part; fine sand, three parts; coarse sand, four parts. He also found that an addition of one-fourth part of the quantity of lime, of burnt bone-ashes, improved the mortar, by giving it tenacity, and rendering it less liable to crack in drying.

The mortar should be made under ground, then covered up, and kept there for a considerable length of time, the longer the better; and when it is to be used, it should be beat up afresh. This makes it set sooner, renders it less liable to crack, and harder when dry.

The stony consistence which it acquires in drying, is owing to the absorption of carbonic acid, and a combination of part of the water with the lime: and hence it is that lime that has been long kept after burning is unfit for the purpose of mortar, for in the course of keeping, so much carbonic acid has been imbibed as to have little better effect, in a composition of sand and water, than chalk or lime-stone reduced to a powder from the crude state, would have in place of it.

Grout is a cement, containing a larger proportion of water than is employed in common mortar, so as to make it sufficiently fluid to penetrate the narrow irregular interstices of rough stone walls. Grout should be made of mortar that has been long kept and thoroughly beat, as it will then concrete in the space of a day: whereas, if this precaution be neglected, it will be a long time before it sets, and may even refuse setting for ever. *See* GROUT.

Mortar made of pure lime, sand, and water, may be employed in the linings of reservoirs and aqueducts, provided it have sufficient time to dry; but if the water be put in while it is wet, it will fall to pieces in a short time; and, consequently, if the circumstances of the building be such as render it impracticable to keep out the water, it should not be used: there are, however, certain ingredients put into common mortar, by which it is made to set immediately under water, or if the quick-lime contain in itself a certain portion of burnt clay, it will possess this property.

From the friable and crumbling nature of our mortar, a notion has been entertained by many persons, that the ancients possessed a process in its fabrication, which has been lost at the present day; but the experiments of Mr. Smeaton, Dr. Higgins, and others, have shown this notion to be unfounded, and that nothing more is wanting than that the chalk, lime-stone, or marble, be well burned, and thoroughly slacked immediately, and to mix it up with a certain proportion of clean large-grain sharp sand, and as small a quantity of water as will be sufficient for working it; to keep it a considerable time from the external air, and to beat it over again before it is used: the cement thus made will be sufficiently hard.

The practice of our modern builders, is to spare their labour, and to increase the quantity of materials they produce, without any regard to its goodness: the badness of our modern mortar is to be attributed both to the faulty nature of the materials, and to the slovenly and hasty methods of using it. This is remarkably instanced in London, where the lime employed is chalk lime, indifferently burnt, conveyed from Essex or Kent, a distance of ten or twenty miles, then kept many days without any precaution to prevent the access of external air. Now, in the course of this time it has absorbed so much carbonic acid as nearly to lose its cementing properties, and though chalk lime is equally good with the hardest lime-stone, when thoroughly burned, yet, by this treatment, when it is slacked, it falls into a thin powder, and the core or unburned lumps are ground down, and mixed up in the mortar, and not rejected, as it ought to be.

The sand is equally defective, consisting of small globular grains, containing a large proportion of clay, which prevents it from drying, and attaining the necessary degree of hardness. These materials being compounded in the most hasty manner, and beat up with water in this imperfect state, cannot fail of producing a crumbling and bad mortar; and to complete the miserable composition, screened rubbish, and the scraping of roads, are thrown in, as substitutes for pure sand.

How very different was the practice of the Romans! The lime which they employed was perfectly burnt, the sand sharp, clean, and large-grained; when these ingredients were mixed in due proportion, with a small quantity of water, the mass was put into a wooden mortar, and beaten with a heavy wooden or iron pestle, till the composition adhered to the mortar: being thus far prepared, they kept it till it was at least three years old. The beating of mortar is of the utmost consequence to its durability, and it would appear that the effect produced by it, is owing to something more than a mere mechanical mixture. *See* MORTAR.

Water cements are such as are impervious to water: they are generally made of common mortar, or of pure lime and water, with the addition of some other ingredient to give it the property of hardening under water.

For this purpose there are several kinds of ingredients, as puzzolana, cellular basalt, or wakke, compact basalt, coal-ashes, coal-cinders, wood-ashes, pumice-stone, brick-dust, powder of quick-lime, forge-scales, roasted iron-ore, &c.

The cement employed by Mr. Smeaton, in the construction of the Eddystone lighthouse, was composed of equal parts, by measure, of slacked Aberthaw lime and puzzolana; this proportion was thought advisable, as the building was exposed to the utmost violence of the sea: but for other aquatic works, as locks, basins, canals, &c., a composition made of lime, puzzolana, sand, and water, in the following proportion, viz., two bushels of slacked Aberthaw lime, one bushel of puzzolana, and three of clean sand, has been found very effectual. It is well known, that sand and lime, mixed together with care, will incorporate and form a mortar impervious to water, and sufficient even for the linings of cisterns and reservoirs; but then the mortar must be hardened before it is exposed to the water, or otherwise it will crumble to pieces; and therefore, if the situation be such as to require the mortar to be dried in a certain time, the use of this cement must be abandoned.

Among the ancient nations, the Romans appear to have been the only people who practised building in water to any great extent, particularly in the sea. The discovery of puzzolana is attributed to the following circumstance, among this great people. The Bay of Baiæ, like our fashionable watering-places, was the summer resort of all the wealthy in Rome: the inhabitants of this place did not content themselves with erecting their houses as near the shore as possible, but they even constructed moles and small islands, on which they erected their summer-houses in the more sheltered parts of the bay. By the fortunate discovery of an earthy substance at the neighbouring town of Puteoli, they were enabled to build both expeditiously and securely in water. From this circumstance, the earth thus discovered was called *pulvis Puteolanus*, "powder of Puteoli," "Puteolean powder," or, as it is now denominated, *puzzolana*, which is a mineral of a light, porous, friable nature, and of a red colour, supposed to be formed by concretion of the volcanic ashes of Vesuvius, near to which mountain the town of Puteoli is situated. The original material seems to be a ferruginous clay, which, baked and calcined by the force of volcanic fire, and mixed with common mortar, not only enables it to acquire a remarkable hardness in the air, but to become as firm as stone under water. The only preparation which puzzolana undergoes, is that of pounding and sifting, by which it is reduced to a coarse powder; in this state it is beaten up with lime, either with or without sand, which forms a mass of remarkable tenacity, that sets under water with great celerity, and at last acquires a strength and hardness equal to those of free-stone.

Among the nations of modern Europe, none have practised the art of building under water to so great an extent as the Dutch, to whom we are indebted for the discovery of another valuable material, admirably adapted for aquatic works: this substance is called *terras*, or *trass*, and is nothing more than *wakke*, or cellular basalt. It is procured chiefly from Bockenheim, Frankfort on the Maine, and Andernach, whence it is transported down the Rhine, in large quantities, to Holland, and is prepared by grinding and sifting, so as to reduce it to the consistence of coarse sand; when it is mixed, in the following manner, with blue argillaceous lime from the banks of the Scheldt. They take such a quantity of quick-lime as may be judged sufficient for a week, and spread it in a kind of bason, in a stratum about a foot thick, and sprinkle it with water; this is covered with a stratum of terras, of about the same thickness, and thus left for two or three days; it is then beaten into a mixture, and left for two days longer; after which such portions as are wanted for daily consumption are taken from the mass, and beaten up again previous to being used.—This is the celebrated terras mortar, with which the mounds and other aquatic works, used as a defence for protecting the low lands of Holland, against the incursions of the sea, are consolidated.

The proportion of the ingredients for terras mortar, as used in Britain in the construction of our water-works, is the same as practised by the Dutch, viz., one measure of quick-lime and two of slacked, in the dry powder, mixed with one measure of terras, and well beaten together to the consistence of a paste, using as little water as possible.

Another kind, almost equally good, and considerably cheaper, is composed of two measures of slacked lime, one of terras, and three of coarse sand; but this composition requires more labour in beating than the foregoing, and produces three measures and a half of excellent mortar. When the building is composed of rough stones, which leave irregular interstices and large cavities, the joints may be filled with pebble mortar, which is thus composed: Take two measures of slacked argillaceous lime, half a measure of terras, or puzzolana, one of coarse sand, one of fine sand, and four of small pebbles screened and washed, and mix them together. Pebble mortar was a favourite cement among the Romans, and has been used, ever since their time, in those works wherein a large quantity of mortar is required.

Terras mortar will only acquire its proper hardness under water; for if permitted to dry by exposure to the air, it never arrives at the same degree of hardness as if the same lime had been mixed with good clean common sand, and is very friable and crumbling; but when kept always wet, it throws out a substance something like the concretion in lime-stone caverns, called *stalactite*, which substance acquires a considerable hardness, and in time becomes so exuberant as to deform the face of the walls.

Although the Dutch terras has hitherto been prepared with cellular basalt, it appears, from the experiments of Morveau, that the common compact basalt, if previously calcined, will answer nearly the same purpose. Compact basalt abounds in all the districts where coal is raised, and may therefore be procured easily, and calcined with the refuse coal.

In some parts of the Low Countries, coal-ashes are substituted for terras with very good effect, of which the valuable *cendrée de Tournay* is a striking instance. The deep blue argillo-ferruginous lime-stone of the Scheldt is burnt in kilns, with a slaty kind of pit-coal found in the neighbourhood. When the calcination of the lime is completed, the pieces are taken out, and a considerable quantity of dust and small fragments remain at the bottom of the kiln. This refuse, consisting of coal-ash, mixed with about one-fourth of lime-dust, is called the *cendrée*, and is thus made into mortar with lime: Put a bushel of the materials into any suitable vessel, and sprinkle it with as much water as is sufficient to slack the lime; then take another bushel, and treat it in the same manner; and so on, till the vessel is filled. In this state it remains some weeks, and may be kept for a much longer time, if covered with moist earth. A strong open trough, containing about two cubic feet, is filled about two-thirds with cement in the above state, and by means of a heavy iron pestle, suspended at the end of an elastic pole, is well beaten for about half an hour; at the end of this time it becomes of the consistence of soft mortar, and is then laid in the shade from three to six days, according to the dryness of the air. When sufficiently dry, it is beaten again for half an hour, as before; and the oftener it is beaten, the better will be the cement; three or four hours, however, are sufficient to reduce it to the consistence of a uniform smooth paste. After this period it becomes too stiff, on account of the evaporation of its water, as no more of this fluid is allowed to enter the composition than what was at first employed to slack the lime. The cement, thus prepared, is found in a few minutes to unite so firmly, upon brick or stone, that still water may be let in immediately upon the work, without any inconvenience; and by keeping it dry for twenty-four hours, it has nothing farther to fear from the most rapid current.

A composition of a similar nature, is the blue mortar, commonly used in London, for setting the coping of buildings and other works much exposed to the weather. It is made with coal cinders and lime, but is seldom prepared with the requisite attention.

Ash-mortar is used in some parts of England, and is prepared by slacking two bushels of fresh meagre lime, and mixing it with three bushels of wood ashes; this mass is to lie till it is cold, and then to be well beaten; in this state it is kept for a considerable time without injury, and even with advantage, provided it be thoroughly beaten twice or thrice over before it is used. This cement is superior to terras mortar, in situations alternately exposed to wet and dry; but under water, terras mortar has the advantage.

The scales which are detached by the hammering of red-hot iron, have been long known as an excellent material in water-works. Mr. Smeaton appears to have been the first person who tried the relative strength of mortar made of the oxide of iron, and several other compositions. The scales being pulverized and sifted, and incorporated with lime, are found to produce a cement equally powerful with puzzolana mortar, when employed in the same quantity. Mr. Smeaton having been successful in his experiments on these materials, was induced to try others of a similar nature. Having substituted roasted iron ore for the scales, he found that this also gave to mortar the property of hardening under water, though it required to be used in greater proportions than either puzzolana or terras. Two bushels of argillaceous lime, two of iron ore, and one of sand, being carefully mixed, produce 3.22 cubic feet cement, fully equal to terras mortar. If the common white lime be employed, it would be advisable to use equal quantities of all the three ingredients.

With respect to the water used in the preparation of aquatic cement, that of rivers or ponds, where it can be procured, is to be preferred to spring water: but for works exposed to the action of the sea, it is usually more convenient, and equally advantageous in other respects, to use salt water.

The Loriot-mortar is a composition which at one time had obtained considerable celebrity in France, and was employed in many large works. It was invented, about seventy years ago, by M. Loriot, who imagined that he had discovered the process used by the Romans. The principle of the invention consisted in adding to any quantity of mortar, made in the usual way with lime and sand, but prepared rather thinner than usual, a certain portion of quick-lime in powder. The lime-powder being well incorporated with the mortar, the mass heated, and in a few minutes acquired a consistence equal to the best plaster-of-Paris; at the end of two days it became as dry as an ordinary cement at the end of several months; and when the ingredients were well proportioned, it set without any cracking. The quantity of powder varied from $\frac{1}{4}$ to $\frac{1}{6}$ of the other materials, according to the quality of the lime: too much, burning and drying up the mass; and with too little, its peculiar advantages being lost. The proportions are essential, but can only be determined by actual experiment.

Loriot's process was at one time, as we have observed, very much in vogue, but has now fallen into disuse. Founded on the false conception that the induration of mortars was the mere result of a more or less rapid desiccation, and presuming it to be possible to obtain this end by the introduction of a powerful absorbent, it met with the usual fate of error, and sunk into disrepute.

Mr. Smeaton says of this composition—"I have made trial of this method, both in small and in large; for however little likelihood of advantage a proposition may contain, yet, when this concerns a physical process, nothing can be safely concluded but from actual trial; and I must candidly own that the effect was much better than I had expected; for I found the composition not only set more readily than mortar as commonly made up, but much less liable to crack, and consequently, if this cement was made use of in water-building, it was less apt to re-dissolve, because it would more speedily get set to a firmer consistence, and so as more ably to resist the water from entering its pores; but when the water was brought upon it, in whatever state of hardness it was at the time, it at best remained in that state without any further induration, while the water remained upon it; and, as I expect, would so remain, till it had some opportunity of acquiring hardness by further drying."

Indeed, for the purpose of quick concretion, various materials are recommended to be added, such as brick and tile powder, and forge scales. The following is an approved receipt: one measure of bricks, finely pounded; two measures of fine river-sand; old slacked lime in sufficient quantity to make a mortar in the usual manner, and sufficiently liquid to quench the lime-powder, which is added to the same quantity as that of the pulverized bricks.

It is somewhat extraordinary, that a process similar to the composition of the Loriot-mortar is described in *A Treatise on Building in Water*, by George Semple, printed in Dublin, 1776. In discoursing on the good qualities of the roach-lime of Ireland, Mr. Semple remarks, that "it has some useful qualities, not much known among the generality of workmen. As, for instance, our lime-stone will make exceeding good terras for water-works, for which purpose you are to prepare it thus: get your roach-lime brought to you hot from the kiln, and immediately pound, or grind it with a wooden maul, on a smooth large stone, on a dry boarded floor, till you make it as fine as flour; then, without loss of time, sift it through a coarse hair or wire sieve, and to the quantity of a hod of your setting mortar (which on this account should be poorer than ordinary) put in two or three shovelfuls of this fine flour of the roach-lime, and let two men, for expedition's sake, beat them together, with such beaters as the plasterers make use of, and then use it immediately. This, I can assure you, will not only stand as well, but is really preferable to any terras." The memoir of M. Loriot was published in 1774, only two years previous to this treatise of Semple, who appears to have been a man rather of practice and experience than of reading; and, besides, in the book quoted from, he expressly, though incidentally, mentions his ignorance of the French language. We are justified, therefore, in stating that the knowledge of the advantages of mixing quick-lime powder in mortar, was not confined to M. Loriot, though it might have been an original invention in him, and that he was the first who drew the public attention to the process, and used it in any considerable works.

We have now to notice the valuable Treatise of M. Vicat, the celebrated French engineer, on the Composition of Mortars and Cements. This scientific and elaborate work has been made extensively known in this country, by the able manner in which it has been translated by Captain J. T. Smith, of the Madras Engineers. The labours of this gentleman have given increased value to M. Vicat's work, and the numerous notes, tables, and other information, added to the original work by Captain Smith, will be found most useful to the professional man, and well worth his careful and attentive study.

In this place we shall briefly describe the mode pursued by M. Vicat in the manufacture of the *Artificial Hydraulic Limes*, he so strongly recommends. We shall have occasion to return to his work hereafter, when on the subject of Concrete.

The practice of M. Vicat seems to have been principally directed to the adoption of the hydraulic limes, in preference to the more energetic cements so generally used in this country, but his investigations have been conducted on so comprehensive a scale, that the processes laid down by him for the manufacture of artificial hydraulic compounds are capable of application to almost every requirement of the Architect or Engineer, or to almost every situation.

The opinion so decidedly expressed by M. Vicat, that the superior adhesion of the hydraulic limes, must inevitably lead to their general adoption in this country, in preference to our (so-called) Roman cements, has been much combated by practical men. It may be said, without entering into a discussion of the question, that it appears to be one on which a contrariety of opinion may be occasioned by a difference of situation and circumstances. Thus, in comparing the merits of the two systems, it is important to consider, that, in one, the means of minute mechanical division are an essential element, in the other that it is unnecessary; and that this element, which in one situation may be obtained at a cheap rate, in another may be expensive and unattainable.

The hydraulic limes, therefore, which do not require to be *ground* previous to use, are at all events most suitable for those situations where the facilities of mechanical agency cannot be resorted to, while the *ground cements* are better adapted to the vicinity of a large capital, where it is of little importance that the builder becomes dependent upon others for his supply.

The difference, in fact, consists in this, that the ground cements, of whatever kind, will ever be furnished by *manufacturers*, whereas the hydraulic limes may at all times be prepared by the common workman, without machinery, and at a cost not much exceeding that of common lime.

The description given by M. Vicat of the mode in which the artificial hydraulic limes are prepared is as follows: — "The artificial hydraulic limes are prepared by two methods: the most perfect, but alsothe most expensive, consists in mixing with rich lime slacked in any way, a certain proportion of clay, and calcining the mixture; this is termed artificial lime *twice kilned*."

"By the second process, we substitute for the lime any very soft calcareous substance (such, for instance, as chalk), which it is easy to bruise and reduce to a paste with water. In this way a great saving is effected, but at the same time is procured an artificial lime of good quality, though not equal to that derived from the first process, in consequence of the rather less perfect amalgamation of the mixture."

"We see that by being able to regulate the proportions, we can also give to the factitious lime whatever degree of energy we please, and cause it at pleasure to equal or surpass the natural hydraulic limes."

"We usually take twenty parts of dry clay to eighty parts of very rich lime, or to one hundred and forty of carbonate of lime. This refers to the lime in the unslacked condition, or to the uncalcined mineral. If the lime be slacked, the proportion should be increased to 110 parts. But if the lime or its carbonate should already be at all mixed with clay in the natural state, then fifteen parts of clay will be sufficient. Moreover, it is proper to determine the proportions for every locality."

"The mixture here described," adds Captain Smith in a note, "is such as to produce the hydraulic limes, whose properties are similar to the Aberthaw, the analysis of which shows it to correspond nearly with the proportions here recommended, as it consists of 86.2 of carbonate of lime to 11.2 clay, (with 2.6 water and carbonaceous matter), being at the rate of 18.2 parts clay, to 140 of the carbonate of lime. The cements now in use in England, are much quicker setting than these, and differ in being unslacked. They contain a greater proportion of clay, but may be manufactured artificially with equal ease, by combining such relative quantities of chalk, or lime, and clay, as will suit the purpose intended. Parker's Patent Cement, as analyzed by Sir Humphrey Davy, contains 45 per cent of clay to 55 carbonate of lime; the Yorkshire cement, 34 clay to 62 carbonate of lime; the Sheppey, 32 clay to 66 carbonate of lime; and the Harwich, which is a quicker-setting cement, 47 clay to 49 carbonate of lime." It seems to be evident from the experiments of M. Vicat, that the manufacture of artificial cements may be almost infinitely varied by the admixture of different ingredients. The character, quality, and proportions of these must be the result of actual practice and experiment, for so different may be the chemical properties of apparently similar materials, that no results, however successful in one locality, can be trusted to with certainty in another. It is only necessary to add, that in all cases, particular attention should be paid to the perfect amalgamation of the materials; and the degree of calcination best suited to it should be carefully observed, before attempting the manufacture on a large scale.

The process made use of at a manufactory of artificial lime at Meudon, near Paris, is thus described by M. Vicat—"The materials made use of are chalk of the country, and the clay of Vaurigard, which is previously broken up into lumps of the size of one's fist. A millstone set up edgeways, and a strong wheel with spokes and felloes, firmly attached to a set of harrows and rakes, are set in motion by a two-horse gin, in a circular basin of about two metres (six feet and a half English) radius. In the middle of the basin is a pillar of masonry, on which turns the vertical arbor to which the whole system is fixed: into this basin, to which water is conveyed by means of a cock, they throw successively four measures of chalk, and one measure of clay. After an hour and a half working, they obtain about 1.50 metres cube (nearly 53 cubic feet English), of a thin pulp, which they draw off by means of a conduit pierced horizontally on a level with the bottom of the basin. The fluid descends by its own weight; first into one excavation, then into a second, then a third, and so on to a fourth or fifth. These excavations communicate with one another at top; when the first is full, the fresh liquid, as it arrives, as well as the supernatant fluid, flow over into the second excavation; from the second into the third, and so on to the last, the clear water from which drains off into a cesspool. Other excavations, cut in steps like the preceding, serve to receive the fresh products of the work, whilst the material in the first series acquires the consistency necessary for moulding. The smaller the depth of the pans in relation to their superficies, the sooner is the above-mentioned consistency obtained.

"The mass is now subdivided into solids of a regular form, by means of a mould. This operation is executed with rapidity. A moulder, working by the piece, makes on an average five thousand prisms a day, which will measure about six cubic metres (211.8 cubic feet English). These prisms are arranged on drying shelves, where in a short time they acquire the degree of desiccation and hardness proper for calcination."

These artificial limes are intended to supply the place of the natural ones in those countries where argillaceous limestone cannot be obtained. The price at which they were sold in Paris a few years back, was about £2 5s. per cubic yard English.

Maltha, and *mastic*, are cements, whose hardness depends on the oily or mucilaginous substances that enter into their composition. The use of these is at present very limited in Europe; but they were highly esteemed by the ancients, especially for stucco. The *maltha* of the Greeks seems to have been more simple than that employed by the Roman architects; at least we are informed, that Panæmas, the brother of Phidias, lined the inside of the temple of Minerva, at Elis, with stucco, in which the usual ingredients of sand and lime were mixed up with milk, instead of water, some saffron being added to give it a yellow tinge. The Roman *maltha*, according to Pliny, was prepared as follows: Take fresh-burnt lime, and slack it with wine, then beat it up very well in a mortar, with hogs' lard and figs: this cement, if well made, is excessively tenacious, and in a short time becomes harder than stone; the surface to which it is to be applied is to be previously oiled, in order to make it adhere. Another kind almost equally strong, and considerably cheaper, was prepared by beating up together fine slacked lime, pulverized iron scales, and bullocks' blood.

In the preparation of *maltha*, as well as of every other kind of mortar, so much depends on the manipulation, and on the care and long beating of the ingredients, that those countries in which labour is of the least value, possess, in general, the best mortar. Hence, no doubt, principally arises the unrivaled excellence of the mortar made by the Tunisians, and other inhabitants of the northern coast of Africa. Dr. Shaw gives the following account of their manner of preparing their mortar: One measure of sand, two of wood-ashes, and three of lime, being previously sifted, are mixed together, and sprinkled with a little water; after the mass has been beaten some time, a little oil is added: the beating is carried on for three or four days successively, and, as the evaporation in that hot climate is considerable, the cement is kept in a proper degree of softness by the alternate addition of small quantities of water and oil. The cement, being completed, is applied in the usual manner, and speedily acquires a stony hardness.

The term *maltha* is also applied to a variety of bitumen or mineral pitch of a viscid and tenacious character; unctuous to the touch, and exhaling a bituminous odour. This substance, as also Asphalte, (see ASPHALTE,) has been successfully used as a cement.

The celebrated *chunam*, of India, is a species of *maltha* which has been used in that country from time immemorial. The method in which it is prepared at Madras is as follows:—

Take fifteen bushels of pit-sand, and fifteen bushels of stone-lime; slack the latter with water, and when it has fallen to powder, mix the two ingredients together, and let them remain for three days untouched. Dissolve 20 lbs. of molasses in water, and boil a peck of *gramm*, (a kind of pea,) and a peck of mirabolans to a jelly; mix the three liquors, and incorporate part of the mixture very accurately with the lime and sand, so as to make a very fluid cement; some short tow is then to be beaten well into it, and it will be fit for use. The bricks are to be bedded in as thin a layer as possible of this mortar; and when the workmen leave off, though but for an hour, the part where they recommence working is to be well moistened with some of the above liquor before the application of fresh mortar. When this composition is used for stucco, the whites of four eggs, and four ounces of butter-milk, are to be mixed up with every half bushel of cement, and the composition is to be immediately applied.

Mastic is an external composition possessing peculiar properties, which, in some cases, render it superior to Roman cement, having the power of resisting heat and adhering to iron, copper, and even glass, with equal tenacity. It is generally applied to the exteriors of mansions, but it may also be very beneficially used for laying the floors of halls, kitchens, &c.

Mastic was first introduced from France by Hamlin, but is now sold only by Messrs. Francis and White, at Nine Elms. It is composed of pounded stone, silver sand, litharge, and red lead, and, when manufactured, has the appearance of very fine sand. The manner of working Mastic is entirely different from that of Roman cement.

To one cwt. of Mastic add one gallon of linseed-oil, and let them be well incorporated by the labourer, which must be effected by treading them together with the feet until the amalgamation is complete, which may be easily ascertained by smoothing a portion of the mixture with the shovel: should any bright spots be observable, the treading must be again and again repeated until they completely disappear, when it is considered fit for use.

The manner in which Mastic is used is as follows:—The joints of the brickwork being well cleaned out, the work must be correctly plumbed up by means of flat-headed nails, and screeds, for the guidance of the floating-rule, formed with Roman cement, and kept about one inch in breadth. This being done, the bricks must be well saturated with boiled linseed-oil of the best quality, and the Mastic laid on with the hands, assisted occasionally by the laying-trowel, until the space between the screeds be covered to the thickness required. The floating-rule is then passed carefully over the work; and when the space between the screeds is sufficiently filled up, it must be floated with a hand-float, composed of sycamore or beech, until it assumes the same appearance as highly-polished stone. Thus a space of large dimensions must be followed up until the whole is completed, when the screeds must be cut out, their places filled with Mastic, and compactly hand-floated into the rest of the work.

Within the last few years various compositions have been invented for the covering of the exterior of buildings, such as Roman Cement, Terra Cotta, Bailey's Composition, and a host of others, all more or less patronized by the public.

It would be impossible for us to give descriptions of all these compositions; but we shall shortly explain the mode of preparing and using the *Roman cement.* This cement, familiarly known among plasterers as *Compo*, was first introduced to public notice by Messrs. Parker and Wyatt, who took out a patent for it, and who succeeded in obtaining for it an extensive sale.

It is prepared from the kind of stone called clay-balls, or septaria, by being, after a manner of manufacturing plaster, first broken into pieces of a convenient size, slowly calcined in kilns or ovens, and afterwards ground to a fine powder, and put into proper casks, great care being taken to preserve it from damp. Two parts of this composition, with three parts of clean grit-sand, will form a very durable substitute for stone. In selecting the sand, great care must be taken to procure it free from clay or mud, and of a sharp and binding quality, or it must be washed until perfectly clean.

This composition, when it is intended to *compo*, as it is termed, the exterior of a building, is thus used:—

After the walls have been well soaked with water, the cement must be prepared by the hawke-boy on a stiff board made for the purpose, adding as much water as brings it to the consistency of paste, but no more must be mixed than can be used in ten minutes. It must be laid on with the greatest possible expedition, in one coat of three-quarters of an inch in thickness, and after being well-adjusted with the floating-rule, the hand-float must be incessantly used to bring it to a firm and solid surface before it sets, which it does in about fifteen minutes.

The work should then be drawn and jointed to imitate well-bonded masonry, and afterwards coloured with a wash composed of five ounces of copperas to every gallon of water —a sufficient quantity of fresh lime and cement—and to the whole adding the colours necessary to imitate any particular stone that may be required.

Terra Cotta, or artificial stone, is an excellent and durable composition, advantageously used at the present day for all kinds of exterior decoration. It is a compound of pipe-clay, stone-bottles, glass, and flint, well pounded together, and sifted through a fine sieve, a small portion of silver-sand afterwards added.

Bailey's Composition is also a valuable invention, which has been used with great advantage in various situations, without being at all injured by winter. The exteriors of many of the public buildings in the metropolis are covered with this composition, amongst which is the Colosseum in the Regent's Park.

It is simply a mixture of lime and sand, the strength of the lime being preserved by the peculiar manner in which it is prepared. In its manufacture, chalk should never be used; it ought always to be made from lime-stone, or carbonate of lime. The lime, being taken before being slacked and ground to powder, must be placed in iron-bound casks to prevent the admission of air or damp. When used, it must be mixed with one-third its quantity of sharp river-sand, the manner of working it being the same as that of Roman cement. *See* MORTAR, GROUT, STUCCO, and CONCRETE.

CEMETERY, a sacred place, set apart for the burial of the dead. The term is of Greek derivation, signifying "a place of rest or sleep," and was applied by the early Christians to common places of interment.

The subject of burial in towns has of late occupied so prominent a place in public estimation, that the description of a few of the great receptacles for the dead lately established in or near the metropolis, cannot be out of place in a work of this kind; the more especially, that the professional talent of the architect has, not unfrequently, been called into action, to furnish designs for the buildings connected with public cemeteries, if not for the ornamental gardens, since it has become the fashion of the day to make these "cities of the dead."

From the very earliest ages the disposal of the bodies of the dead has been a necessary, and with many nations, a sacred duty. Among some we find that a superstitious veneration for those who had "passed away;" the necessity of funeral rites to secure the future happiness of the deceased; and the crime attached to the violation of the tomb, formed a part both of their civil and religious code. The practice of burying the dead in the earth is probably the oldest, as it is the simplest mode of disposing of them: but the custom of burning the body, and afterwards collecting the ashes, and depositing them in a tomb, or urn, became very general amongst the Greeks and Romans. The Egyptians do not seem to have ever adopted this practice; and even amongst the ancient Greeks and Romans, it seems likely that interment in the earth was mostly resorted to by the lower orders. At the present day, all European nations deposit their dead in the earth, and the ceremony of burning is extinct.

The establishment of public cemeteries is now becoming general in the neighbourhood of large cities; a practice probably suggested to us by the customs of the Orientals, with whom the burial-places of their departed friends are objects of peculiar care, and who cultivate, with extreme affection and solicitude, the flowers and trees with which it is their delight to adorn them.

"Among the first objects that present themselves to a stranger entering Turkey," remarks a recent writer, "are the groves of cypress extending in dark masses along the shores. These are the last resting-places of the Turks; and their sad and solemn shade, far more gloomy than any which Christian usage has adopted, informs the traveller that he is now among a grave and serious people.

The situation of cemeteries is of great importance, both with regard to the public health, and from considerations of convenience. Among the Greeks we find that they were usually without the cities. Among the Romans the tombs were generally placed by the sides of the public roads. The early Christians followed the custom of the Romans, but they afterwards transferred their burial-places to the vicinity of the churches, and within towns. This insalubrious practice, it is to be hoped, will soon entirely cease, and the health of the living be no longer endangered by the too close proximity of the graves of the dead.

Cemeteries should be placed on high ground, and to the north of habitations, so that southerly winds should not blow over the houses, charged with the putrid exhalations; low wet places should be avoided, and care should be taken that bodies be not interred near wells, or rivers, from which people are supplied with water.

It may not be uninteresting here to state that extra-mural or suburban cemeteries, formed part of the plan of the celebrated Sir Christopher Wren, for the rebuilding of London after the grea tfire. "I would wish," says he, "that all burials in churches might be disallowed, which is not only unwholesome, but the pavements can never be kept even, nor the pews upright; and if the church-yard be close about the church, this is also inconvenient, because the ground being continually raised by the graves, occasions in time a descent by steps into the church, which renders it damp, and the walls green, as appears evidently in all old churches." He then proceeds to recommend, that a piece of ground, being purchased in the fields, should then be "enclosed with a strong brick wall, and having a walk round, and two cross walks, decently planted with yew-trees. The four quarters to serve four parishes, where the dead need not be disturbed at the pleasure of the sexton.

"In these places beautiful monuments may be erected; but yet the dimensions should be regulated by an architect, and not left to the fancy of every mason; for thus the rich with large marble tombs would shoulder out the poor: when a pyramid, a good bust, or statue on a proper pedestal, will take up little room in the quarters, and be properer than figures, lying on marble beds; the walls will contain escutcheons and memorials for the dead, and the real good air and walks for the living."

Though the cemeteries which have been formed are pronounced to be only improvements on the places of burial in this country, and far below what it would yet be practicable to accomplish; they have indisputably been viewed with public satisfaction, and have created desires of further advances by the erection of national cemeteries. Abroad the national cemeteries have obtained the deepest hold on the affections of the population. They have been established near to all the large towns in the United States. To some of them a horticultural garden is attached; the garden-walks being connected with the places of interment, which, though decorated, are kept apart. These cemeteries are places of public resort, and are there observed, as in other countries, to have a powerful effect in soothing the grief of those who have departed friends, and in refining the feelings of all.

At Constantinople, the place of promenade for Europeans is the cemetery at Pera, which is planted with cypress, and has a delightful position on the side of a hill overlooking the Golden Horn. The greatest public cemetery attached to that capital is at Scutari, which forms a beautiful grove. In Russia, almost every town of importance has its burial-place, at a distance from the town, laid out by the architect of the government. It is always well planted with trees, and is frequently ornamented with sculpture. Nearly every German town has its cemetery, planted and ornamented. In Turkey, Russia, ard Germany, the poorer classes have the advantages of interment in the national cemeteries.

One of the most celebrated cemeteries in Europe is that of Père la Chaise, but in this, as in all the cemeteries of Paris, it has been a subject of complaint, that the graves of the poor are neglected and little cared for, amidst the splendid monuments and sculptured ornaments which mark the tombs of the higher classes.

The first attempt at a metropolitan cemetery, in imitation of that of Père la Chaise, was made by the General Cemetery Company, who, in the year 1833, opened to the public their new and extensive burial-ground at Kensall Green. This cemetery occupies above fifty acres of ground; which is tastefully laid out with flowers and plants; well-gravelled walks lead to various parts of the ground; and yews, evergreens, and shrubs, deemed appropriate to a place of sepulture, ornament and diversify the landscape. On the road-side, the cemetery is bounded by a high wall, affording protection and seclusion; on the other side, towards the canal, an open iron palisading permits an uninterrupted view of the country, which here presents a prospect both extensive and beautiful. At the entrance there is a handsome gateway, from which a central walk leads to the church in the *consecrated* portion of the cemetery. In this building are solemnized the funeral rites according to the Church of England. In front of the church a large circle is appropriated to many of the more splendid tombs and mausoleums, and beneath it are extensive catacombs.

In the *unconsecrated* part of the cemetery, set apart for the burial of Dissenters of every denomination, a neat chapel has been erected for the performance of service according to their several forms of worship. The principal feature of this chapel is a rather handsome Doric colonnade, and near it also are catacombs.

The etablishment of the cemetery at Kensall Green was immediately followed by that of several others in the suburbs of London; one of the most picturesque of these is Highgate Cemetery, situated on the rising slope of the hill behind Highgate Church. Here, the natural beauty of the ground has been tastefully made use of, and the result produced is pleasing, if viewed as a pleasure-garden, though certainly conveying but little of that solemnity of thought and feeling we are accustomed to associate with a burial-place for the dead.

The southern entrance, in Swain's Lane, is in a style compounded of Gothic of all periods, exhibiting more of tawdry decoration than the sobriety which should have characterized it. The Egyptian style has been selected for the catacombs, which are approached through an arched avenue, with an entrance flanked by two obelisks. This passage, in the upper part of the grounds, is lined on each side by a range of sepulchral chambers, and leads into another avenue, forming a circular walk between similar chambers, each of which has its Egyptian doorway. These sepulchres, amounting altogether to forty-six, besides eighteen others in the first mentioned avenue, form as many sides of two polygons, an outer and inner one. Midway is an ascent, first by a single flight of steps, and then by others on each side, leading to a terrace overlooking the catacombs, from which they present a striking appearance; the summit of the inner polygon being covered with earth, and having a large cedar in the centre. The back wall of this terrace is in a semi-Gothic style, crowned by a fancy open-work parapet, placed before another terrace, under the south end of the Gothic Church, erected a few years ago by Mr. Vulliamy. The prospect from this terrace is exceedingly beautiful.

Norwood Cemetery occupies about forty acres, on the north-west side of a hill to the east of St. Luke's, Norwood. The entrance is an open arch, which, with the lodge adjoining it, are in much better taste than that of Highgate, although, had there been a gateway, the design would have been greatly improved. There are two chapels—one for members of the Church of England, the other for Dissenters — though varying somewhat in design, there is great similarity in their style, which is a sober, but correct Gothic. The principal objection is the injudicious position of these two buildings, which, from being too near together, neither form distinct architectural pictures, nor group so as to form one design. The architect is Mr. W. Tite.

Abney Park Cemetery contains about thirty acres, and displays evidence of a simple and pure taste, in its buildings and general arrangement. The entrance, if wanting in architectural composition, has something bold and effective in its general appearance. The four piers are lofty and well-proportioned masses, constructed of Portland stone, upon granite plinths, and are surmounted by handsome coved cappings, in the Egyptian style. The lodges are in the same style, and extend the frontage to 118 feet, 40 of which are occupied by the piers and gates in the centre. The effect of this entrance is greatly enhanced by the park-like aspect of the grounds, and the fine old trees with which they are adorned. Nearly in a line with the entrance is the chapel, in the early pointed style, with lancet windows. The architect is Mr. W. Hosking.

The South London Cemetery comprises fifty acres of dry well-drained land, in one of the most beautiful spots within the vicinity of the metropolis. It is situate at Nunhead, between Peckham Rye and New Cross. The grounds are most tastefully laid out—there are handsome lodges, a residence for the superintendent, episcopal and dissenters' chapels, and extensive catacombs. The architectural arrangements were superintended by Mr. Bunnings.

The West of London Cemetery, situate at Earl's Court, consists of about forty acres. The buildings, &c. in the Italian-Doric style, are of a similar character to those previously described, and the grounds are laid out in the pleasure-garden manner, so popular with those who have the management and designing of Cemeteries. It would be well, were a few hints taken from the solemn, beautiful burial-places of the Orientals, in laying out such establishments in this country.

CENOTAPH (from the Greek, κενοταφιον) an honorary monument erected to the memory of the dead, when the funeral rites have been performed in some other place.

CENTAUR, in heathen mythology, a fabulous monster, with the head and breast of a man, and the body of a horse.

CENTERING, the act of making a centre, or the centre itself. *See* Centre.

Centering to Trimmers, the centre made to support a brick arch suspended between the wooden trimmer and the wall, for supporting the hearth or slab.

CENTRE, or Center, (Greek, κεντρον, *a point*, or *puncture*,) in a general sense, denotes a point equally remote from the extremes of a line, figure, or body; or the middle of a line, or plane, by which a figure or body is divided into two equal parts; or the middle point, so dividing a line, plane, or solid, that some certain effects are equal on all its sides.

CENTRE OF GRAVITY, that point at which all the weight of a mass might be collected, without disturbing the equilibrium of any system of which the mass forms a part. Thus, if a lever were balanced by means of two solid spheres of uniform density hung at the ends, the equilibrium would still remain, if all the matter of either of the spheres could be concentrated at its centre. The centre of the sphere is then its centre of gravity.

CENTRE OF PRESSURE, the point at which the whole amount of pressure may be applied, with the same effect as it has when distributed.

CENTRE, in building, is a combination of timber-beams, so disposed as to form a frame, the convex side of which, when boarded over, corresponds to the concavity of an arch; or the wooden mould, used for turning an arch of stone or brick during the time of erection.

Centre of a cylindric or cylindroidal arch, which rises more than the breadth of a plank, is a number of boards supported transversely by one or more vertical frames, or trusses, as the length of the cylinder, or that of its axis, may require.

Centre for a groined arch upon a rectangular plan is thus constructed: Make the centre for one of the cylinders, or cylindroids, viz. that of the greatest diameter, when there is a difference, as if there had been no other cylinder crossing it; find out the places on the surface of this cylindric or cylindroidal centre, where the surface of the transverse vault would intersect: fix the whole ribs on the cross vault, and parts of ribs on the surface of the vault already completed, observing to keep the outer edge of these ribs the thickness of the boards within the intended surface of the intrados of the arch; when this transverse vault is boarded over, the boards will intersect the lines drawn on the first centre, and the surfaces of the boards of each vault will form the true surface of the groined centre, on which the stone or brick arch is to be turned.

The frames or trusses which support the boarding are frequently called *ribs;* and the short ribs which are fixed to the boarding, and made to range with the whole ribs, are called *jack-ribs.*

Under the word STONE-BRIDGE, &c., the theory and construction of arches will be described; in the present article we propose to show how the arch-stones are supported till the arch is completed; and the most commodious and least expensive manner in which this can be accomplished.

The proper construction of such supports, or the best mode of framing the centres for large works, has always been considered so important a subject, that it has occupied the attention, and exercised the talents, of the most eminent engineers and architects. The principal object to be kept in view is, to fix the various parts of the centering in such a manner, as to support, without change of shape, the weight of the materials that are to come upon them, throughout the whole progress of the work, from the springing of the arch to the fixing of the key-stone. This object has not always been sufficiently attended to by the professional men, either of this, or of other countries; for in many instances it has been ascertained that the centres of bridges, from the injudicious principles of their construction, have changed their shape considerably, or entirely failed, before the arch was complete; and in consequence of change of shape only, the arches built upon them have varied, both in form and strength, from the intention of the engineer. In the large works of this kind, however, erected in Great Britain, our best engineers have constructed their centres on principles calculated to support every weight, and resist every strain to which they might be exposed.

"The qualities of a good centre," says Tredgold, "consist in its being a sufficient support for the weight or pressure of the arch-stones, without any sensible change of form throughout the progress of the work, from the springing of the arch to the fixing of the key-stone. It should be capable of being easily and safely removed, and designed so that it may be erected at a comparatively small expense."

The centre of a large vault, as that of a bridge, is constructed of trusses disposed equidistantly in vertical parallel planes, and boarded over so that the convexity of the boarding may coincide with the intended internal intrados of the arch. The distance of the ribs may be disposed at from three to eight feet, according to the strength of the boarding and weight of the arch. In very large works, a bridging is laid for every course of arch-stones, with blockings between, to keep them at regular distances. The ring-stones do not always rest upon these bridgings; planks being sometimes put between, that they may be cut away afterwards, to separate the centre and the intrados from each other, in order to ascertain whether there are any settlements, to repair the damages, and put the arch in a state of equilibrium.

Where the river is not navigable, the trusses may be constructed with a beam at the bottom: in this case, there is no difficulty. The forms for the trusses of roofs with tie-beams, may form the grand or principal part of the truss for the centre. But when the river is navigable, the centre requires as large an opening as is consistent with its strength, in order that vessels may pass under it; and as the horizontal tie is interrupted, this disposition of the timbers will require much greater skill in the carpenter.

If the river over which a bridge is to be built be not navigable, the manner of constructing the centre is so easy, that it would be unnecessary to give any examples here; but where the river is navigable, instead of the horizontal tie, a number of ties are disposed around the polygon, forming the interior part of the centre; but as in many practical cases the most judicious and well-skilled theorist might be deceived as to the equilibrium of the arch to be supported, or the points in which it has the most tendency to fall, it would be very difficult to say what are ties and what are strutts; and even if the true pressure of the arch could be ascertained, the knowledge of this alone would not be sufficient; for the same parts of the vaults, in the process of execution, vary their pressure in every succeeding additional part, and what was a tie at one time, becomes sometimes a strutt; while a strutt, on the contrary, will become a tie, either in building, or at the completion of the vault. This ought to be well considered; and where the pressure is doubtful, or any of the lengths of timber forming the centre are ascertained to be in the two different states above mentioned, such timbers should be made to act in either case.

Though the timbers upon which the vault immediately rests, cannot be supported transversely throughout, the other pieces, which support the arch from the several pressing points, may all be made to act, by a judicious arrangement, in the direction of their lengths. The abutting joints, which are pressed, will be sufficiently resisted, when their shoulders are made perpendicular to the direction of their force, and with the small tenon; but if the timbers are drawn in a direction of their length, the joints ought to be strapped.

The beauty of every truss is to have as few quadrilaterals as possible. All the openings should be triangles: the intersection of the timber should be as direct as possible. Oblique directions exert prodigious strains, which require timbers of very large sections to withstand them, and press upon the abutments so much as to make the whole truss sag by the compression of the intermediate joggles.

If proper attention be paid to these circumstances, and the bearings of the timbers be well ascertained, a centre, constructed upon such principles, must answer its intended purpose, provided a proper estimate be taken of the communicating forces during the execution of the vault, and the centre be well secured at its abutment.

A centre for the arch of a bridge over a navigable river, may either be accomplished with one centre around the interior of the entire arch, supported between the piers; or, if the span of the arch will admit, the aperture may be subdivided into two or more apertures, by one or more supporters, each consisting of one or more posts of wood, braced together when necessary; these supporters, together with the sides of the stone piers, support the centre of the aperture, on which the stone arch is to be erected over the whole. By this mode, the centering is much more simple in its construction and requires fewer timbers, and these of smaller scantlings than when made in one centre.

If a centre be truly constructed, every point of the vault to be built ought to be supported, without giving any transverse strain to the incumbent part of the centre: but this is impracticable; for, as it would require a multiplicity of joints, it would, from the shrinking of the timber, be less sufficient than if composed of few pieces, supporting only a certain number of points disposed at judicious distances, leaving the intervals to be supported by timbers in which the superincumbent part of the arch might act transversely, but still presenting such a resistance, as not to be materially bent or put out of form by the load of the arch above.

By these precautions, the centre will be constructed so as not to yield, or give way, though the load should vary during the erection of the arch, and will stand as firm as if the whole had been constructed out of a single solid: the only thing to be attended to, as before observed, being to make the timbers sufficiently strong to withstand either tension or compression.

There are several other principles of constructing the ribs of centering; one of these may be that of a large truss, spanning the whole opening, having its vertex supporting the summit of the arch, and its rafters, or principal braces, supporting other subordinate trusses which resist the pressure of the arch at other intermediate points.

Of this kind is that of the bridge of Orleans, by M. Hupeau, one of the boldest centres ever executed in Europe. Another principle is that of two independent trusses, one supporting the sides or haunches of the arch, and the other the crown. Of this construction was the centering of the nave and transepts of St. Peter's church, at Rome, by Michael Angelo, and two centres by Pitot. Another principle of centering is that of inscribed equilateral polygons; that is, the exterior beams, supporting the curve, are of equal lengths, and joined together in the form of a polygon: another polygon is formed within this, having its angles in the middle of the sides of the former, and so on, alternately, until there are as many polygons inscribed as will make the centering sufficiently strong or stiff. This mode of centering may be of two kinds: one, when the angles are fixed at their junction to the sides of the last polygon with bolts; bridles, or double truss-pieces, being put over the angles to prevent a transverse strain at the section of the timbers where the two pieces meet, and to support the curve above. The other kind is, when the polygons act independently of each other; these polygons are brought into action by bridles, which support the curve, and act upon the angular points of each other's polygon. Of this kind were the centering of the bridges of Cravant, Nogent, Mayence, and Neuilly, constructed by Perronet. Though these centerings have been executed to very large spans, the last mentioned being 120 feet, their equilibrium is by no means so secure as when the angles of the inner polygon are fastened to that immediately preceding, as is evident from the information given of the erection of these bridges, by the ingenious architect who has favoured the world with a treatise on this subject.

Another principle of centering is that of Westminster and Blackfriars bridges, London. They consist of a series of trusses, each supporting a point in the arch, the principal braces having their lower extremities abutting below, at each end of the centering, on the striking-plates, and at the upper end, upon apron-pieces, which are bolted to the curve that supports bridgings for binding the pieces which compose them together at their junction. There is one disadvantage under which this mode labours; that is, the frequent intersection of the principal braces with each other: they must either be halved one upon the other, otherwise they must be discontinued, and made in various lengths. Both these modes diminish their lateral strength, and consequently make them much more liable to buckle than when whole; but of the two, that of halving is to be preferred; as by the braces being in one length, there can be no sagging occasioned by intermediate joggles, and the braces may be rendered sufficiently secure, laterally, by running straps longitudinally across the notched part on each side, bolting these straps to the braces.

Lastly, another mode of centering may be that of a number of quadrilateral frames abutting on each other, having their joints radiating to a centre, in the manner of the wedge-stones of an arch in masonry. These frames should all be resolved into triangles by one or two diagonals, according to the kind of strain, keeping in view that a piece, which is a tie in one diagonal, is, in the other diagonal of the same quadrilateral, a strutt; but if the kind of strain on any frame be not well ascertained, it would be better to place two diagonals, halved upon each other. The frames are to be secured with keys or bolts, and by this precaution each frame will be rendered quite immovable.

The general principle of construction is a series of triangles, of which every two are connected by a common side.

Plate I., *Figure* 1. Let A B C D E F G be the curve of an arch which requires a centre; let the points A, B, C, &c., be connected so as to form the equilateral polygon, A B C D E F G, and join A C, C E, and E G; the timbers thus disposed will form three triangles, which may be looked upon as so many solids, revolvable about the angular points A, C, E, G; suppose now, that these are to be in equilibrium, the smallest force on either side would throw it down, and therefore, without other connecting timbers, it would be unfit for the purpose of a centre.

Figure 2. Let A B C D E F G be the curve of an arch which requires a centre; first, form the equilateral polygon, A B C D E F G, with the timbers A B, B C, C D, &c., and fix the timbers A C, C E, E G, as before, which will form three triangles, movable round A, C, E, G; let the timbers B D and D F be fastened, and thus the whole will be immutable; so that if supported at the points A and G, and a force applied at any other of the angles B, C, D, or F, the timbers will be all in a state of tension, or in a state of compression, and the whole may be looked upon as a solid body; for suppose the triangle A B C to be supported at the points A and B, the point C, and the other two sides, B C, C A, will be fixed; and because B C D is a triangle, and the points B and C are fixed, the point D, and consequently the sides C D and D B; in like manner, since C D E is a triangle, and the points C and D fixed, the point E will also be fixed, and therefore the sides D E and E C. The same may be shown, in like manner, for the points F and G. Suppose, then, two equal and opposite forces applied at the points A and G, in the plane of the figure, the figure can neither be extended out, nor compressed together. The pieces A H, H B, and G I, I F, are of no other use than to make the centre stand firmly on its base. This disposition of the timbers will cause them to occupy the least possible space.

If the timbers are fixed at the points, *k*, *l*, *m*, *n*, *o*, *p*, *Figure* 2, the same immutability of figure may be demonstrated; for, suppose the points A and H to be fixed, the point *k* will also be fixed; the points A and *k* being fixed, the point B of the triangle A *k* B; again, the points B and *k* being fixed, the point *l* will also be fixed: in the same manner, all the remaining points, C, *m*, D, *n*, E, *o*, F, *p*, G, I, will be proved to be stationary in respect of the points A, H; and the whole figure being kept in equilibrio by any three forces, acting in the plane of the figure, at any three angles, the action of the forces will only tend to compress or extend the timbers in a direction of their length.

In the construction of this truss, the triangular parts may be constructed all in the same plane, as in Figure 1; and the pieces B D and D F may be halved upon the pieces C A and E G; but the utmost care must be taken to secure the several pieces concurring at each of the angles, by bolting or iron straps, as no dependence can be put in any such joint without iron: but perhaps the best method of any is to halve the thickness of the pieces A C, C E, E G, at the points C and E, and also the pieces A B, B C; C D, D E; E F, F G; at the points B, D, F: then bolting the ends A and C of the pieces B A, B C, the ends C and E of the pieces D C and D E, and the ends E and G of the pieces F E and F G, and then fixing double braces B D, D F, that is, fixing B D upon one side of the truss, and another upon the other side of the truss, opposite to it, also fixing D F upon one side, and another opposite to it.

The disposition of the timbers forming only a series of

CENTERING.

Fig. 1.

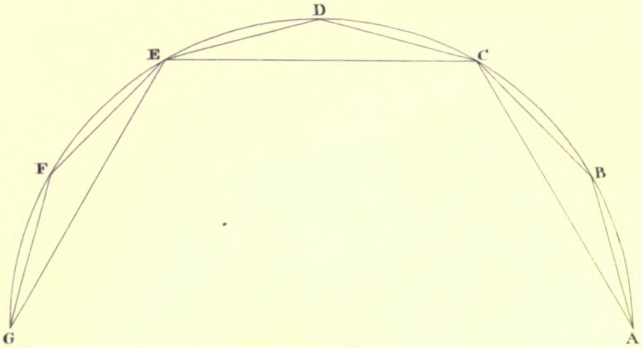


Fig. 2.

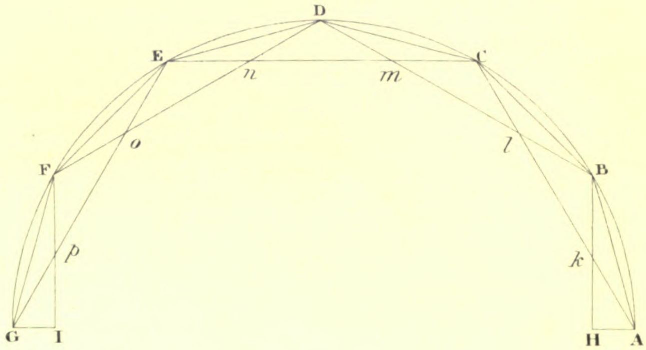


Fig 3

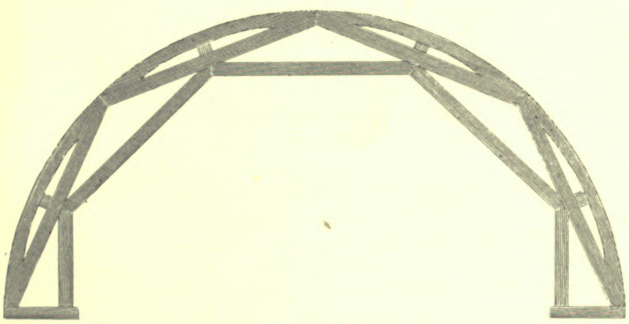


Fig. 4.

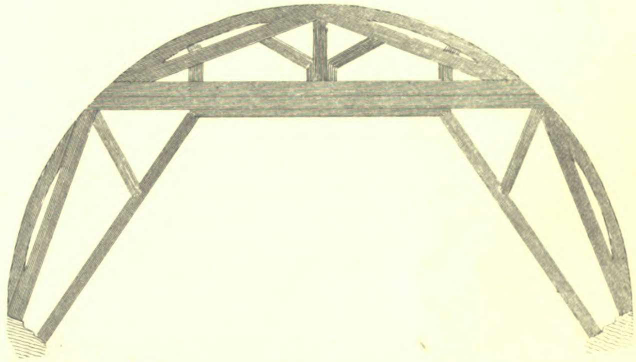


Fig. 5.

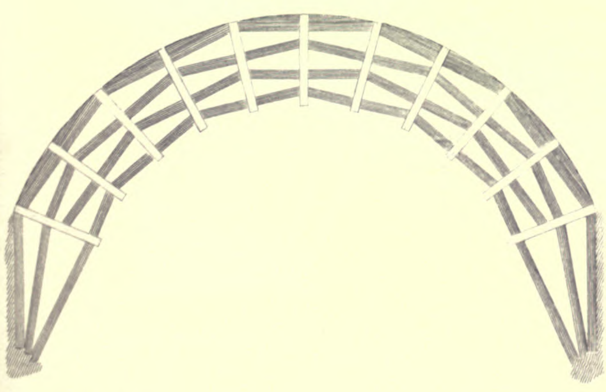
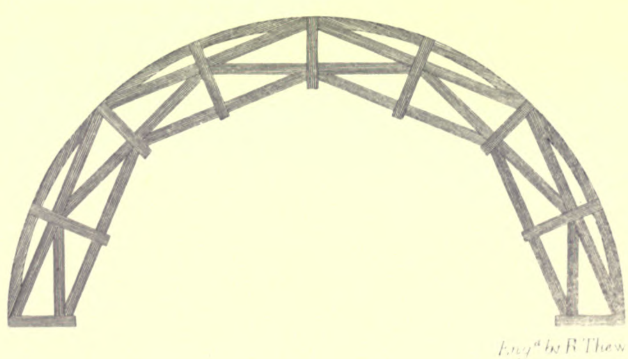


Fig. 6.



Drawn by M A Nicholson. *Eng^d by R. Thew.*

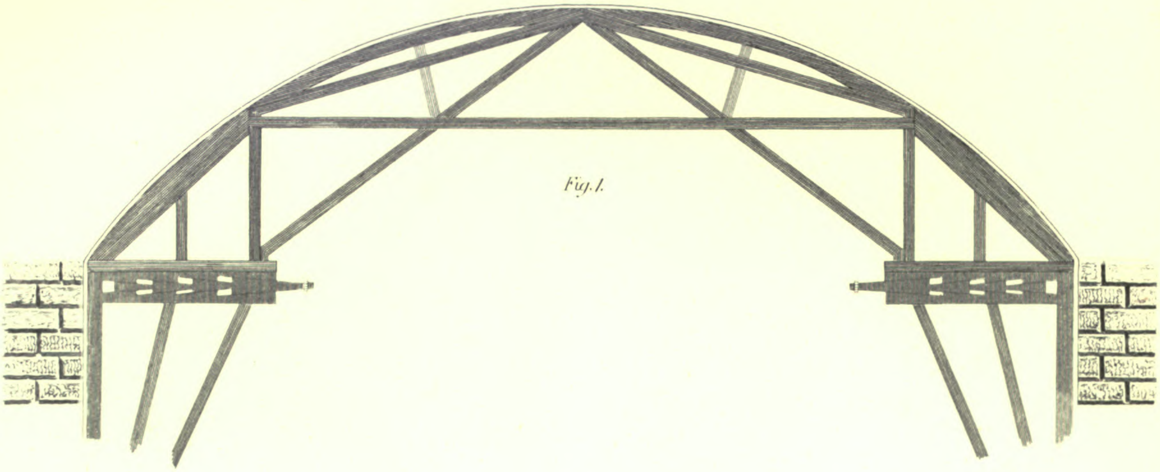


Fig. 1.

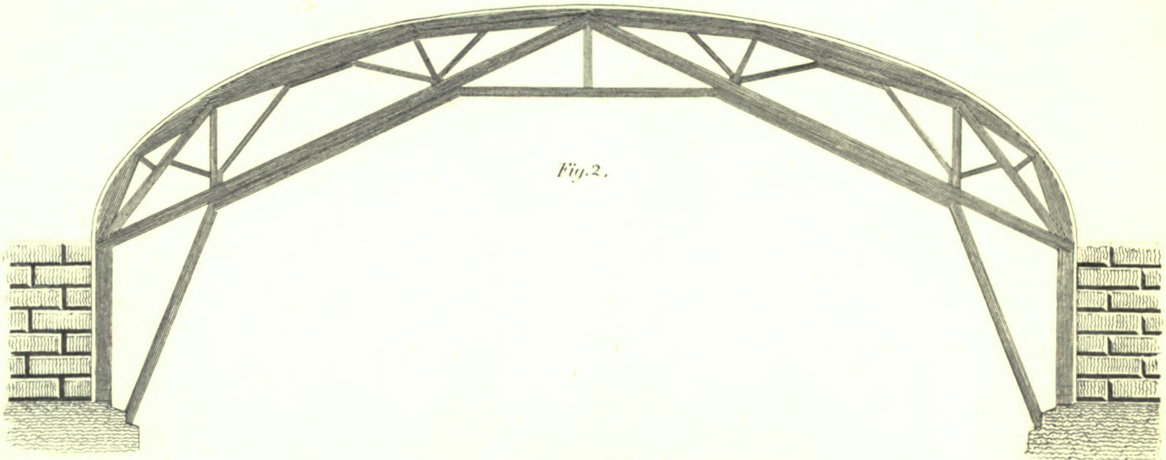


Fig. 2.

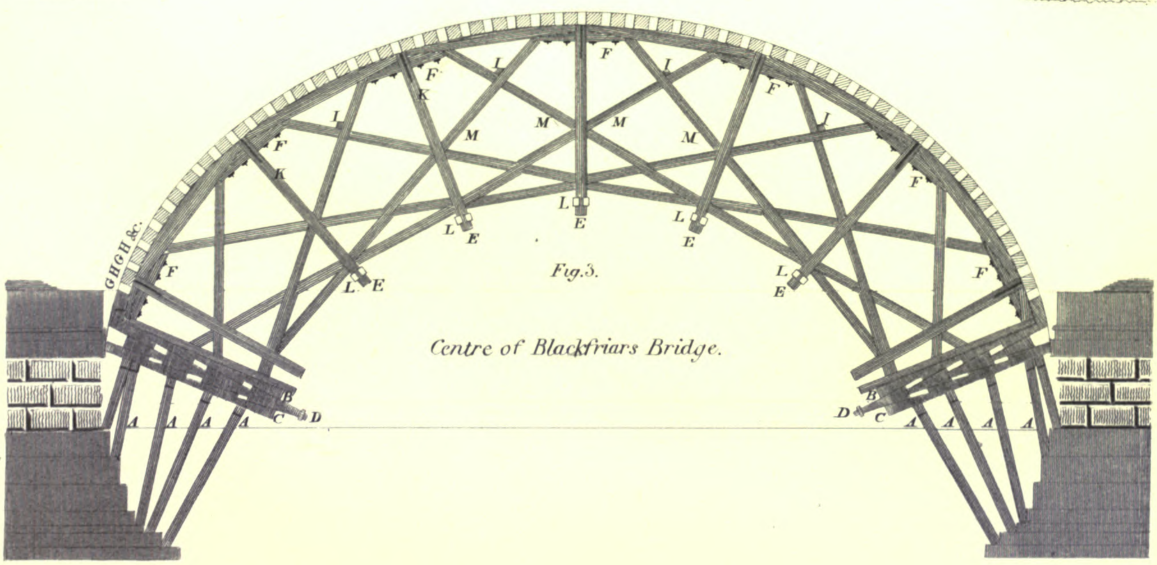
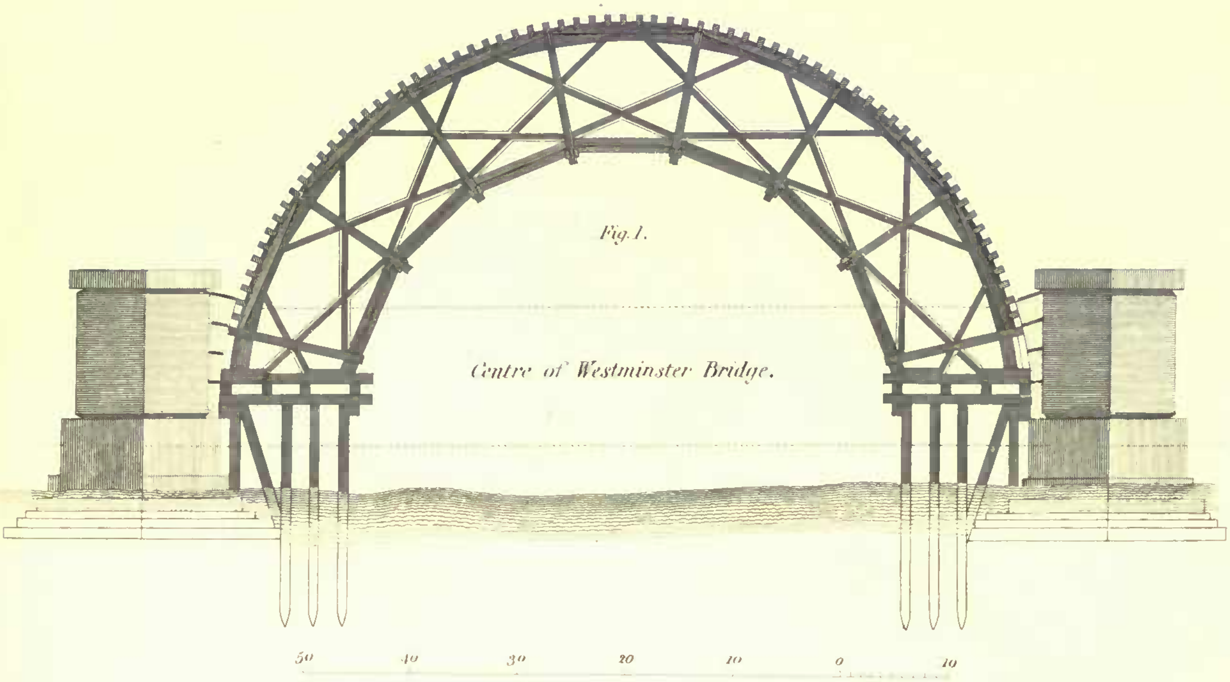
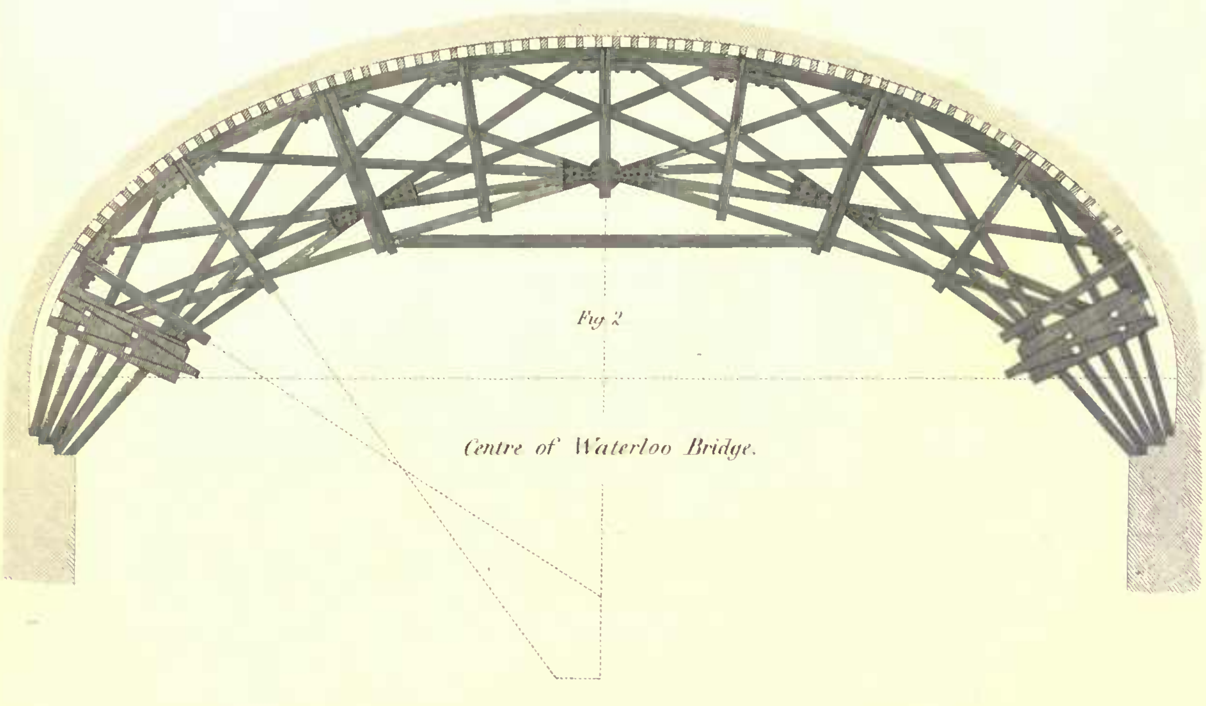


Fig. 3.

Centre of Blackfriars Bridge.

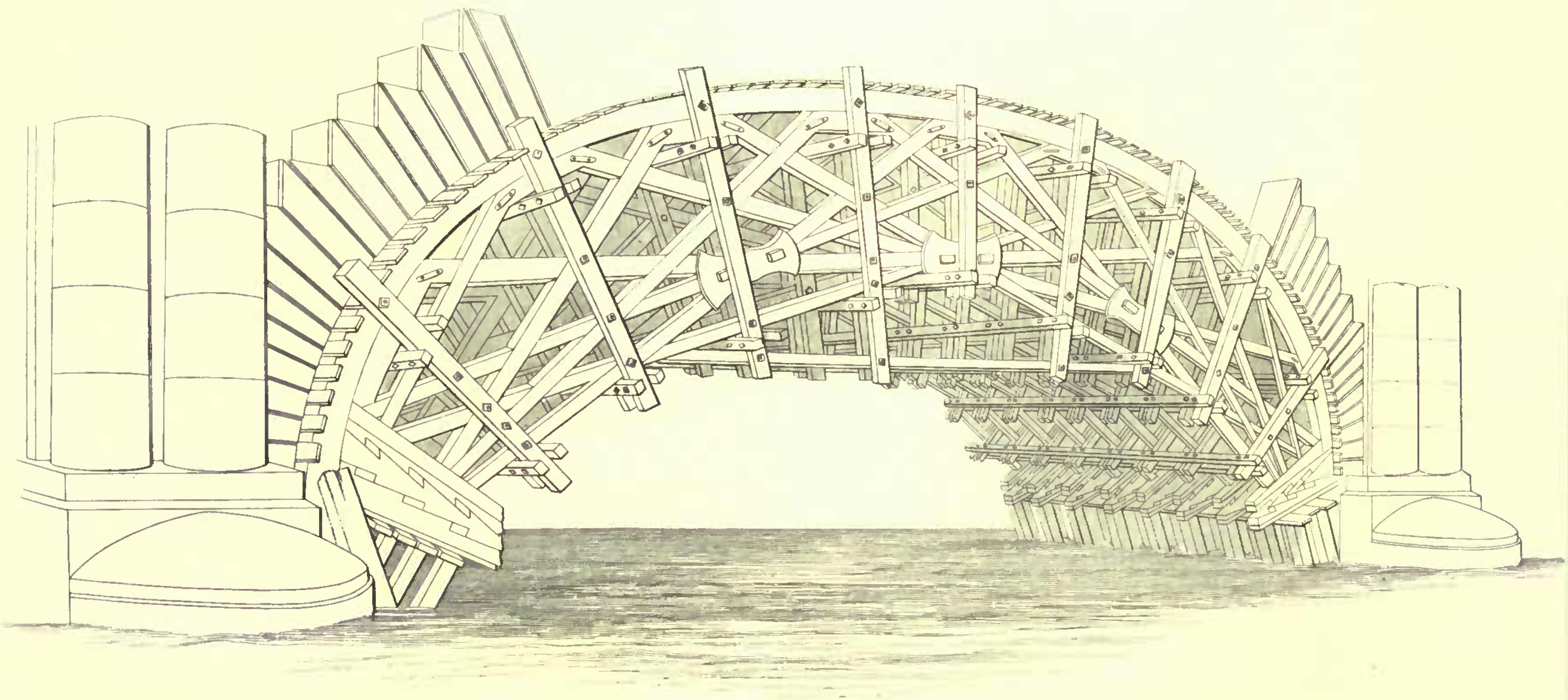
Drawn by M. A. Nicholson. Eng.d by R. Thew.





Drawn by P. Nicholson. Eng^d by R. Thew

CENTRE OF WATERLOO BRIDGE.



A. Gilbert del. P. Thew sc

quadrilaterals, gives nothing but immutability of figure. It can only derive its stiffness from the resistance of the joints.

Figure 3 shows the manner of forming a centre by two polygons, of which the interior one is secured to the exterior: in this there is no occasion for double trussing-pieces, as the parts of the inscribed polygon act either as strutts or ties to that of the circumscribing one.

Figure 4 is the manner of forming the rib for a centre, by two independent trusses; in this form of centering there is no occasion for bridles, or double trussing-pieces, as in those of Pitot, of the same construction.

Figure 5 is the manner of constructing a centre, according to Perronet, with four polygons, independent of each other, but with this improvement, that the lower extremities of each ring of polygons are framed into the two abutments; this gives a much firmer base than if they were all to meet at the same place, and renders the centre much stronger, by making the angles more acute. In this it becomes also necessary to have bridles, otherwise the exterior polygon only would be effective.

Figure 6 is the manner of constructing a centre with three polygons, which are all secured to each other. In this, truss-pieces become necessary, otherwise the angles of the inner polygon would bend the sides of that next to it.

Plate II., *Figure* 1, is the design of a centre, its principle being that of two roofs intersecting each other. In this example, the forces which are communicated to the various parts of the frame are resisted longitudinally, either by compression or extension; and no force is exerted transversely on any part, excepting the curved pieces in contact with the boarding supporting the arch-stones.

Figure 2 is the design of a centre; it is first framed in one large truss, like a common roof, with two principal rafters, and a collar-beam; each of the rafters becomes a tie for the two small trusses above, which are framed in the manner of a roof, with queen-posts and braces. The lower angles of the principal rafters are braced from the lower queen-posts to the posts. This truss is free from transverse strains in all its parts, except the curve, which supports the arch-stones; and, if well secured at the abutments, an arch of immense weight may be sustained by it.

Figure 3 is the celebrated centre used at Blackfriars Bridge. The names of the timbers are as follows:

A. Timbers which support the centering.

B, C. Upper and lower striking-plates, cased with copper.

D. Wedge between striking-plates, for lowering the centre.

E. Double trussing-pieces, to confine braces.

F. Apron-pieces, to strengthen rib of centre.

G. Bridgings laid on the back of the ribs.

H. Blocks between bridgings, to keep them at equal distances.

I. Small braces, to confine the ribs tight.

K. Iron straps bolted to trussing-pieces and apron-pieces.

L. Ends of beam at the feet of truss-pieces.

M. Principal braces.

The centre used at Westminster Bridge was formed by independent trusses, consisting of two rafters; the intersections all supposed to be halved together, and firmly strapped across the notchings. Double truss-pieces were also used, but for these there was evidently no occasion, as the pressure would be directed to the abutments, or to two opposite points of the arch in the same level.

The annexed plate is a perspective view of the centering of one of the arches of Waterloo Bridge. This magnificent bridge was built under the direction of the late Mr. John Rennie, and is a noble specimen of simplicity of design, skilful arrangement, and solidity of execution. The centre was composed of eight frames or trusses, and, though somewhat complicated, was on the whole a judicious combination; exhibiting rather an excess than a deficiency of strength.

In the erection of Chester Bridge, finished in 1832, an entirely different principle was adopted in the construction and the mode of relieving the centre; it is thus described in the Transactions of the Institution of Civil Engineers. Vol. I.:—

"The centre on which the stupendous arch of Chester new bridge was raised, and which is stated by Mr. Hartley, (the engineer of the bridge,) to have been exclusively designed by Mr. Trubshaw, claims a detailed notice, from the novelty of the principle it was formed on, the efficiency with which it did its work, and the economy that attended its use. The centre consisted of six ribs in width, and the span of the arch was divided into four spaces by means of three nearly equidistant piers of stone built in the river, from which the timbers spread *fan-like* towards the soffit, so as to take their load *endwise*. The lower extremities of these radiating beams rested in cast-iron shoe-plates on the tops of the piers, and the upper ends were bound together by two thicknesses of 4-inch planking bending round, as nearly as they could be made, in the true curve of the arch. On the rim thus formed, the *lagging*, or covering, which was $4\frac{1}{2}$ inches thick, was supported over each rib by a pair of folding wedges, 15 or 16 inches long, by 10 or 12 inches broad, and tapering about $1\frac{1}{2}$ inch; for every course of arch-stones in the bridge, there were therefore six pairs of striking wedges. The horizontal timber of the centre was only 13 inches deep, and the six ribs were tied together transversely near the top, by thorough bolts of inch iron, but with a view not to weaken and injure the timber more than was absolutely necessary, the least possible of iron was used."

This centre thus differs essentially from any other hitherto employed; each rib, instead of forming one connected piece of frame-work, consisting in this of four independent parts, and hardly any transverse strain has to be resisted. It has also this advantage, that the bearings may be gradually relieved, or tightened at one place, and slackened at another, as may be necessary, because the wedges are in this construction borne by the centre, instead of the centre being borne by the wedges.

In striking centres it is of great advantage to be able to suffer them to rest at any part of the operation; for it is important that the arch in taking its proper bearing do not acquire any sensible degree of velocity, or settle too rapidly. The centre, says Alberti, should always be eased a little as soon as the arch is completed, in order that the arch-stones may take their proper bearings before the mortar becomes hard. If the mortar be suffered to dry before the centre be lowered, the arch will break at the joints in settling, and the connection of the arch will be destroyed. In small centres, the wedges are driven back with mauls, men being stationed at each pair of wedges for that purpose. But in larger works a beam is mounted, as a battering-ram, to drive the wedge-formed blocks back. The French engineers, in removing centres, destroy, by little and little, the ends of the principal supports; a work of difficulty, as well as danger, and which cannot be done with so much regularity in this way as by wedges. *See* Iron Bridge, Stone Bridge, and Suspension Bridge.

Centre, in geometry, a point in a figure or solid, such that if any straight line be supposed to pass through the point until it terminate on both sides of the figure or solid, the line will be bisected. Figures of this property are infinite. Some of them are the circle, ellipsis, parallelograms, of every species, &c.; and some solids of this nature are the sphere, spheroids, parallelopipeds, &c.

In a circle, the centre is everywhere at an equal distance from the circumference. In a sphere, the centre is everywhere at the same distance from the surface. In the ellipsis, any two straight lines passing through the centre, terminating at each end on the circumference, and making equal angles with either axis, are equal; or the four lines drawn from the centre to the circumference, are equal. The same property applies to the opposite hyperbolas.

Centres of a Door, two pivots, round which the door is made to revolve.

CENTROLINEAD, an instrument for drawing converging lines, when the point of intersection is inaccessible.

CENTRY-GARTH, an old English term for a burial-ground.

CEROFERARIUM, a candlestick used to hold the paschal taper.

CEROMA, the anointing-room in ancient baths and gymnasia.

CESTOPHORI, sculptures of females bearing the cestus, or marriage-girdle.

CESSPOOL. *See* Sesspool.

CHAIN-TIMBER, in brick houses a timber of larger dimensions than common bond, placed in the middle of the height of the story, for strengthening the building; the scantling of chain-timber is 8 inches by 5 inches, or 8½ inches by 5½ inches, viz., equal to the length and breadth of a brick.

CHALCIDICÆ, a large magnificent hall, belonging to a tribunal, or court of justice. Vitruvius employs the term for the auditory of a basilica; and other ancient writers use it for an apartment in which the gods were supposed to sup.

CHALICE, the cup used to contain the wine at the celebration of the eucharist. In early ages, chalices were made of glass, wood, or horn; but in the council of Rheims, A. D. 847, the materials for the chalice were restricted to gold or silver. The rim of the chalice should never turn over.

CHALK, an opaque mineral, of a yellowish white, or rather of a snow colour, of a fine earthy fracture, without lustre, breaking into blunt-edged angular fragments; when contaminated with iron, it has more or less of an ochrey tinge, and stains the fingers; but when pure it is very soft and almost friable, gives a white streak, has a meagre feel, and adheres to the tongue. It effervesces violently with acids; and when mixed with iron becomes harder and heavier: its specific gravity varies from 2·4 to 2·6. It occurs generally in a mass, sometimes disseminated, or investing other minerals.

In a state of purity, it appears to be composed only of water, lime, carbonic acid, and a small quantity of alumine. Mr. Kirwan obtained the following analysis:

3	water
53	lime
42	carbonic acid
2	alumine
100	

Chalk occurs in thick beds, nearly horizontal, alternating with thin layers of flint nodules, which are also irregularly dispersed through its substance. It contains a vast quantity of the relics of disorganized marine bodies, and often the hard parts of amphibious and land animals, as the heads and vertebræ of crocodiles, elephants' teeth, &c.

Chalk beds occur frequently in the east and south parts of England, in the north-east of France, in Poland, and in some parts of the Danish islands.

Its uses are numerous; it is employed in walling or vaulting, as building-stone; many of the groins or vaults of our Gothic churches are constructed with it; it is also employed in the composition of mortar, in countries where lime-stone is less abundant; and when well burnt, is found not much inferior to lime-stone.

CHAMBER, (from the Latin *camera*, derived from the Greek *καμαρα*, *a vault*, or *curve*,) a vaulted apartment, a part of a lodging. This term was formerly applied to any room, and sometimes even to a suite of apartments; but in modern times it is used to designate rooms ordinarily intended for sleeping in. The proportion of its horizontal dimensions may be varied, to accommodate different circumstances, which may occur either in the form of a building, or in the disposition of the apartments, from the square to the proportion, of which the breadth is two-thirds of the length; its altitude may be three-fourths of the breadth. The word originally implied a vaulted apartment.

In building bed-chambers, the situation of the bed, as well as of the fire-place, ought to be attended to, as should the disposition of the windows, when they can be shifted without destroying the symmetry of the exterior. If the bed and fire-place be opposite to each other, the fire-place may be in the middle of its own side; but if it should be found necessary to have the bed on the same side of the room with the fire-place, on account of doors or windows, or both, then the chimney ought to be placed in the middle of the remaining distance between the bed and the wall, the bed being supposed to stand at one extremity. The situation of doors may be the same as in other apartments; passage-doors should be within about two feet of the angle of the room, on whatever side they are made; and may either be on the same side with the fire-place, or on the opposite side to the fire-place, or in the return side, opposite to the window, next to the farther corner from the fire-side of the room.

The bed ought to be so placed as to be out of the current of air, which usually rushes from the door to the fire-place.

The most eligible figure of chambers, for furniture, is the rectangle; though sometimes the circle, ellipsis, or octagon, may be allowed to some particular room, for the sake of variety. Besides passage-doors, it is convenient for chambers to communicate with each other, or with a dressing-room.

Chamber of a Lock, in inland navigation, the space between the gates, in which a boat rises and sinks from one level to another, in order to pass the lock.

Chamber-Story, a story of a house appropriated to bedrooms. In good houses it should never be less than 10 feet high; and in mansions 12, or even 15 feet high. Chambers should not be too high, because it is difficult to warm them; nor too low, as it is prejudicial to the health.

CHAMBERS, SIR WILLIAM, a distinguished architect, is said to have derived his descent from the ancient family of Chalmers, in Scotland, barons of Tartas, in France. He was born, however, at Stockholm, in Sweden, where his father had resided for many years, in order to prosecute certain claims he had on the government of that country. When a very young man, he made a voyage to China, as supercargo in the service of the Swedish East India Company, and probably thus acquired his taste for the Asiatic style of ornament. At the very early age of eighteen, we find him established in London as an architect and draughtsman, in which capacities he soon acquired considerable reputation; and obtaining an introduction to Lord Bute, shortly afterwards was appointed through that nobleman's influence drawing-master to the Prince of Wales, afterwards George III.

He was employed, soon after the accession of George III., to lay out the gardens at Kew, and there displayed, without restraint, his predilection for the Chinese style, both of architecture and gardening, decorating the royal gardens with numerous temples, pagodas, and other Asiatic buildings. Being patronized by the King and Princess-dowager, he was employed as architect to the most considerable buildings of the day; and was also appointed Surveyor-General to the Board of Works in Somerset House, a situation worth at least two thousand pounds a year. Sir William died in 1796, leaving a large fortune. As an architect, although his taste was fantastic, he frequently displayed a certain grandeur in his designs, and in the disposition of interior arrangements particularly, showed considerable ingenuity and practical ability. His *chef-d'œuvres* are his staircases, particularly that in the Italian villa he erected for the Earl of Besborough, at Roehampton; and also those at Lord Gower's and the Royal Antiquarian Society's.

In the time of Sir W. Chambers, pure Greek architecture was only beginning to be known in England; and at first its introduction was not much favoured. The indiscriminate adoption of Greek models for public buildings in London has filled the metropolis with structures quite unsuited in external form to improve the appearance of a large city, and often ill adapted in their internal arrangements to the purposes for which they are designed. Instead of large masses and lofty buildings, the streets of London are crowded with mean porticos and pigmy pillars, attached to edifices of so little elevation, and so much cut up into small parts, as to suffer by comparison even with many of the adjoining houses.

The street-front of Somerset House, Chambers's best work, is, in all respects, better adapted to a great city, than the Greek models which are now too generally adopted; and the river-front forms one of the boldest architectural objects in the metropolis, particularly when beheld from the water. Its extent and elevation, and the majestic breadth and range of its terrace, give it an air of grandeur exceedingly striking and imposing.

The works published by Sir William Chambers were—*A Treatise on Civil Architecture*, of which a new edition, by Joseph Gwilt, Esq., F. S. A., appeared in 1824. *Plans, Elevations, Sections and Perspective Views of the Gardens of Kew; Chinese Designs;* and *Chinese Gardening.* His *Treatise on Civil Architecture*, though prejudiced against Grecian architecture in favour of the Roman, is an excellent work.

CHAMBRANLE, the border of stone, or the wooden frame, surrounding the three sides of a door, window, or chimney; the head of the chambranle is called the *traverse*, and the two sides, the *ascendants.*

When the chambranle is plain, it is called *a band*, *case*, or *frame.* In an ordinary door, it is called the *door-case;* in a window, *the window-frame;* in the latter case, it comprehends also the sill. When the chambranle is moulded with one or more faces, and bordered outwardly with one or several mouldings, it is called *an architrave;* though it should rather be said to be *architrave-moulded*, being only an imitation of that division of the entablature of an order.

CHAMFERED, *Rustic. See* RUSTIC.

CHAMFERET, a half scotia, being a kind of furrow, or gutter, on a column; called also *strix*, and *stria.*

CHAMFERING, *καμπτειν*, *to bend*, the act of cutting the edge of anything, which was originally right-angled, aslope, or bevel; so that when placed in its destined situation, the plane formed by this cutting may be inclined to the horizon, while the other parts are perpendicular and parallel to it.

A chamfer differs from a splay in being smaller, and in cutting off an equal portion from either side. In Gothic architecture chamfers are very frequent, and are often ornamented with mouldings and foliage at their terminations.

CHAMP, a flat surface, the ground of relieved sculpture, or engraving.

CHAMPAIN LINE, a conjunction of straight lines, forming indentations similar to the projecting parts; the sides of each ascending part, which are also the sides of the alternate indentations, being parallel to each other; the bottom of each indentation being formed of three internal angles, and the top of each projecting part of three external angles; each ascendant and each indentation being shaped alike on both sides; that is, the corresponding angles and lines, whether of the ascendants, or in the depressions, being equal.

CHANCEL, that part of a church which is appropriated to the clergy and others officiating in the public services.

The term comes from the Latin, *cancellus*, which, in the lower Latin, is used in the same sense, from *cancelli*, lattices, or cross-bars, which anciently partitioned the chancel from the other part of the church.

Externally, the chancel is distinguished as a projection at the east end, of smaller dimensions than the nave, and without aisles; so that when the body of the church is accompanied by aisles, it is very readily recognized, and in other cases by its proportionate dimensions. Sometimes, however, the chancel is of the same size and height as the nave, and the aisles are continued to its eastern extremity; but even in this case the division may be shown by means of a belfry on the apex of the roof at that spot or by some other such method; in some instances there is no distinction externally. Internally the chancel is usually separated from the nave by a lofty arch, in the spandrels above which is often a picture of the Last Judgment; a further separation is effected by an ornamental screen of wood or stone, more frequently of the former, panelled and pierced in open tracery, surmounting which was in former times, the rood-loft, or gallery in which the rood, or large crucifix, accompanied by the images of the blessed Virgin and St. John, was placed, facing the west end of the church. Here the level of the flooring was raised by one or more steps, and again before you arrive at the platform on which stood the altar; in one or two cases the chancel is depressed below the level of the nave, but these are purely exceptions.

When the aisles of the nave are continued eastward, the only division consists of the screen and steps; but the distinction will be effected by some difference in the roof, or by the superior quality of the decoration. In such cases the aisles are partitioned off from the chancel by other screens or parcloses.

The chancel is lighted by the east window, which should be the most important in the building, and by two or more in the north and south walls, according to its length. There is a door in one of the side-walls, towards the east end, for the priest, leading into the vestry, or forming his entrance into the church. The roof is of a more elaborate character than that in other parts of the structure, as indeed are all the enrichments. The floor was often covered with encaustic tiles, with devices of various colours painted on their surface, while the aisles in the body of the edifice were paved with tiles of a plainer description; the whole of the walls were sometimes decorated with colour and rich hangings, a method which has of late been adopted with success in one or two churches in London.

In the centre of the eastern wall was the altar, and on the south of it the piscina, usually formed by a recess, in the eastern extremity of the south wall, and used to wash the sacred vessels, to contain which, when not in use, was provided an aumbry or cupboard near the piscina, and taken out of the thickness of the south or north wall, furnished with a door and means of securing it. Adjacent to the piscina are sometimes found, especially in the larger churches, seats for the officiating priests. These sedilla, as they are termed, consisted of stone or wooden seats, varying in number from one to five, the more usual number being three, raised in gradation one above the other, according to the rank of the clergy who were to occupy them; when of stone, they are more generally cut out of the thickness of the wall; when of wood, they may be movable. Westward of these, disposed on each side of the chancel, are the seats for the choristers, consisting of two or three rows, one in front of the other and a little below it. Occasionally these seats are returned in front of the rood screen, and in that case they always face eastward toward the altar.

In the north wall of some chancels is found an arched recess, which sometimes contained a stone tomb, occasionally that of the founder; this was the holy sepulchre on which the ceremonies commemorative of our Lord's burial and resurrection were celebrated at the season of Easter. Where there is no sepulchre, a movable wooden structure was employed for the purpose.

The principal feature of the chancel is the altar. This is an elevated table of an oblong shape, constructed of either wood or stone; in the first ages of the church, up to the fifth century, they were generally made of the former material, though stone was recommended by Pope Sylvester, early in the fourth century. The council of Hippo forbade the use of wood, as did also that of Epone, in France, at the commencement of the sixth century, from which period they have been made of stone. Stone altars were disused in England at the Reformation, and so few survived the turmoils of this period, and of the succeeding rebellion, that we have scarcely an entire example left; those in the chantries and side-chapels are almost the only ones that escaped destruction. The high altar of Arundel church, Sussex, which was preserved by being enclosed in wood, will give us a fair idea of their form and construction. It consists of a slab 12 feet six inches long, by 4 feet wide, and 2½ inches in thickness, supported on a solid stone 3 feet 6 inches in height, and quite plain; in some cases, however, the front and sides were carved in panels and various devices, and richly coloured. Sometimes the slab is supported on stone legs, and sometimes on brackets, as at Broughton Castle, Oxford; it was generally marked on its upper surface with five crosses in recession, one in the centre, and one in each corner, representing the five wounds of our Lord. In the church of Porlock, Somersetshire, the crosses do not appear on the slab, but are found in the centre panel in the face of the supporting masonry.

That part of the east wall immediately above the altar is frequently ornamented with a reredos of tabernacle work, or a series of enriched arches; sometimes this space is occupied by a triptych, or painting of three compartments, often representing the crucifixion.

" Pertaining to the high altar," says Mr. Bloxham, in his valuable little manual, " which was covered with a frontal and cloths, and anciently enclosed at the sides, with curtains suspended on rods of iron projecting from the wall, was a crucifix, which succeeded to the simple cross placed on the altars of the Anglo-Saxon churches; a pair of candlesticks, generally with spikes instead of sockets, on which lights or tapers were fixed; a pix, in which the host was kept reserved for the sick; a pair of cruets, of metal, in which were contained the wine and water preparatory to their admixture in the eucharistic cup; a sacring bell; a pax table, of silver or other metal, for the kiss of peace, which took place shortly before the host was received in communion; a stoup, or stok, of metal, with a sprinkle for holy water; a censer, or thurible; and a ship—a vessel so called—to hold frankincense; a chrismatory, an offering basin, a basin which was used when the priest washed his hands; and a chalice and paten."

Another part of the furniture of the chancel is the credence-table, or table of prothesis, on which the elements were placed previous to consecration, usually situate on the north side of the altar. This is of much smaller dimensions than the altar, sometimes of stone richly panelled, as at the church of Holy Cross, near Winchester, and Fyfield, Berks, where it is in shape semi-octagonal; they were sometimes also of wood, a specimen of which is pointed out at Chipping-Warden, Northamptonshire, the date of which is A. D. 1627. The credence is very frequently found in the form of a shelf above the piscina, and under the same niche and canopy.

We must not forget to mention the lettern, or desk, from whence the lessons were read, which was placed at the western end of the chancel; it was generally of brass, sometimes in the shape of an eagle with expanded wings, and sometimes forming a sloping desk, with the slope on one or two sides, in all cases supported on an ornamental stem. Eastward of this, immediately in front of the altar-steps, was the fald-stool, a low, sloping desk, at which the priest knelt at the Litany.

The chancels of our old churches vary so much in size and proportion, that it is impossible to lay down any rule by which their dimensions may be determined; we always find them, however, of sufficient space to form a prominent feature in the building; sometimes they are as long, or longer than the nave, but this practice we would not recommend for adoption. It may be laid down as a general rule, that the chancel be well defined and fully developed, yet not of so great length as to prevent the voice of the celebrant being heard throughout the nave; on an average, we may give the length of 30 feet as a standard for most modern churches, but of course this dimension will vary with the size and width of the church. The materials and workmanship in this part of the edifice should always be of the very best description, and the ornamentation more rich and frequent; care must be taken to avoid the use of any decoration except such as is of a strictly religious character, and adapted to its particular situation: all meretricious ornament should be at once discarded; severity is wanted, not display.

CHANDELIER, a candlestick, lamp, &c. suspended by a chain, rope, or bracket.

CHANDRY, a room where candles and other lights are kept.

CHANNEL, a canal, or long gutter, sunk within the surface of a body.

Channel of the Larmier, a hollow soffit, or canal, under the corona, which forms the pendent on the front. *See* Beak.

Channel of the Volute, in the Ionic capital, is the hollow spiral, sinking between the fillets. *See* Canal of the Ionic Volute.

Channel Stones, in paving, are those prepared for gutters or channels, for collecting and turning off the rain-water with a current.

CHANTLATE, in building, a piece of wood fastened near the ends of the rafters, and projecting beyond the wall, to support two or three rows of tiles, so placed as to prevent the rain-water from trickling down the walls.

CHANTRY, or Chauntry, was anciently a church or chapel, endowed with lands, or other yearly revenues, for the maintenance of one or more priests, daily saying or singing mass for the souls of the donors, and such others as they appointed.

Chantries, are also small chapels attached to a church, and are sometimes external additions to the church; but more frequently, especially in cathedrals and the larger churches, erections within it; they are separated off from the body of the church by screens of open work surrounding and enclosing the tombs of the founders, and are usually provided with an altar at the east, with its appendages, such as piscina, aumbry, &c. Many beautiful specimens are to be found in our cathedral and abbey churches, and amongst the most costly may be enumerated those of Henry V. and Henry VII. at Westminster, the latter of which is, as is well known, of great size and magnificence; of Edward IV. at Windsor; of Edward II. at Gloucester; and of Bishops Waynfleet, Beaufort, and Wykeham at Winchester.

CHAPEL, a small detached building for divine service, subordinate to, and usually dependent on, the parish church, from which it is distinguished by the fewer privileges belonging to it, such as having no proper priest attached, or being deprived of the power of having baptism administered within it.

Chapel, is also a building adjoined to a church, as a part thereof, having only a desk, &c. to read prayers in, and, in the Romish churches, an altar, &c. to celebrate mass on; but without any baptistry or font.

The eighteen chapels on the sides of King's College chapel, Cambridge, are formed between the buttresses; most of them were originally provided with altars: those on the south side of this magnificent building, are appropriated to the college library.

Previous to the Reformation, nearly all castles, palaces, mansions, and religious establishments, were provided with private chapels. These were either detached buildings, or portions of the entire edifice constructed and set apart for sacred purposes.

Chapel, also denotes the deep recesses made in the walls of ancient edifices, and is of a similar signification to what is otherwise called *exhedræ*, by Vitruvius; thus the Roman Pantheon has seven chapels in its circumference, the entry corresponding to what otherwise might have been the eighth; and the sides of the courts of the great temple at Balbec are full of chapels, or *exhedræ*. Those of the rectangular court of this temple, and those of the Pantheon, are alternated with circular and rectangular plans, and most elegantly decorated with columns in the front towards the interior. The semicircular recess at the end of the basilica, and at the end of our most ancient churches, is often denominated *chapel*. Smaller recesses in ancient edifices, for containing statues, are denominated *shrines*, or *niches*.

CHAPITER, the same as Capital, which see.

Chapiters with Mouldings, are those without foliage, or other ornaments, as the Tuscan and Doric capitals.

Chapiters with Sculptures, are those that are adorned with foliage, and other carved ornaments; the finest yet invented is the Corinthian capital.

CHAPLET, a small ornament cut into olives, beads, &c.; a sort of fillet.

CHAPTER-HOUSE (from *capitulum*), a place belonging to a cathedral, or collegiate church, wherein the assemblies of the clergy were held.

The greater number of chapter-houses were connected with the cloisters of the church to which they belonged, by which means they were approached from the church; but, at Wells, York, and Lichfield, they are adjacent to the north transept, in the first case being considerably elevated above the level of the church; they are seldom found westward of the transept. The earlier of these edifices, dating of the eleventh and twelfth centuries, are in plan parallelogramic, terminating sometimes toward the east in a semicircle, as at Durham Cathedral; at later periods we find them octangular or polygonal, while that of Worcester is circular internally, with ten sides on the exterior. In elevation the walls are supported by buttresses—that of Lincoln with flying buttresses—with one or more windows between each pair, the whole being covered in the later instances, with a very high-pitched roof gathering from each side of the building, and terminating in a point at its apex. Below the windows, in the interior, runs a continuous seat or bench-table, backed with a series of niches or arcades, and at the east end, facing the entrance, stand three stone seats, usually of greater elevation than the rest, appropriated to the superior members of the chapter. The ceiling is more frequently vaulted. Among the earlier specimens may be enumerated Durham, probably the oldest, parallelogramic, with circular east end; Gloucester, Bristol, Oxford, Chester, Canterbury, and Exeter, all of which are rectangular. The first variation seems to have been at Worcester, which is circular within and decagonal without; the vaulting of the interior being supported by a central pillar and brackets in the side-walls. Of the remainder, Lincoln has ten sides, the vaulting supported by a central column and flying buttresses, which last appendage forms its peculiarity; Wells, Lichfield, Salisbury, and York, only eight sides, the vaulting sustained, as in the previous examples, that of York only excepted, where the vaulting is carried across the building in a single span of forty-seven feet. Wells chapter-house is erected over a crypt, a peculiarity which it shares with that of Westminster; that of Lichfield, although octangular, has two of its opposite sides of longer dimensions than the others, in which respect it is perfectly unique; while that of Salisbury is perhaps of all specimens the most beautiful.

The subjoined List of Chapter-Houses in England, (from Britton's valuable works,) may be found useful.

	Length. Int.	Length. Ext.	Breadth. Int.	Breadth. Ext.	Height. Int.	
						Rectangular.
Bristol	43ft.	53ft.	25ft.	36ft.	26ft.	Date 1142; adjoins S. transept; approached from cloister by a vestibule; vaulted roof.
Canterbury	87	99	35	45	52	N. of transept; entrance from cloister; vaulted roof with wood and tracery; large E. and W. windows.
Gloucester.......	68	77	35	44		Very lofty entrance from cloister; arched roof.
Durham	78	90	36	45		Date 1133; semicircular end; taken down.
Chester	50	58	26	36	36	
Oxford	54	64	24	34		Temp. Henry II.; S. of transept; entrance from cloister.
Exeter	55	62	28	38	50	Lower part about 1230—upper part 1427.
Winchester	88					One side remains; and joins S. transept with slyp between.
Llandaff	23	27	21	26		Early pointed.
						Octagonal, Polygonal, &c.
Worcester	55	65	55	65		About 1150; separated from S. transept by passage.
Lincoln..........	62	70	62	70	42	Before 1200; 140 feet diameter including buttresses.
Lichfield	45	54	28	36		About 1200; large vestibule.
Westminster	58	66	58	66		Temp. Henry III.: octagon; central column; over crypt.
Wells	55	65	55	65	42	Over crypt; small vestibule.
Hereford	45		45			Decagon; fragment remaining.
Salisbury	53	58	53	58	52	S. of transept; entered from cloister; vestibule; about 1260.
York............	57	70	57	70		Connected with N. transept by vestibule; vaulted roof, of wood.

CHAPTREL, from *chapiter*, the capitals of pillars and pilasters, which support arches, commonly called impost. *See* IMPOST.

CHARGED, a term in architecture, implying that one member of an edifice is sustained by another; in which case, the latter is said to be *charged* with the former. Thus, a frieze, or other surface, when ornamented, is said to be *charged* with the ornament; but when the ornament is too abundant, it is said to be *over-charged;* a column supporting an entablature is said to be *charged* with the entablature.

CHAR or CHARE; on old term equivalent to the word hewn or wrought; thus charred stone is hewn stone, as distinguished from rubble.

CHARNEL-HOUSE (Latin, *caro-carnis*, flesh) a vaulted apartment, beneath or adjoining a church, in which human bones are deposited.

CHARTOPHYLACIUM (Greek, *χαρτης*, *paper*, and *φυλασσειν*, *to guard*), the place where records were kept.

CHASE-MORTISE, or PULLEY-MORTISE, a long mortise cut lengthwise in one of a pair of parallel timbers, for inserting the one end of a transverse timber, by making the transverse to revolve round a centre at the other end, which is fixed into the other parallel timber. This is applicable to ceiling-joists, where the binding-joists are the parallel timbers first fixed, and the ceiling-joists are the transverse joints.

CHAUNTRY. *See* CHANTRY.

CHECKERED, or CHEQUERED, a surface is said to be checkered, when it is divided into a number of equal contiguous parallelograms, alternately coloured. The term is sometimes applied to reticulated masonry. *See* RETICULATED and MASONRY.

CHEEKS among mechanics, are those pieces of a machine which form corresponding sides, or which are double and alike: two equal and similar parts, generally placed parallel to each other.

CHEEKS OF A MORTISE, the two solid parts upon the sides of the mortise. The thickness of each cheek should never be less than that of the mortise, except mouldings on the styles require it to be otherwise.

CHEESE-ROOM, a room appropriated for the reception of cheeses, after they are made. Rooms of this description should be lined round the walls, and fitted up with shelves, having one or more stages, according to the size of the room, and proper gangways for commodious passages. In places where much cheese is manufactured, the dairy-room may be placed below, the shelf-room immediately above, and lofts over the shelf-room, with trap-doors through each floor. This will save much carriage, and be very advantageous for the drying of cheeses.

CHEQUERS, in masonry, stones in the facings of walls, having all their joints continued in straight lines, without interruption, or breaking joints. Walls constructed in this manner, are of the very worst description, particularly when the joints are made horizontal and vertical. Those consisting of diagonal joints, or joints inclined to the horizon, were used by the Romans. *See* MASONRY and RETICULATED.

CHEST, in bridge-building, the same as CAISSON, which see.

CHEVET (French), the eastern end of a church, when of a circular or polygonal form: equivalent to APSIS, which see.

CHEVRON-WORK, a zig-zag ornament, somtimes called the dancette, usual in the archivolts of Saxon and Norman arches. The outline of chevron-work is a conjunction of right lines, of equal lengths, alternately disposed, so as to form exterior and interior angles, with the exterior angles equal to the interior ones; and all the angular points in the same straight line, or in the same curve line, when they are the ornaments of arches.

The lines of chevron-work are similar to what is denominated *indented* lines in heraldry, and not unlike the indentations or teeth of a joiner's hand-saw; the only difference being the greater inclination of the teeth on one side than on the other; but in chevron-work, they are equally inclined to the line passing through the angular points.

CHIMNEY (from the French, *cheminée*, derived from the Latin, *caminus*, borrowed from the Greek, *καμινος*, *a chimney*, from *καιω*, *I burn*), that part of a building wherein the fire is contained, and through which the smoke passes away.

The chimney generally consists of an opening in, and through a wall, upwards, beginning at the floor on one side of an apartment, and ascending within the thickness of the wall, till it comes in contact with the atmosphere, above the roof of the building.

The parts of the chimney, and of the wall in which it is inserted, are denominated as follows:

The opening, facing the room, being the place where the fire is put, is termed *the fire-place.*

The stone, marble, or plate, under the fire-place, is called *the hearth.*

That on the same level, before the fire-place, is called *the slab.*

The vertical sides of the opening, at the extremities of the hearth, forming also a part of the face of the wall of the apartment, are called *jambs.*

The head of the fire-place, resting at its extremities on the jambs, presenting one face vertical in the surface of the wall, and another towards the hearth, is called the *mantel.*

The whole hollow, from the fire-place, to the top of the wall, is denominated *the funnel.*

That part of the funnel which continually contracts, or diminishes in its horizontal dimensions, as it ascends, is termed *the gathering*, or by some, *the gathering of the wings.*

The long narrow prismatic tube, over the gathering, or that part of the funnel which has its horizontal dimensions the same throughout the altitude of the chimney, is called *the flue.*

That part between the gathering and flue, is denominated *the throat.*

That part of the wall which faces the apartment, and forms the side of the funnel parallel thereto, or that part of the wall which forms the sides of the funnels of several fire-places, is called *the breast.*

In an outside wall, the side of the funnel opposite the breast, is called *the back.*

When there are two or more chimneys in the same wall, the divisions between them, or the solid parts of brick, stone, or metal, are called *withs.* A gable, partition, or party-wall, containing a collection of chimneys, is termed *a stack of chimneys.*

The turret above the roof, for discharging the smoke into the air, of one, two, or a collection of chimneys, is called *the chimney-shaft;* and the horizontal surface, or the upper part of the said shaft, *the chimney-top.*

When the parallel sides of the jambs are faced with stone, marble, or metal, so as to form four obtuse angles, viz., two internally with the back, and two externally with the breast or side of the apartment, making the horizontal dimension of the outside of the fire-place of greater extension than that of the back, the facings are called *covings.*

In stone walls of ordinary buildings, the most common dimensions for the sections of the flues of sitting-rooms are from twelve to fourteen inches square, and for the brick-work, nine by fourteen inches. The section of the flue must, however, be proportioned to the section of the fire, which, when found necessary to vary from ordinary cases, should be equal to the said horizontal section of the fire, or nearly so.

To prevent smoke, the chimney ought to be so constructed, that a current of air may pass immediately over the fire, so as to be rarefied in its passage, and not to pass entirely through the fire, as many have erroneously imagined. For this purpose, the throat should be so near to the fire, as to prevent the cold air from passing over it, and its horizontal dimension in the thickness of the wall should not exceed four inches and a half, or five inches at most.

This contraction is to be formed by facing up the back, and bevelling the covings, so that no cold air may be admitted by the ends of the fire; by thus obliging the overplus above the quantity necessary to produce combustion, to pass over the fire, it becomes so heated, as to consume the smoke in part, and to drive the remaining portion before it, with celerity and violence.

The covings are in general placed at an angle of one hundred and thirty-five degrees with the back and breast, and should be made to form an abrupt plane on their top, so as to break the current of a sudden gust of wind.

The greater the quantity of rarefied air that passes up the flue, and in general the higher the chimney, the more celerity and force will it ascend with. The flue ought, therefore, to be carried as high as conveniency will admit.

To prevent the absorption of heat, the back and covings should be constructed of white materials, or, if not, they should be covered with plaster, and whitened as often as they become black, and thus they will reflect a greater quantity of heat.

Most metals absorb the heat, and are therefore unfavourable for this purpose.

The back and covings are most conveniently put up after the house is built. The introduction and general use of "registers," has obviated any difficulty in this respect; they form a great improvement on the old method.

Some of the principles in the construction of chimneys are very well ascertained, others are not easily discovered till tried.

The tops of flues should not have such wide apertures, as to permit a greater quantity of air to rush down the chimney, and counteract the force of the ascending rarefied steam.

Smoky chimneys are frequently occasioned by the situation of doors in a room, the grate being placed too low, or the mantle too high. There are many cases in which it is not easy to discover the cause; but if once known, it may be easily removed.

Flues with circular sections are, with some reason, supposed to be more favourable for the venting of smoke, than those whose sections are square or rectangular.

There is much difference of opinion as to the origin of chimneys. They do not seem to have been in use among the classics, as they are not found, as Winklemann informs us, amongst the ruins of Herculaneum, although coals have been discovered in some of the rooms, from which he conjectures that the Romans used charcoal fires; Mr. Lysons, however, describes a fire-place, which he found in one of the rooms of the Roman villa at Bignor, in Sussex. There does not seem to be any evidence of the use of chimneys in England before the twelfth century, when we meet with them in the castles of Rochester, Hedingham, &c., also in a Norman house at Winwall in Norfolk, in these cases, however, the flue is carried up only a short distance in the thickness of the wall, and is then turned out at the back, the apertures being small oblong holes. Shortly afterwards we meet with flues carried up the whole height of the wall, as at the castles of Conisborough, Newcastle, Sherbourne, &c., as also at Christ Church, Hants. At this period the shafts were carried up to a considerable height, and are generally circular; in after times the forms varied considerably, and terminated frequently with a spire, pinnacle, or gable, with apertures of ornamental forms in the sides underneath for the escape of the smoke. During the fourteenth century the shafts were very short, and of great variety of forms. In the fifteenth, the shafts were more usually octangular, sometimes square, with the aperture at the top; at the latter end of this century we find clustered shafts, which afterwards became so common in Elizabethan buildings. These clustered chimneys are most frequently of brick, variously and elaborately ornamented all the way up the shaft, and indeed form a very prominent and beautiful feature in buildings of this period. Fine specimens of the kind are to be seen at Hampton Court Palace, Eton College, East Basham Hall, Norfolk, and all the larger buildings of the Elizabethan style; examples in stone, though more rare, exist at Bodiam Castle, Sussex, and on houses at South Petherton and Lambrook, Somersetshire.

CHINESE ARCHITECTURE, that which is used by the inhabitants of China, and employed in their temples and other edifices. It would be very difficult to give such a definition as should point out the species of architecture practised by the Chinese; we must therefore have recourse to the descriptions of those who have drawn and actually measured their edifices with care. To the attainment of this, our materials are few. Sir William Chambers is the only author we are acquainted with, who has given representations of Chinese edifices from measurement, and who was able to discriminate, as an architect, those characteristic forms by which it is distinguished from other species of architecture, and to mark out its peculiar features. In his preface he observes:

"To praise too much or too little, are two excesses which it is equally difficult to avoid. The knowledge of the Chinese, their policy and skill in the arts, have been praised without bounds; and the excessive encomiums that have been given them, show with what force novelty strikes us, and how natural it is to pass from esteem to admiration.

"I am far from joining in the over-strained eulogies of the Chinese. If I find among them wisdom and sublimity, it is only when I compare them with the people that surround them; nor shall I put them on a parallel with the inhabitants, either ancient or modern, of our quarter of the world. At the same time, we must acknowledge, that our attention is due to this distinct and singular race of men, who, separated from the polished nations of the world, have, without any model to assist them, been able of themselves to mature the sciences and invent the arts.

"Everything that regards a people so extraordinary, has a claim to our attention; but though we are pretty well instructed in most things respecting them, we are very little so in their architecture. Many descriptions that have been hitherto given us of their edifices, are unintelligible, the best give but indistinct and confused ideas of them, and none of the drawings deserve the least attention.

"Those which I at present offer to the public, are drawn from sketches and measures that I took at Canton some years ago. I took them merely to satisfy my own curiosity. I had not the least intention to publish them; and they would not have appeared at present, had I not yielded to the solicitations of several amateurs of the fine arts. They have thought them worthy of the attention of the public, and that they might be useful in stopping the course of those extravagant productions, that appear every day, under the name of Chinese; although the most part of them are pure works of fancy, and the rest only mutilated representations that have been copied from porcelain and various paintings on paper.

"What is really Chinese, has at least the merit of being original. Seldom, or never, have this people copied or imitated the inventions of other nations. Our most authentic accounts agree on this point. Their government, their customs, their dress, and almost everything else, have continued unchanged for thousands of years. Their architecture has, besides, a remarkable resemblance to that of the ancients; and this is the more surprising, as there is not the least probability that the one has been borrowed from the other.

"In the Chinese architecture, as well as that of the ancients, the general form of almost all their compositions tends to that of the pyramid. In both, the columns serve for supports, and in both the columns have diminutions and bases, which in many respects are similar. The entrelas, so common in ancient edifices, are often seen in those of the Chinese. The *ting* of the Chinese differs but little from the *peripteron* of the Greeks. The atrium, and the monopterous and prostyle temples, have a considerable resemblance to some among the Chinese; and the manner in which they construct their walls is on the same principle with the revinctum and emplecton, described by Vitruvius. There is, besides, a great resemblance between the utensils of the ancients and the Chinese; both are composed of similar parts, combined in a similar manner.

"It is by no means my intention, in publishing a book on Chinese architecture, to bring in vogue a taste so inferior to the ancient, and so little suited to our climate. But the architecture of one of the most extraordinary people of the universe offers an interesting phenomena to a lover of the fine arts; and an architect ought to be acquainted with so singular a manner of building. The knowledge of it is, at least, curious; it may even be useful on particular occasions. An architect is sometimes asked for Chinese compositions; and, in certain cases, they may be judicious. For though, in general, the architecture of China is not suitable to Europe, yet, in parks and gardens, where the extent demands a great variety, or in large palaces that contain numerous enfilades of apartments, I do not think that it would be improper to decorate some of the most inconsiderable pieces in the Chinese taste. Variety never fails to please, and novelty, when there is nothing disagreeable or shocking in it, often holds the place of beauty. At the time that the Greek architecture prevailed the most among the Romans, history informs us that Adrian, who was himself an architect, erected, at his country seat at Tivoli, several buildings in the style of the Egyptians and some other nations.

"The grandeur or the richness of the materials is not the distinguishing characteristic of the Chinese edifices. But there is a singularity in their manner, a justness in their proportion, a simplicity, sometimes even a beauty, in their form, that deserves our attention. I look upon them as gewgaws in architecture; and if singularity, prettiness, or neatness in the work, give a place to trifles in the cabinets of the curious, we may likewise introduce Chinese buildings among compositions of a better kind."

Sir William has above noticed the pyramidal form of Chinese structures, and indeed the similarity of the architecture of this extraordinary people with that of all the early nations in this respect, is worthy of notice; yet the resemblance of their buildings to tents is even more remarkable, so striking indeed is it, that some travellers have compared their cities to vast encampments. The Chinese, like all the Tartar tribes, were a nomadic race; and doubtless in their wanderings were accustomed to employ tents, coverings portable and readily erected, to defend them from the heat and inclemencies of the weather, and when they settled permanently, preserved the same form in the construction of their dwellings. The construction of their buildings is indeed remarkable, and tends to confirm the foregoing statement; for, as Mr. Gwilt remarks, "though the carpentry of which they are raised has for ages been subjected to the same forms, when we consider the natural march of human invention, especially in cases of necessity, we cannot believe that, in a country where the primitive construction was of timber, the coverings of dwellings would have been at once so simple and so light. Their framing seems as though prepared merely for a canvas covering. Again, we have, if more were wanting, another proof, in the posts employed for the support of their roofs. On them we find nothing resting analogous to the architecture for receiving and supporting the upper timbers of the carpentry; on the contrary, the roof projects over and beyond the posts or columns, whose upper extremities are hidden by the eaves, thus superseding the use of a capital. A canvas covering requires but a slender support, hence lightness is a leading feature in the edifices of China; whilst other materials than those which formed tents have been substituted for them, the forms of the original type have been preserved, making this lightness the more singular, inasmuch as the slightest analogy between those of the original and the copy is imperceptible. This change of material prevents in the copy the appearance of solidity, and seems a defect in the style, unless we refer to the type."

Another peculiarity which strikes the European upon first beholding a Chinese city, is the gaiety of their buildings, arising from the prevalent application of colour. Their roofs are composed of coloured and glazed tiles, their floors of variegated stone or marble, and their porticos not only coloured with the brightest tints, but also profusely varnished, all uniting to produce an effect altogether different from that presented by all other styles.

Sir William then proceeds with the work as follows:

"*The Temples of the Chinese.*—A great number of temples are to be seen at Canton. The Europeans call them commonly *pagodas*. Many of these temples are extremely small, and consist only of one single apartment. Some others have a court, surrounded with galleries, at the end of which is a *ting*, where the idols are placed; and there are a few, which are composed of many courts, surrounded with galleries. The bonzes, or priests, have cells there, and the idols different halls. These are properly convents, and some of them have a great number of bonzes, who are attached to them by particular vows, and who live in them in the exact observance of certain rules.

"The most considerable of these pagodas is that of Honang, in the southern suburb, *Plate* I., *Figure* I. It occupies a great extent of ground; and accordingly it contains, besides the temples of the idols, apartments for two hundred bonzes, hospitals for many animals, a large kitchen-garden, and a burying-ground. The priests and animals are buried promiscuously, and equally honoured by monuments and epitaphs.

"The first object that presents itself, is a court of considerable extent. In it are three rows of trees, which lead to an open vestibule, A, to which the ascent is by a few steps, B. From this first vestibule, we pass to a second, C, wherein are four colossal figures in stucco; they are seated, and hold in their hands divers emblems. This vestibule opens into another large court, D, surrounded by colonnades, E, and cells for the bonzes, F. Four pavilions, G, are placed in it, on socles. These pavilions are the temples; the two stories, of which they are composed, are filled with idols, and the bonzes perform their religious service in them. At the four corners of the court are four other pavilions, H, where the superior

CHINESE ARCHITECTURE.

PLATE I.

Fig. 3.

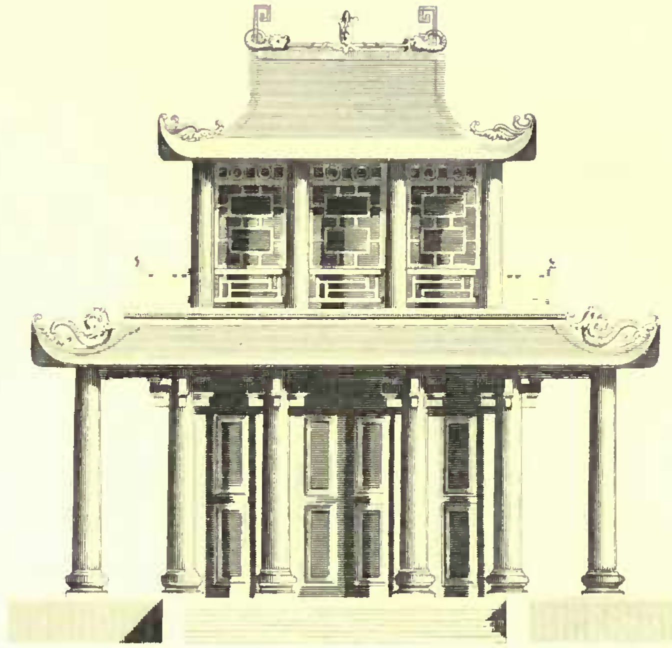
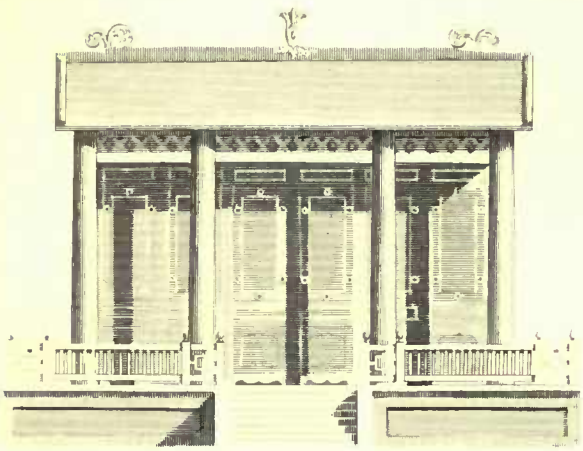


Fig. 2.



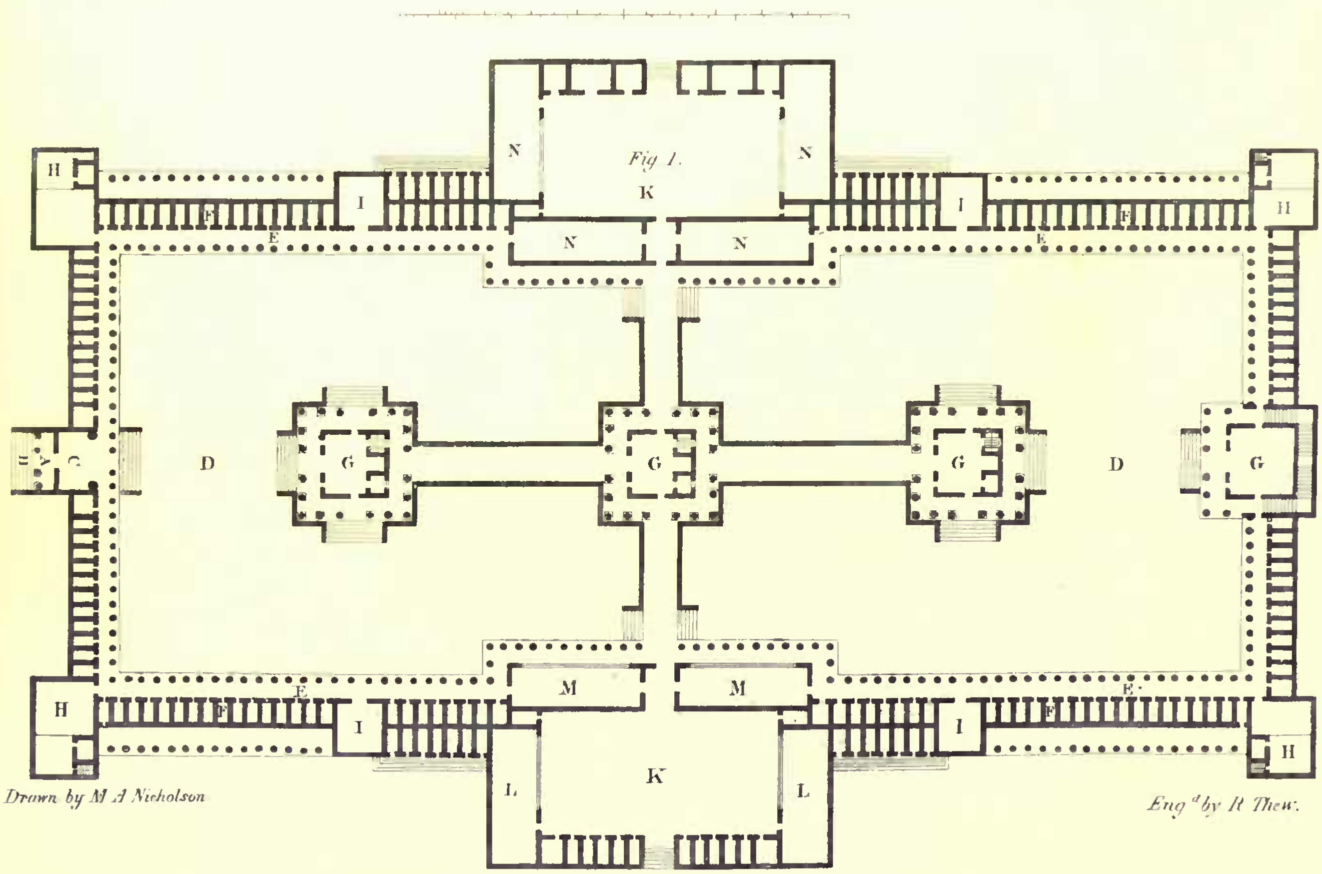


Fig 1.

Drawn by M. A. Nicholson

Eng^d by R. Thew.

bonzes have their apartments; and under these columns, between the cells, are four halls, I, occupied by idols.

"On each side of this great court are two other small courts, K, surrounded with buildings. One is for the kitchen, L, and for the refectories, M; the other serves for the hospitals, N, of which we shall speak.

"I do not give the elevation of the great court, because it could not have the suitable dimensions, without occupying at least three plates. The pavilions are of different forms; but they all present a very similar appearance, and the proportions between the colonnades and the pavilions are also nearly the same. The boxes or cells of the bonzes are of stone, they are very small, and admit no light but by the door. The bodies of the pavilions are built of the same material, and the columns which surround them, as well as the colonnades, are of wood, having bases of marble. All the buildings are covered with tiles, made of a coarse kind of porcelain, painted green, and varnished.

"The same plan is observed in all the temples of this kind; and by detaching from them the three pavilions that occupy the middle of the great court, we may form an idea of the manner in which Chinese edifices of great extent are planned, or laid out. The imperial palace, those of the princes of the blood, the palaces of the mandarins, the Kong Quaens, or colleges of letters, are all disposed nearly in the same manner; the principal difference consists in the number and extent of the courts.

"The edifices that the Chinese make use of for religious purposes, are not, like those of the ancients, of any appropriate form; the particular kind of construction that they call *ting*, or *kong*, enters indifferently into all kinds of edifices, they are seen in almost all temples, in all palaces, above the gates of towns, and, in short, in all buildings where they wish to show magnificence.

"I have seen, in several quarters of Canton, four different kinds of *tings*. The three first are found in temples, and the fourth in many gardens.

"The most common form in these temples is seen in *Plate* I., (see Chambers' work.) It is a pretty exact copy of the *ting* of the Nagada of Cochin-china, in the eastern suburb. I have measured many buildings of this kind; but have found so much difference in their proportions, that I am inclined to think the architects, in that particular, follow no exact rule, but that every one varies the proportion according to his fancy.

"In the drawing that I have given, the edifice is, as they all are, raised on a base; the ascent to it is by three steps. It is a square, surrounded by a colonnade of twenty columns, which support a roof surmounted by a wooden balustrade, which contains a gallery, or passage, surrounding the whole second story.

"The second story has the same figure and the same dimensions as the first. It is covered with a roof, of a construction peculiar to the Chinese; the angles are enriched with ornaments of sculpture, representing dragons.

"The breadth of the edifice, measuring it from the exterior surface of the columns, is equal to the height; and the diameter of the body of the building takes two-thirds of the breadth. The height of the order makes two-thirds of the diameter of the body, and the height of the second story is equal to two-thirds of the height of the first. The columns have in height nine of their diameters, the bases two, and the beams and brackets, which hold the place of capitals, only one. That is also the elevation of the entrelases, which make the turn of the colonnade under the first roof, and which forms a kind of frieze.

"The second kind of *ting* differs so little from that which I have just described, that it has not appeared to me necessary to give a drawing of it. The first story is the same, and all the difference of the second, is, that it is neither surrounded with a gallery nor with a balustrade, and that the roof which covers the colonnade comes close to the wall.

"The third kind is represented, *Plate* I., *Figure* 3. This drawing has been taken from several edifices of this kind; and particularly from one of the pavilions of the pagoda of Honang. The first story differs little from that of the first *ting;* but the second has columns on two of its sides, which stand out and form covered galleries. I have seen, in some of these buildings, a continued colonnade all round the second story; but the form was not so agreeable to the sight as that which I have represented.

"There is very little difference between the proportions of this drawing and that of *Plate* I. The columns of the first story are, in height, eight of their diameters, and the bases one. All the columns, except those of the corners, have eight brackets at the top of their shafts, which form a kind of very clumsy capitals. This ornament, very common in Chinese edifices, is not at all pleasing to our eyes. The columns of the second orders are in diameter about four-fifths of the diameter of the first. Their height is six diameters and a half, and they are without bases. Under the second roof is seen an entrelas, all around, composed of circles and squares. The corners of the two roofs are enriched with ornaments, which represents monsters and foliage; and the top is ornamented with two dolphins at the two extremities, and in the middle with a great fleuron resembling a tulip.

"These three forms are more frequent than any other in the temples of China, and especially in those of much extent. For the small temples they often use the model shown in *Plate* I., *Figure* 2. Sometimes, as may be seen in that drawing, the edifice is shut before by movable gates, having four columns that advance in the manner of pro-style temples. At other times the building is quite open in the front, and has simply four columns that support the roof.

"I have seen at Canton some other forms of temples; but none of them appeared to me worthy of representation except two little buildings, of wood, raised in the courts of one of the pagodas of the western suburb. (*Figures* 2 and 3, of *Plate* III. he gives the plans of them.) These are two pavilions, that cover two iron vases, that the Chinese use in the sacrifices of gilt paper, which they make to their idols on festival days; they are both octagons, and composed of eight columns, which support a roof surmounted with a lamp and other ornaments, which are represented in the drawing. *Figure* 3, is a little raised, and surrounded with steps. The columns have bases of a profile little different from the attic. A frieze charged with inscriptions in large Chinese characters, surround the space between the columns under the roof. The lantern has eight sides, it is covered with a roof in sima inversa, and on the top is seen an ornament consisting of a small globe surrounded with leaves and flowers."

Figure 2, "is raised on a socle, and surrounded with an entrelas of masonry. There are no bases to the columns, and under the first roof is seen an ornament composed of interwoven lozenges. The lamp has eight little columns, without bases or capitals, which support a conic roof, ornamented with eight dolphins, each of which rests on one of the columns. The top of the building consists of a pierced ball, whose top ends in a flower.

"The proportions of these little temples may be deduced from the scale that I have annexed to the drawings."

"*Towers*, or *Taas.*—The Chinese give the name of *taa* to their towers, and the Europeans call them (as well as temples) *pagodas:* they are very common in China. Du

Haldè says, that in some provinces they are in every city, and even in every considerable village. The most remarkable of these edifices are the famous porcelain tower of Nang-king and that of Tong-chang-fou. They are both very magnificent.

"The form of these *taas* is pretty uniform; they are octagons, divided into seven, eight, and sometimes ten stories, which diminish gradually both in height and breadth, from the base to the top. Every story has a kind of cornice, which supports a roof, at the corners of which are hung copper bells, and is surrounded with a narrow gallery bordered with a balustrade. These edifices have commonly a long pole at the top, surrounded by several circles of iron, supported by eight chains, tied by one end to the top of the pole, and by the other to the angles of the roof of the highest story."

The origin and objects of these towers have been the cause of much discussion among European antiquaries, nor has the question been as yet satisfactorily settled, some considering them as merely commemorative, some as campaniles or belfries, some as landmarks and beacons, while others assert that they are sepulchral, and produce as a confirmation of their opinion the discovery of a stone coffin fitted in the pedestal of the tower of Ardmore. Valleney affirms that they were fire-towers erected to Baal, while others no less learned identify them with the round towers of Ireland. This last idea may appear extravagant at first sight, yet upon further examination it will be found equally as reasonable as any of the preceding. The Irish towers are generally believed to be of Celtic origin, erected by the same hands as the structures of Stonehenge, and others similar to them scattered over the British Isles; now, strange to say, we have the same class of erections in China, in the province of Keang-nan, and in a locality famed not more for its romantic scenery than its ancient legends: here we find not only the monolithon, or single, upright column, the counterpart of those already described under *Celtic Architecture;* but even the most perfect form of Druidical structures, the circle, and several of the intermediate erections, proving without doubt the connection between them, and the remains of Celtic erection in the remote west. Add to this, that towers are found in close proximity with such structures, and it must be allowed that their supposed identity with those of Ireland is not indulged without some reason.

Plate III. *Figure* 1, "represents one of these towers, which are found on the banks of the Ta-ho, between Canton and Hoang-pou. It is approached by three steps, and consists of seven stories. The first story is pierced with four arched gates, and contains an octagonal chamber, in the middle of which is a staircase conducting to the second story. The stairs of the other stories are placed in a similar manner. The cornices over the several stories are all alike, consisting of a fillet and large cavetto, enriched with representations of shell-fish; an ornament as common in the edifices of China, as in those of the ancients. The roofs are turned up at the corners, and, with the exception of the lowest, are ornamented with leaves and bells. The pole on the top is surmounted with a globe, from which descend chains, that are fixed to the angles of the highest story, and around them are nine iron hoops. I have not set down the stairs of the different stories in the drawing, to prevent confusion."

The porcelain tower of Nan-king is octagonal in plan, forty feet in diameter, and consists of nine stories, diminishing in size as the structure rises, and surmounted with a cupola and gilded ball. From this ball a rod of iron rises, and from its highest extremity eight chains descend, from which seventy-two bells are suspended. Each story is covered by a projecting roof of coloured tiles, and the total height of the building is variously estimated at three hundred and forty-six, two hundred and fifty-eight, and two hundred and thirty-six feet.

"The inner part or body of the wall," says Mr. Wright, "is brick, but the inside lining and the facing without, of beautiful white glazed porcelain slabs, fixed in the masonry by means of deep keys, cut like a half T in the brick. The projecting roof of each story consists of green and yellow porcelain tiles in alternate perpendicular rows; and running up each angle, is a moulding of larger tiles glazed and coloured red and green alternately. From each story projects a balcony, enclosed by a light balustrade of green porcelain, upon which open four doorways, set to the cardinal points, their arches being elegantly turned with glazed tiles, cast in all imaginable fancies of design, and variation of colour, representing deities, demons, and monsters of all descriptions." Bells are suspended from dragons' mouths at the angles of every story, making with those attached to the chains of the cupola, a total number of one hundred and fifty-two.

"*Several other forms of buildings used in China.*—I have given descriptions of three kinds of *tings*, that I saw in different temples at Canton. It remains for me to speak of a fourth kind, which is found in gardens. These edifices are in general composed only of twelve columns, raised on a socle, which serve to support the roof.

"The building that served me for a model, was placed in the middle of a small lake, in a garden in China; its singularity made me give it the preference.

"The base that supports it is pretty high. A balustrade surrounds it. The bases of the twelve columns of this pavilion have a profile very similar to that of a Tuscan base of Palladio. The roof, which rests on these columns, is crowned with a lantern. The idea of this ornament is taken from those which surmount the towers. The tops of the shafts of the columns are pierced by beams that support the roof, having their extremities ornamented with little grotesque heads and bells. A frieze ornamented with an entrelas, goes all round, under the roof, in the spaces between the columns."

Sir William describes another pavilion thus: "It is the same with that of a temple with one wing; but the elevation is different. It is composed of ten columns, which support a roof and a lantern, covered in the form of a cone, and terminated by a ball.

"The *paylous*, or triumphal arches, are very common in China. There are many in Canton; but none, that I have seen, have any beauty.

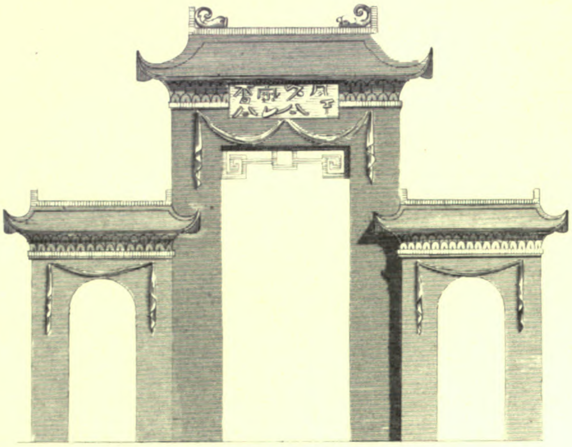
"*Houses of the Chinese.*—The distribution of their houses is perfectly uniform; and it would be improper, and even dangerous, for an individual to depart from the general mode. Le Compte tells us of a mandarin, who having built a house higher and more beautiful than those of his neighbours, was accused before the Emperor, and, fearing the consequence, he pulled down his house, without waiting for the sovereign's decision.

"The Chinese lay out more than half of the ground occupied for their houses in courts and narrow walks; those of the merchants of Canton, which are close by the water, are narrow and very long; but there is no difference in the disposition of their interior. The level ground is crossed in its length, by a broad walk, passing through the middle, and stretching from the street to the river. On each side are the apartments, consisting of a saloon for receiving visits, a bed-chamber, and sometimes a study, or closet. Before each set of apartments is a court, having a fish-pond, or cistern, at its extremity, containing an artificial rock in the middle, whereon grow bamboos and several other kinds of

CHINESE ARCHITECTURE.

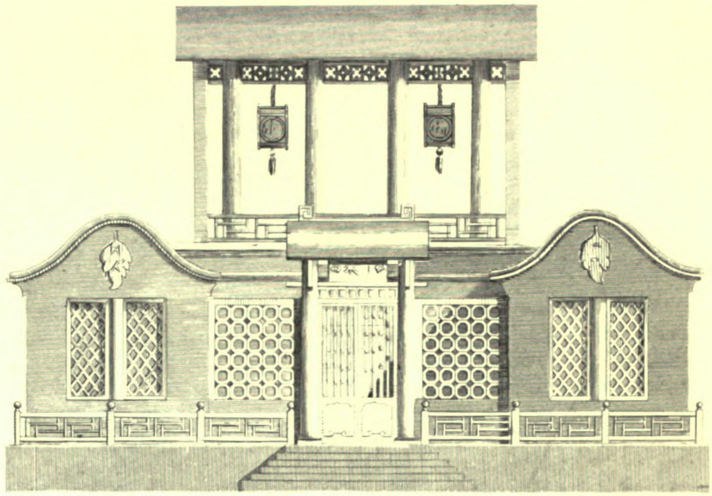
PLATE II.

Fig. 1.



TRIUMPHAE ARCH

Fig. 2.



HOUSE OR SHOP

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 3.

Drawn by M. A. Nicholson

Eng^{d} by R. Thew.

Fig. 1.

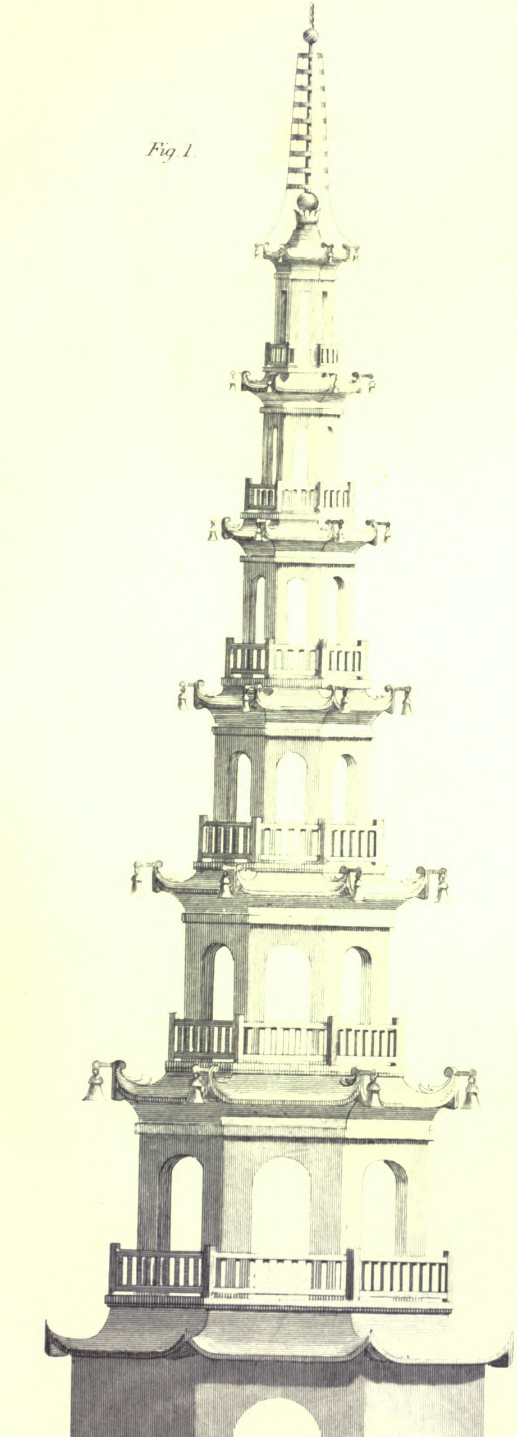


Fig. 2.

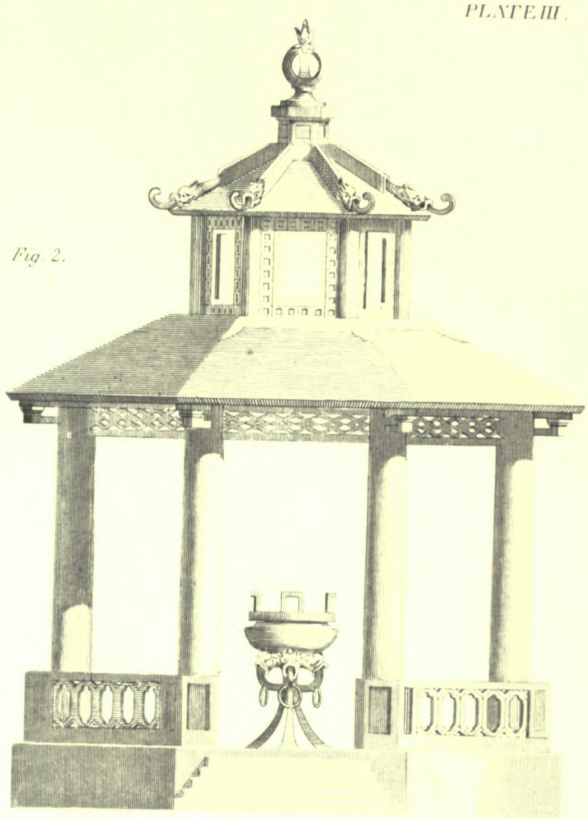
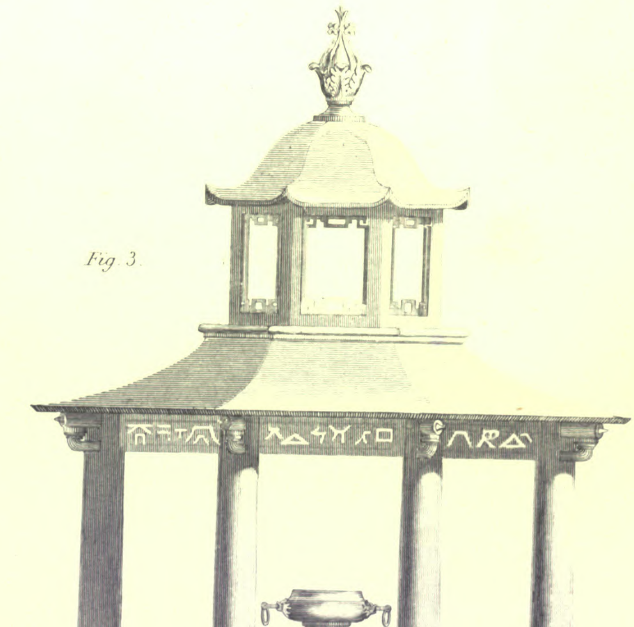


Fig. 3.



Drawn by M. A. Nicholson.

Engd. by R. Thew

plants; all which form a miniature landscape, of picturesque appearance. Some of the fish are so familiar, that they come to the surface of the water, and allow themselves to be fed with the hand. The sides of the courts are ornamented sometimes with flower-pots, and sometimes with shrubs in flower, vines, or bamboos, forming green arbours. In the middle, upon a pedestal, a large porcelain vase is generally placed, filled with those beautiful flowers, called *lien-hoa*. They also frequently keep in these little courts, pheasants, bantam-hens, and other curious birds.

"The great chamber, or saloon, is commonly from 18 to 20 feet in length, and about 20 feet in breadth. The side which looks to the court, is entirely open; but a screen of canes, which is let down at pleasure, keeps out the rain and the rays of the sun. The pavement is composed of pieces of stone or marble, of several colours. The side walls are covered with screens, to the height of three or four feet from the ground; and the upper part is neatly decorated with white, crimson, or gilt paper.

"Instead of paintings, the Chinese hang up large pieces of satin or of paper, set in frames, and painted in imitation of marble or bamboo, on which are written, in characters of azure blue, proverbs and distichs of morality, taken from the principal Chinese philosophers. They also sometimes have leaves of white paper, quite smooth, containing large characters, traced by some skilful hand, in China ink; this ornament is much esteemed. The bottom of the drawing-room is composed of folding-doors, over which is a lattice, covered with painted gauze, for the admission of light into the bed-chamber. The doors, which are of wood, are of very neat workmanship, ornamented with different characters and figures, and sometimes richly varnished and painted red, blue, yellow, or some other colour.

"In the middle of the lower part of the chamber, and above a table which contains various ornaments, a very large leaf of thick paper is frequently suspended, covered with ancient Chinese paintings of different figures, enclosed in squares. The Chinese have a great veneration for these ornaments, under the idea that the painters were inspired; and the connoisseurs pretend to distinguish the hands of the several masters, and give a very great price for such as pass for originals. I have seen many of these paintings: they usually consist of landscapes or figures, drawn with China ink, on white paper. In general they are touched with spirit, but they are too incorrect, and too little finished, to deserve much attention.

"The furniture of the large room consists of chairs, stools, and tables, made of rosewood, ebony, varnished wood, and sometimes simply of bamboo, which, though cheap, is very neat. When the furniture is of wood, the tops of the stools are often of marble or of porcelain; and though such seats are very hard, they are very agreeable in a climate where the heat of the summer is excessive. On small tables, or stands, four or five feet high, placed in a corner of the room, are seen dishes of citrons, and other odoriferous fruits, branches of coral in porcelain vases, and glass globes containing gold-fishes, with a kind of herb something similar to fennel. They also decorate their tables, which are made only for ornament, with small landscapes, composed of shell-work, plants, and a kind of lily that grows among pebbles covered with water. They have also artificial landscapes, made of ivory, crystal, amber, pearl, and precious stones. I have seen some that cost a thousand *taels*, (more than three hundred guineas), but they are mere toys, and wretched imitations of nature. Besides these landscapes, the tables are ornamented with porcelain vases of different kinds, and small copper vessels, the latter of which are much esteemed. The forms of these vessels are generally simple and agreeable; the Chinese say they were made two thousand years ago, by some of their most celebrated artists; and such as are really antique, (for there are some counterfeits), sell at an excessive price; one of them sometimes costs no less than three hundred pounds. They are kept in small pasteboard boxes, and are only shown on great occasions; nobody touches them but the master, and, to keep them clean, he brushes them from time to time with a hair-pencil, made solely for the purpose.

"Lamps form the most prominent ornaments of the chambers; there are generally four of them hanging from the ceiling, by cords of silk. They are of various shapes, as square, octagon, &c., and are composed of an extremely fine silken stuff; decorated with very neat drawings of flowers, birds, and landscapes.

"A partition of folding-doors separates the large room from the bed-chamber. I have already observed, that, in warm weather, these doors are left open all night, for the admission of cool air. The chamber is very small, and has no other furniture than the bed and some varnished clothes-trunks. The beds are sometimes extremely magnificent: the bedsteads, or frames, which very much resemble those of Europe, are of rosewood engraved, or of lackered wood; the curtains are of taffety, or gauze, sometimes flowered with gold, and commonly dyed blue or purple. A band of embroidered satin, about a foot in breadth, goes round the whole top of the bed; the embroidery is in compartments, of various forms, and represents flowers, landscapes, or human figures, accompanied with moral sentences and fables, written with China ink and vermilion.

"By the side of the bed-chamber is a passage, leading to the cabinet, which is always enclosed by walls, and lighted by windows. The walls are ornamented, like those of the saloon, with moral sentences and antique pictures; the furniture consists of arm-chairs, settees, and tables. The books are disposed on shelves, and on a table near the window, lie the pencils, and other things necessary for writing, the instruments used for arithmetical calculations, and some select books, all laid out in great order.

"Besides these apartments, there are also the dining-room, the kitchen, the apartment for the domestics, the bath, the privy, the office, or counting-house, and, towards the street, the shop.

"Such is the distribution of the houses of all the merchants at Canton. Those of other people only differ in having their general plan accommodated to the ground on which they are built: for the apartments, the courts, and other conveniences, have everywhere the order just described.

"The *leou*, or upper-story, consists of many great halls, occupying all the breadth of the house, above the apartments of the ground-floor. They are used occasionally as chambers, for lodging strangers. In every house there is a number of shutters, two or three feet broad, and ten or twelve feet high. When they wish to make chambers, they fix these shutters to the floor and ceiling, and in a few hours make as many apartments as they wish. Some of these shutters are cut from the top to within four feet of the ground, and the openings filled with very thin oyster-shells, which are sufficiently transparent to admit daylight. All the windows in China are made of these shells.

"In one of these great halls, and commonly in that next the door, the image and altar of the domestic idol are placed, so that all who enter may see it. The rest of the second story is divided into apartments for the family; and over the shops are the rooms for the shop-keepers.

"The sides of the Chinese houses next the street, are altogether plain, or employed as shops. There is no opening except the door, before which a mat is hung, or a screen is placed to prevent passengers from looking in. The houses of the merchants of Canton have a very gay and handsome appearance towards the river.

"The materials used for building are wood and brick. The latter are either simply dried in the sun, or baked in an oven. The walls of the houses are commonly about eighteen inches thick, and the bricks, which are about the size of our own, are used in the following manner: the masons place three or four beds at the foundation, entirely solid; after which they dispose their bricks alternately length and breadthwise, along the two sides of the wall, so that those laid across touch one another, and occupy the whole breadth, but those placed lengthwise have a space between them; on this layer, or bed, a second is laid, with all the bricks lengthwise, and the joinings of the cross-bricks, in the first layer, are covered with a whole brick in this. The work is thus continued, alternately, to the top; and by this means, the expense of work and time, as well as the weight of the wall, are very much diminished.

"The tiles that cover the roofs, are plain and semi-cylindrical; the latter are laid on the joinings of the former, and the manner in which they are supported, is represented in Plate III. The Chinese, like the Goths, always let the wood appear withinside the ceiling; for which reason, the beams and columns are frequently made of precious wood, and sometimes they are richly inlaid with ivory, copper, and mother-of-pearl.

"*Various kinds of columns used by the Chinese.*—Columns are at least as common in Chinese edifices as in those of the Europeans. They support the roof, and are commonly made of wood, with bases of stone, or marble, having no capitals; but, instead, the top of the shaft is crossed by the beams. Their height is from 8 to 12 diameters, diminishing gradually towards the top, while the lower part of the shaft terminates in an ovolo, producing an effect just the reverse of the terminations of the ancient columns. This peculiarity is observable in the drawings of the *Antiquities of Egypt*, published by Captain Norden some time ago. The bases show a great diversity of profile; none of them are very handsome, but the most regular that I have seen, are the six represented in Plate III." *See Chambers'* Work.

Figure 2, No. 1, "is taken from the colonnade that surrounds the court of the pagoda of Cochinchina: the column is about seven diameters in height, and the base one. This profile is very common."

Figure 2, No. 2, "is taken from one of the temples of the same pagoda, represented in Plate I. It is the only place where I have seen this kind of column. They are about nine diameters high, and their base two."

Figure 3, "is taken from the colonnade of the great court of the pagoda of Honang. The height of the column is nine diameters, and that of the base one. The ends of the beams are ornamented with heads of monsters, terminating in foliage, and the brackets that support them come out of the mouths of grotesque heads, cut in half-relief on the columns."

Figure 4, "is taken from a little pagoda in the eastern suburb of Canton. The height of the column is eight diameters and a half, and that of the base three-fourths of the diameter. The ends of the beams represent heads of dragons, and all the wood-work of the ceiling is ornamented with monsters and foliage, in inlaid work of copper, ebony, ivory, and mother-of-pearl."

Figures 5 and 6, "the transverse elevation of Figures 3 and 4."

Figure 7, "is seen in almost all the houses of the Chinese. Their height is from 8 to 12 diameters, and sometimes more; that of the base is from one-half to two-thirds of the diameter. The profile resembles one of the Tuscan bases of Palladio."

Figure 8, "is found in almost all the pagodas, with some little varieties. The model from which I have taken my drawing, is in a little pagoda, in the street where are the European factories. The columns are octagonal, and of stone. Eight diameters of the circumscribed circle make the height; and they have no diminution toward the base. The bases are the most regular that I have seen in China, and much resemble the attic base of the ancients. Their height is equal to double one of the sides of the column.

"The particular divisions of all these profiles are marked at the side of each drawing.

"The insides of the temples, represented in Plates I. and II. (see *Chambers*), are quite plain; having no ornaments beside the idols. The buildings represented in Plate II. Figures 3 and 4, have no ceilings; the beams which support the roofs are seen; and their joinings are according to the principles of that in Plate III. The interior of the tower in Plate III. is also quite plain."

We must not omit to mention the Great Wall; it consists of an earthen mound supported on each side by walls of brick and masonry, the thickness of the whole being twenty-five feet at the base, diminishing to fifteen at a height of fifteen feet, which is the level of the platform; but this platform is defended on either side by a parapet five feet in height, thus making the total height of the wall twenty feet. At intervals of about two hundred paces are towers, rising to a height of thirty-seven feet, and measuring forty feet square at the base, and thirty feet at the top; there are however some larger towers, which consist of two stories, and are about forty-eight feet in height. This wall is carried round a great portion of the empire, passing over in its way mountains, valleys, and rivers, and is altogether fifteen hundred miles in length.

CHIP, a small piece cut away from any material, by an acute-angled instrument.

CHISEL, an instrument used in masonry, carpentry, and joinery, and also by statuaries and carvers, for cutting, either by the impulse of pressure, or of the blows of a mallet or hammer. There are several kinds of chisels used in carpentry and joinery; as, the *former*, the *paring-chisel*, the *gouge*, the *mortise-chisel*, the *socket-chisel*, and the *ripping-chisel*. These names they have obtained from the uses to which they are respectively applied. *See* Tools, Tooling.

Chiseled Work, in masonry, stones that have a chiseled surface.

CHIT, an instrument for cleaving laths.

CHOIR, (from χορος. Greek, chorus;) that part of the church in which the choir or singers are located, and the services for the most part performed. The term is sometimes made equivalent to chancel, and defined as that portion of the building eastward of the nave appropriated to the priests, but incorrectly so, as the choir does not extend to the extreme east. The fourth council of Toledo directs "the priests and deacons to communicate before the altar, the inferior in the quire, and the people without the quire;" thus making a distinction between the choir and sanctuary, or division on which the altar stood. In fact the chancel is divided into two parts—the choir, and the presbytery or sanctuary; the former containing the singers and inferior ministers; the latter the altar, and the superior officiating clergy. The choir was at the western end of the chancel, separated from the nave by one or more steps and the rood screen, and from the sanctuary by steps only; it contained seats or stalls on either side, which were returned sometimes on the western extremity in front of the screen, the returns always facing the altar: in large churches, there are generally two or three ranges of such stalls rising a step or two in succession above each other. When there are aisles at the sides of the choir, which is generally the case in cathedrals and the more important churches, they are separated from it either by a screen of open work, or by the stalls being carried up to a considerable elevation; the latter method is more usual in cathedrals, where the higher stalls are canopied, and enriched with tabernacle work. In our cathedrals, the choir is situate more generally to the east of the tower, but is sometimes seen under the tower, as at York and Winchester.

The choir was originally separated from the altar, and elevated in the form of a theatre, enclosed all round with a balustrade: on each side was a pulpit, from which the epistles and gospel were sung; as may still be seen, at Rome, in the churches of St. Clement and St. Pancratius, the only two remaining in the original form. It was separated from the nave in the time of Constantine, and enclosed with a balustrade, covered with curtains, which were not to be opened till after the consecration. In the twelfth century, the choir was surrounded with walls.

In nunneries, the choir is a large hall, adjoining the body of the church, but separated by a grate, where the devotees chant the service.

CHORAGIC MONUMENT of Lysicrates, at Athens. *See* Monument of Lysicrates.

CHORD, the extent between the two extremities of an arch.

CHRISTIAN ARCHITECTURE, a designation applied by some to Gothic art exclusively, but in our opinion, unreasonably; because, although Gothic is doubtless the perfection of Christian art, and the best adapted for religious purposes, and in that respect more fairly entitled to the name than any other style, still we think all others ought not to be excluded from the title, since some of them, such as Byzantine and Lombardic, owe their origin entirely to Christianity, and were never profaned by being applied to pagan usages. The term ought to include all styles of building invented by the Christians, and adapted to religious purposes, differing essentially from pagan architecture.

CHRONOLOGICAL COLUMN. *See* Column.

CHURCH, (Greek, Κυριου οικος, the Lord's house,) a Christian edifice set apart for the public celebration of divine service.

Churches vary in size, magnificence, and architectural features, according to their rank and situation; and are denominated accordingly: thus we have metropolitan, patriarchal, cathedral, cardinal, conventual, collegiate, monastic, and parish churches; for a description of which, we must refer to each separate title, more especially to Cathedral and Monastery. Under this article we shall confine ourselves more particularly to the consideration of parish churches; as, however, the distribution and architectural peculiarities of churches vary considerably in different countries, we must premise further, that we include only the parish churches of our own country. The history and progress of Church Architecture in this and other countries, and a comparison of the whole, will be treated of under the title of Ecclesiastical Architecture.

As there is a general similarity in the division and arrangement of parts in all churches of whatever date or situation, it may not be out of place at the commencement of this article, to say something of the primitive churches, as far as relates to these particulars. The earliest buildings erected for the purpose of Christian worship, or at least the earliest of which we have any account, as also the first in which Christians had an opportunity of following their own mode of construction, are those which owe their existence to the zeal of Constantine the Great; and the most ancient and most perfect model of these now remaining, is that of Saint Clement at Rome. From this and some few other structures at Rome, we are enabled to determine, to a certain extent, the form of the churches of that period; and our conclusions derived from this source, are confirmed by Eusebius, who has left us a description of a Greek church of his own time. From these combined authorities, we learn that the plans of such buildings were either oblong or cruciform, and were divided into distinct portions as follows:—At the entrance to the church was the vestibule or narthex, in which were stationed the catechumens and penitents of various stages, and which was frequently divided into two or more parts, each of which was destined for a different class of penitents, the outermost for those who were under the more severe censures of the church, and the innermost for the catechumens; this last division was termed ναρθηξ, *ferula*, because those who were admitted into it, began to be subject to the discipline of the church. These vestibules or porticos led to the nave properly so called, in which were assembled the body of the faithful; and which was divided in its width into three or more parts—a central one, with an aisle on each side of it. In the central avenue or body of the building, and at the remote end of the nave, was the choir, shut off from the other parts of the church by a rail or otherwise; in this were the ambones or pulpits for reading, as also the seats for the choristers, and here was the greater portion of the service performed. From the choir was an ascent of steps to the sanctuary, which was of an apsidal form, having seats all round for the priests, and a more elevated one in the centre of them for the bishop, immediately in front of which stood the altar. Attached to the church, but forming a distinct erection, was the baptistery, in which persons were admitted into fellowship with the body of believers. Having thus given a rapid sketch of a primitive church, we shall pass to the consideration of our more immediate subject, begging our readers to bear in mind the preceding observations, while we describe the form and arrangement of our English churches.

In speaking of our parochial churches, we would be understood to refer solely to those erected before the Reformation, in the styles usually denominated Gothic. This is not the place, even were argument necessary, to discuss the comparative merits of the Italian and Gothic styles, or their adaptation to sacred purposes. The improved taste of the age has led to the preference of the latter, and there are few of the present day who would be found to question its correctness. Gothic is the prevailing fashion now, as was Italian in the preceding generations; apart from this, however, we think there can be no man of correct taste and unbiassed judgment, but would prefer the quiet unobtrusive simplicity of our old parish churches, to the more pompous grandeur of those of the last two centuries. Nothing can be more diverse than the impressions conveyed by the two—the one, solemn, subdued, and peaceful; the other, secular, showy, and luxurious: it is astonishing how completely the application of the two styles to the same general form, will change the features and general appearance of an edifice.

Our parish churches are perfectly unique; different from what we find elsewhere, they form quite a national characteristic, of which an Englishman may indeed be proud. Their origin is attributed to Archbishop Theodore, who noting the inconvenience which arose from the previous practice of sending priests from the cathedral into the neighbouring hamlets, adopted the plan of distributing each diocese into manageable districts or parishes, with a resident pastor to take charge of each; he carried out his idea by instigating the Saxon thanes in the erection and endowment of churches within the precincts of their own estates. The plan thus commenced, was found to be so advantageous, that it was carried out and enlarged upon by the succeeding generations. We shall not stop here to inquire into the form and construction of the earlier churches of this island, but refer the reader, as well to the articles above mentioned, as also to that on SAXON ARCHITECTURE, and proceed at once to the general description of a church.

Of the parts or divisions.—There are two parts, and only two parts, absolutely essential to a church: nave and chancel. These it must have, or it is not entitled to the designation of a church; without the former it is no more than a chapel, and without the latter, little better than a mere lecture-room. A church consisting only of the above divisions, is one of the most simple form, few, however, are found without some further additions: the first addition is that of a porch on one side of the building, forming a covered entrance into the church. Buildings consisting simply of these three parts are not unfrequent, nor devoid of beauty, although but seldom imitated in the present day. In larger churches, the capacity of the nave is increased by the addition of one or two aisles, more frequently of one on each side of the body of the building, thus dividing the nave transversely into three avenues and affording greater accommodation for worshippers without enlarging the chancel, as this part does not so much require spaciousness as length. In some cases it is true the aisles were continued eastward, so as to encroach upon the chancel, and sometimes extended its whole length; the spaces thus gained, were used for the most part for chapels, and contained side-altars with their appurtenances. These chapels were dedicated, the one in honour of the Virgin, which was more frequently on the southern side, and the other in the name of the patron or other saint. Churches with only one aisle, are constantly to be met with.

Another division of a church which we have not yet noticed, and which, though not an essential, forms a most imposing feature, is the tower; this is situated most usually at the western end of the nave, or at the intersection of the nave and transepts, when the church is cruciform; and in its most perfect and beautiful state is surmounted by a lofty spire. We have now arrived at the most complete form of a parish church, which consists of a nave flanked on either side by an aisle; a chancel at the east, and a tower at the western extremity of the same, with a projecting porch towards the western end of the south aisle. This is the most frequent form of our smaller churches, but not the only one; we not unfrequently find them in the shape of a cross, which is doubtless the most appropriate and expressive form that could be adopted in the erection of a Christian temple; but the simple parallelogram is on many accounts the more convenient, nor is it so greatly inferior in symbolical meaning; for while the cross plan portrays the emblem of Christianity, the latter is an evident representation of the ark in which Noah was preserved, which has ever been considered a type of the Christian church.

Of the position of Churches.—Almost all the old churches of this country range east and west, having the chancel at the eastern extremity; nor is this merely a local peculiarity, but a universal custom; such was the practice of all Christians from the earliest ages. It is true, exceptions are to be found, but not more than sufficient to prove the rule. The church dedicated by Paulinus, bishop of Nola, to the memory of S. Felix, is an instance of deviation from the usual position, but of this it is related, that it was not built so as to face the east, "as was usual," but so as to turn towards another church previously dedicated to that saint; and Socrates, describing the church at Antioch, tells us, that it stood in a different posture from other churches, the altar not being at the east end, but at the west. The canonical position is ordered in the apostolical constitutions. When we state that the chancel pointed eastward, we do not mean to say that it faced that quarter precisely; very few churches indeed do this, the orientation varying in many instances considerably north or south; such variation is said to have arisen from the practice of pointing the church to that part of the horizon where the sun rose on the day of the patron saint.

Of the exterior elevation.—The smaller churches present to us an elevation of only one story of rough walling, pierced at intervals with windows, which are usually filled with tracery; those at the east and west ends, being of larger dimensions than those in the side walls. At the angles of the building, the outline is broken by massive projecting buttresses, and at other situations where they are required for the support of the building; they are sometimes seen between every two windows. A more imposing projection is afforded by the porch on one side; this is carried up nearly as high as the side walls, and is surmounted by a high-pitched gable roof; it is formed either of rubble, with or without windows, or of wood, in which material we have many beautiful specimens of the later styles pierced and carved in the most elaborate manner; some of the plainer ones, however, form very picturesque additions to a small church.

The chancel, in most cases, is of smaller dimensions than the nave, both in width and height, and forms a picturesque break in the elevation; but in some cases it is of the same size as the nave, and occasionally, though rarely, larger in both dimensions, showing a western wall projecting beyond the nave on all its sides. There is a priest's door in one side of the chancel, and sometimes a vestry, the form and elevation of which varies in different examples.

The whole of the building is covered by a high-pitched gable roof of lead, slate, or tile, and sometimes of shingles or thatch, the eaves projecting a little beyond the walls; parapets are not found, except in large churches. A very beautiful addition is frequently to be seen on the apex of the western gable, consisting either of a continuation of a part of the gable in a vertical direction, pierced with arched apertures to contain the bells, and finished with a gable top; or otherwise of a little turret of four or more sides, to be employed for the same purpose: the eastern gable is for the most part finished with an ornamental cross.

In the larger churches of three aisles, the elevation consists most frequently of two stories, the lower one similar to that already described, and an upper one called the clere-story, which is carried up above the arches which separate the nave and aisles, and pierced with windows of a smaller description, sometimes with mere quatrefoils or other small apertures. In very large churches, the clere-story windows are often larger than those of the aisles. The nave is covered as before with a gable roof, but the aisles with a lean-to, sloping upwards from the exterior walls to the clere-story, with a much more gentle acclivity. In some three-aisled churches, where the width is not considerable, the gable roof spans both nave and aisles; sometimes in one inclination, but at others, the inclination over the aisles is considerably depressed; in such cases there is of course no clere-story. On the other hand, when a church is of a great width, especially when the additional width is in the aisles, we have three gable roofs, one over the nave, and a similar one over each aisle; the gable ends of such churches have a very pleasing appearance; they have no clere-story, and the chancel is mostly but a continuation of the nave; not unfrequently the aisles are continued the whole length of the building in such churches.

In cruciform churches, the elevation, with the exception of such differences as the plan necessitates, is for the most part similar to that of the more common forms.

Of the tower.—A beautiful appendage to a church is the tower, nor is it added merely for effect; its principal object is perhaps to contain the bells, which require to be suspended at a considerable height, in order that they may be heard at a distance; another end which it serves, is to point out the situation of the sacred building, and, as some suppose, to act as a beacon or landmark for the guidance of travellers: an instance of a tower serving this purpose, may be pointed out at Boston, Lincolnshire, as also at Dundry, near Bristol, at both of which places the towers are raised to an extraordinary height. The tower is very generally surmounted by a spire, which serves as a most efficient covering, while at the same time it gives additional height, and forms a beautiful finishing, "pointing," as it does, "in silence heavenward." It is remarked that spires are not so frequent in elevated situations, or in level tracts of land, as they are in valleys and in wooded country; which fact would seem to imply that they were added more especially for pointing out the spot occupied by the house of prayer.

The situation of the tower with respect to the church is various; sometimes we see it at the end, sometimes in the middle of an aisle, frequently at the west end of the nave, and occasionally between nave and chancel; in short, almost in every situation, except at the eastern extremity of the chancel. Its plan is usually square, though occasionally we find it octagonal, and even circular, and sometimes square at the lower part, but finished off at the top in an octagonal form; in elevation, the outline is broken by buttresses projecting considerably at each angle, and, where there is no spire, is frequently found a stair turret running up in the corner next the church, and continued some little distance above the parapet. The base or lower story of the tower is usually plain and massive, but the upper portion is of a more elaborate appearance, being pierced with windows, the heads filled with tracery, and the lower parts with louvre-boarding. When there is no spire, the tower is finished with a parapet, battlemented or otherwise; and in later examples, the parapet is not omitted, even when there is a spire, and is sometimes enriched by continuing the buttresses above the tower, in the shape of pinnacles. During the earlier periods of English architecture, the spires sprang direct from the eaves of the tower, without the intervention of a parapet.

Spires are, in plan, square or multangular, most frequently octagonal; sometimes they spring from the tower on a square plan, which at a short elevation is merged in the octagonal; some spring from the tower at a greater angle than others, but all terminate in a point surmounted by a vane, often by the symbolical cock, the emblem of St. Peter's fall, which proposes an opportune warning to the passers-by, not to neglect the aid of divine power, but to "watch and pray, lest they likewise enter into temptation." The elevation of the spire is relieved by one or two tiers of spire-lights, which are small open windows, carried up vertically, and therefore projecting from the line of spire as they rise upwards. Spires are built either of stone or of wood, in which latter case, they are usually covered either with lead, slate, or shingles; and though not so imposing as those of stone, have a very picturesque appearance. Towers of wood are very frequent in Sussex, Surrey, and Essex; they are surmounted with low spires, the whole being covered with weather-boarding, with small apertures of luffer-boarding for windows: wooden bell-cots of a similar description are commonly to be met with in Essex. Detached towers are not of frequent occurrence in this country, but several are to be found, especially in Lincolnshire.

Of the internal structure.—The principal portion of the structure to which the eye is directed, in the interior is the chancel; this is entered from the nave under an arch, termed the chancel-arch, and is elevated from the body of the church on a raised platform, which is ascended by three or more steps; a further separation is effected by the rood screen, which is carried across the opening formed by the arch, and stretches from pier to pier. In three-aisled structures, the aisles are separated from the nave by an arcade or series of arches, supporting in most cases a clere-story, to admit light into the body of the church. The proportion between the width of the nave and aisles, varies considerably; in some cases, the aisles being less than half the width of the nave, and in others, of nearly equal dimensions.

The roofing throughout the church is composed in by far the majority of instances, of timber, the few exceptions, which are in the larger churches, being of stone vaulting. In roofs of the former kind, the timbers were originally open to view, and not concealed, as too many of them are at the present day, with a flat plaster-ceiling. The timbers were of oak, and consisted of principals, purlins, and common rafters, the whole of which were boarded over, and the boards protected by lead or other covering. The principals are placed at regular intervals, dividing the roof into a number of bays or compartments, each inclosing several common rafters, and are partially supported either on corbels, or on the capitals of shafts ascending from the floor; they are formed either of collars with collar braces continued to the lower part of the rafter, of collars with intersecting collar braces, of intersecting braces only, or of timbers disposed in the form of an arch, and in many other ways which will be discussed in the proper place; tie beams are seldom used; in most instances the timbers are plain, but in many, of the later ones more especially, a considerable degree of ornamentation is introduced in the shape of carved bosses, open panelling, and such like.

Of the internal arrangement.—On entering the church through the wicket, at the entrance of the porch, we sometimes notice on the right-hand side of the door, often projecting from the wall, and partially covered by a niche, a stone bason, which is called a stoup, or aspersorium, from its use, which was to contain the holy water, with which, in olden times, the worshippers sprinkled or crossed themselves before entering into the body of the church. This was a very ancient practice, and was adopted in a somewhat different shape by the early church; the small stoup, in fact, is a substitute for the fountain to be seen in front of some of the Constantinian churches, at which Christians were accustomed to wash before entering the sanctuary; the custom is typical of the purity of mind which should accompany our devotions. Before proceeding further, we may notice the stone seat, or bench-table, which runs along the sides of the porch, and is occasionally covered with an arcade, and sometimes surmounted with a window to give light to the porch: in ancient times, several religious ceremonies took place in the porch, especially those preliminary to baptism and matrimony. Having passed under the inner arch of the porch, we are now fairly in the church, and the first object to attract our attention is the font, which is placed always near the principal entrance, as being the most fitting situation for the performance of that rite by which men are admitted into the membership of the church; the exact locality is not fixed, being sometimes in the central avenue of the nave opposite the entrance, and at others under one of the arches of the aisle near the porch, in which case it frequently adjoins one of the adjacent pillars; it is not unfrequently raised on a series of steps, which give it a more imposing appearance, and has always a space left around it for the accommodation of the priest, sponsors, &c.; for the former there is sometimes a kneeling-stone on the west side. Fonts in a perfect state are provided with covers, generally of wood, some flat, and others of a pyramidal form more or less enriched. We here speak of fonts as they were in former times, not as they are now found in old churches, for the original ones are sometimes not only moved from their ancient positions, but even taken out of the church, and altogether discarded.

On proceeding further into the church, the next object which probably strikes our eye is the chancel, and at its extremity the altar, with its appendages, but as this has been described in its proper place, we shall not stop to re-consider it here; and besides this, in fixing our attention on the more striking portion of the edifice, we have overlooked the pulpit. Few pulpits are to be met with of an earlier date than the fifteenth century, the oldest which remain are of stone, built up with the fabric, from which circumstance we may infer that they are coeval with the entire structure; there is a beautiful specimen at Beaulieu, Hants, which is attached to the wall, and entered by a staircase partly cut out of its thickness; another specimen is to be found in the church of the Holy Trinity, Coventry, which is attached to one of the piers of the building. The later pulpits are of oak, usually of an octagonal form, having the sides panelled and enriched with carving, and the whole sometimes surmounted with a richly-groined canopy projecting over the head of the preacher. The position of the pulpit was probably always at the north-east or south-east end of the nave, near the arch which separates the nave and chancel.

We have now to consider the form and arrangement of the pews. There are few churches which have not suffered severely by the removal of their ancient seats, and the substitution of close boxes, with high backs; the old seats were low, with very low backs, so as not to destroy or shut out a full view of the church. The backs and seats of such low benches were fitted at either end into a standard, which served at the same time as a support and finish, being frequently carved in panels, and sometimes finished at the top with a poppy-head, or knop of foliage; at other times they were quite plain, with only a simple moulding, or even chamfer at the top: between every two benches was an open space left for ingress and egress to and from the seats, which were never closed with doors. These benches were all arranged north and south, so that the congregation might face the east, having an avenue between them in the centre of the nave, and another leading into it from the entrance, which, in three-aisled churches, must have been carried right across the church, to give access to another avenue leading to the seats in either aisle. These formed the only seats in the church for the laity; it is scarcely necessary to add, that galleries never formed a part of the original arrangement.

Of the internal decoration.—There is one method of decoration so universally applied in our ancient churches, that we cannot pass it over unnoticed; it consists in the application of colour; the roof, the floor, the walls, the furniture and ornaments, and, not to omit the principal feature, the windows, nay, even the very books, were all enriched with gilding and colour. In paving, the use of encaustic tiles of various colours and patterns was most common, but besides these, the floors were not unfrequently covered with mosaic work, as instanced at the Prior's Chapel, Ely, where in the chancel immediately in front of the altar was represented "the temptation" in this method, the other parts of the floor being adorned with ordinary patterns. Frequent specimens of painting on the roof have been lately brought to light, a very usual method of decorating which is by a powdering of gilt stars on an azure ground. Few restorations take place without some additional testimony to the employment of fresco paintings, which have been previously concealed by successive coatings of plaster and whitewash. Mr. Poole, speaking of the internal decoration of churches, says—"Besides the immense variety of Scriptural and other subjects which are found sculptured on the walls and roofs of our Gothic churches, we have also sometimes fresco paintings, covering great portions of the walls. These paintings have, for the most part, been covered with the successive coats of whitewash and yellow ochre, with which the churchwardens have literally daubed the interior as well as the exterior of churches; as if, to their eyes, whiteness and yellowness were the only two elements of beauty. Accident has discovered several of them, and more are being discovered every day. The most remarkable with which I am acquainted is in the church of the Holy Trinity, Coventry; the subject is one which cannot be unprofitably suggested to Christians,—the last judgment; and it is treated in a manner by no means deficient in expression. At Preston, in Sussex, is another fresco, discovered also accidentally; one of the subjects is the murder of Thomas à Becket; the story is minutely and well told. Another subject is the archangel Michael weighing the soul of a Christian, which appears in one side of a pair of scales, against the devil, in the form of a boar's head, in the opposite scale. By the intervention of a female saint, most probably the blessed Virgin, who stands by, the soul is manifestly the weightier.

"In the late remains of Rotheram church, several frescos were discovered, especially a large one over the nave arch, of our blessed Lord and the twelve apostles, with other saints and angels in act of adoration. The figures were much destroyed in the process of laying them bare; and they are now covered over again. Might they not have been restored?" This question we shall leave for future consideration; meanwhile, we may remark, that many specimens of fresco have been discovered since the above was written, and no doubt fresh discoveries will be made as the process of restoration goes on in our ancient churches.

Another old method of decorating the walls, the appropriateness of which cannot be questioned, is by covering them with texts of Scripture, on which our previous author, Mr. Poole, remarks as follows:—"The most simple occupant of the walls of churches is a series of passages from the Sacred Scriptures, or of moral sentences of tried wisdom and appropriate tendency. The introduction of the inscriptions is very ancient. Bingham gives us several instances, and, among others, two distichs written over the doors of the church, one on the outside, exhorting men to enter the church with a pure and peaceable heart:—

> 'Pax tibi sit quicunque Dei penetralia Christi
> Pectore pacifico candidus ingrederis;'

and the other within, requiring those who go out of the church to leave at least their heart behind them:—

> 'Quisquis ab æde Dei perfectis ordine votis
> Egrederis, remea corpore, corde mane.'

"St. Ambrose tells us of an appropriate passage of Scripture, written on the walls of that part of the church which was allotted to the virgins. And besides these moral lessons and texts of Scripture, records of the dedication of the church were sometimes inscribed on the walls; such was that written by the altar of Sancta Sophia, by Justinian.

"To convey some notion how appropriately such passages may be selected and arranged, and how impressive may be their general effect, we will adduce the whole series of inscriptions from a small chapel at Luton, in Bedfordshire. This chapel, which is now the property of the Marquis of Bute, was built by one of the Napier family, in the reign of James I., and the beautiful wainscoting with which it is fitted up, was brought from Tittenhanger, where it had been fixed by Sir Thomas Pope, in 1548.

"Over the principal doorway are the words, Domus Dei porta Cœli: 'The House of God is the Gate of Heaven;' and on the north and south side of the entrance: Laudate eum juvenes, laudate eum virgines, 'Praise Him, ye young men; praise Him, ye maidens,' from Psalm cxlviii. 12. On the two transverses of a beautifully carved door, is an inscription from Psalm cxviii. 20, Porta Domini, Justi intrabunt, 'This is the gate of the Lord, the just shall enter in.' With reference to a nearer approach to the altar, we have the words—Lavabo inter innocentes manus meas, et circumdabo altare tuum Domine: 'I will wash my hands among the innocent, and I will compass thine altar, O Lord:' and on the altar itself not only are the names of our blessed Lord, found in Hebrew, Greek, and Latin, as they were inscribed by Pilate on his cross, but also the following passages from Heb. xiii. 10; Matt. xxvi. 27; 1 Peter i. 12; and 1 Cor. xi. 24, 25: Habemus altare—Ex hoc omnes—in quæ desiderant Angeli prospicere—Hoc in memoriam mei: 'We have an altar—Eat ye all of this—Into which the angels desire to look—Do this in remembrance of me.' Even the singular addition of a chimney-piece in this chapel, has its appropriate inscription: Ecce ignis et lignum, ubi est victima holocausti? 'Behold the fire and the wood, but where is the victim of the whole burnt offering?'—Gen. xxii. 7."

Such was the decoration of the walls of our old churches, nor were the details or furniture neglected, but all enriched with colour, and the smaller parts with gilding. The richness produced by this treatment, which might otherwise have appeared too glaring, was chastened and softened down by the dim religious light shed through the storied panes of the stained windows, which, while they added to the general effect, imparted a chasteness throughout the whole structure. An old church in all its glory, must have been truly beautiful.

Of the materials.—Our old churches were most generally built of stone, and the majority of them of rough unhewn rag or rubble, built up into the fabric in the same state as brought from the quarry; the individual stones were small, and not all of the same size; they varied likewise in shape, not being built up in regular courses, but fitted together as neatly as circumstances would permit; the longer spaces being filled up with smaller stones, and the lesser ones with cement. This masonry was bonded at intervals by longer stones running through the work, and at the angles by coins of more regular workmanship. The dressings of the building, such as the jambs and finishings of windows, doorways, and other apertures, as well as the pinnacles, water-tables, string-courses, mouldings, and all other portions of the edifice which required much labour, were of some more manageable stone, such as Caen; and in some of the more highly embellished structures, of Purbeck marble. In some localities, flint is employed instead of rubble, more especially in Norfolk and Suffolk, not unfrequently in Essex and other counties; in many cases of this kind, the walls are made up of flints, inserted in a kind of framework of freestone, which method, with the aid of good cement, produces a very durable and not unpleasing structure. Nor are these the only materials employed in the construction of churches; we occasionally meet with brick and wood as substitutes for stone, more frequently than elsewhere, in the county of Essex. Brick, however, was not used during the best periods of ecclesiastical architecture, nor does it produce an effect so pleasing to the eye, as either of the before-mentioned materials; their colour, red, is not nearly so agreeable as the more subdued tones of flint or rubble. The walls, in all the above cases, were of great thickness, which tended not only to the greater stability of the structure, but also to maintain an equability of temperature in the interior. A good specimen of a wooden church is that of Greenstead, Essex, which has recently been restored, and of which the following description, previous to its restoration, is given in one of Weale's Quarterly Papers:—

"The timber walls, which," says the writer, "I take to be of oak, though some imagine them to be of chestnut-wood, are but six feet in height on the outside, including the sill; they are not, as usually described, 'half-trees,' but have had a portion of the centre or heart cut out, probably to furnish beams for the construction of the roof and sills: the outside or slabs thus left, were placed on the sill, but by what kind of tenon they are there retained, does not appear; while the upper ends, being roughly adzed off to a thin edge, are let into a groove, and which, with the piece of timber in which it is cut, runs the whole length of the building itself; the door-posts are of square timber, and these are secured in the above-mentioned groove by small wooden pins, still firm and strong—a truly wonderful example of the durability of British oak. At the west end I had an opportunity of examining the very heart of the timber; to the edge of an exceedingly good pocket-knife, it appeared like iron, and has acquired from age a colour approaching to ebony, but of a more beautiful brown; and if any conclusion may be drawn from the appearance of the building, I see no reason why it should not endure as long as it has already existed. The outsides of all the trees are furrowed to the depth of about an inch into long stringy ridges by the decay of the softer parts of the timber, but these ridges seem equally hard as the heart of the wood itself; the north doorway, which measures only four feet five inches in height by two feet five inches in width, is at present closed with masonry; but the aperture must have been original. It is generally thought that the woodwork of the roof is coeval with the walls, and it was most likely formerly covered with thatch, as Bede describes, and as may still be seen on many village churches in the county of Norfolk.

"The body of the church is lighted by windows in the roof, but these are decidedly of a recent date; what little light its interior enjoyed in its primitive state, was probably admitted from the east end, if any windows existed at all.

"How the interior was originally finished, cannot be now determined; at the present moment it is kept in a very neat and reputable state; its walls and ceiling are plastered and whitewashed, and its area affords sufficient accommodation for the population of the parish."

The nave is the portion of the church here alluded to, for the chancel is not of the same material, and is of a later date; the tower is also of wood weather-boarded, with luffer boards for the admission of light.

Since the above account was written, this unique little edifice has been restored, under the superintendence of Messrs. Wyatt and Brandon; and in an article on the subject, to be found in "The Builder," a short period subsequent to its restoration, the following remarks occur. The writer, in combating Mr. Suckling's opinions as to the timbers being less than half-trees, says—"We see no evidence of this, for the timbers were evidently left rough, and the dimensions prove them to have been, as nearly as may be, 'half-trees.' These uprights," he continues, "were laid on an oak sill, 8 inches by 8 inches, and tenoned into a groove 1½ inch deep, and secured with oak pins. The sill on the south side was laid on the actual earth; that on the north side had, in two places, some rough flints, without any mortar driven under. The roof-plates averaged 7 inches by 7 inches, and had a groove corresponding with the sill, into which the uprights were tenoned and pinned. The plates were also of oak, but they and the sills were very roughly hewn, in some parts being 10 inches by 10 inches, and in others 6 inches by 6 inches, or 7 inches.

"There were twenty-five planks or uprights on the north side, and twenty-one on the south side. The uprights in the north side were the least decayed. Those on the south side required an average of 5 inches of rotten wood to be removed, those on the north about 1 inch only, and the heights of the uprights, as now refixed, measuring between plate and sill, are on the north side 4 feet 8 inches, on the south side 4 feet 4 inches, the sills being bedded on a few courses of brickwork in cement, to keep them clear of damp. The uprights were tongued together at the junction with oak strips, and a most effectual means it proved of keeping out the wet; for although the interior was plastered, there was no evidence, in any part, of wet having driven in at the feather-edge junction of the uprights—a strange contrast to many of our modern churches, where, with all the adjuncts of stone and mortar, it is found no easy matter to keep out the driving weather from the south-west.

"The roof was heavy, and without any particular character; it consisted of a tie-beam, at less than six feet from the floor, with struts. The covering was tile."

We have given the description of this little church at so great length, because we think buildings erected after this manner would form very good substitutes for those un-ecclesiastical-looking structures termed Temporary Churches, which are become so fashionable now-a-days; and not only so, but might be even erected as permanent ones, in places where a better could not be provided.

Of symbolism.—Although many persons are so far prejudiced against the system as to deny the existence of symbolical meaning in the peculiar structure and arrangement of churches, to the unprejudiced mind there can be little doubt of the fact. It is true that some of the advocates of the system have carried it to too great a length, and have strained their point to such an extent as to appropriate a deep theological meaning to the smallest details, yet this should not hinder us from giving attention and credit to those who hold themselves within reasonable limits. This idea respecting the æsthetic character of ecclesiastical buildings, has but lately been brought into general notice, but it is no new fancy; on the contrary, we find mention of it in the writings of the early Christians. The following passage is from the Apostolical Constitutions:—"When thou callest an assembly of the church, as one that is the commander of a great ship, appoint the assemblies to be made with all possible skill; charging the deacons, as mariners, to prepare places for the brethren, as for passengers, with all care and decency. And first let the church be long, like a ship, looking towards the east, with its vestries on either side at the east end. In the centre, let the bishop's throne be placed, and let the presbyters be seated on both sides of him; and let the deacons stand near at hand, in close and small garments, for they are like the mariners and managers of the ship." As we have before remarked, the material structure of the church was from the earliest period considered emblematical of the ark of Noah. Similar allusions to that just quoted, are constantly occurring in the patristic writings; thus S. Ambrose tells us why baptisteries should be octagonal, and Clement of Alexandria gives rules by which the selection of sacred emblems should be guided; Eusebius informs us that Constantine surrounded the apsis of the church of S. Cross with twelve pillars, according to the number of the twelve apostles; and Hermas, in his visions, represents the building of the spiritual temple under figures wholly taken from the material fabric. But of all writers on the subject, Durandus is the most copious, and is held up as the highest authority in such matters. Mr. Lewis, in his description of Kilpeck church, Herefordshire, is one who has of late brought the subject of symbolism into notice; he is one of those, however, who in our opinion have laboured to apply the system to a greater extent than is warranted by facts; he enlists every portion of the fabric, even to the minutest details, to illustrate his views, and makes the arrangement of the sacred edifice to indicate the minutiæ of theological doctrine. Mr. Poole, in his lectures on church arrangement, does not attempt so much; he maintains "that ecclesiastical architecture is a language; that it has always, so long as it has deserved its name, aimed at expression; and not at mere accommodation without splendour, or even at splendour without a spirit and a meaning: that from the first it was rational; that it had a soul and a sense which it laboured to embody and convey to the beholder: that its language was not only expressive, but appropriate; that it aimed not only at accommodating a congregation, but at elevating their devotions and informing their minds." He is of opinion that the greater mysteries of our religion are symbolized in the fundamental design of the structure, while other Christian verities are set forth in the minor arrangements and in the ornamental details. For instance, the mystery of the Trinity is symbolized by the threefold division of our churches into nave and aisles, and perhaps in the longitudinal division into nave, choir, and chancel, otherwise the division into nave and chancel is said to point out the division of clergy and laity: but the æsthetic principle is more evident in our larger churches; thus in our cathedrals we have the form of the cross in the ground-plan, also the threefold division of body and aisles, as well as of nave, transept, and choir; we have likewise the same number of divisions vertically in the lower arcade, triforia, and clerestory, as also in the exterior elevation in the central and two western towers. Mr. Poole concludes—"On a review, then, of the facts mentioned, we may safely conclude, that, from the first, there has been a sufficient degree of uniformity in Christian churches, to indicate a unity of design, which could not be accidental; that the origin of that unity is to be found in the desire to symbolize the truths of our holy religion in every apt manner, and, above all, in the sacred edifices of the Christians." "A Gothic church, in its perfection, is an exposition of the distinctive doctrines of Christianity, clothed upon with a material form; and is, as Coleridge has so forcibly expressed it, 'the petrifaction of our religion.'"

As church-architecture is receiving a fair modicum of attention at the present time, and churches are being multiplied to keep pace with the requirements of a vastly-increasing population, it may not be out of place, in a work which pretends rather to useful and practical information, than to amusing recreation, to give some rules for the guidance of those who are called upon to prepare plans and designs for church-buildings.

In the first place, then, let the architect consider well the amount which is to be laid out in the erection, for this must determine every other consideration; if the amount be small, do not let him attempt a large or highly-decorative building. He must first take care to ensure soundness and strength in the construction, and leave the details to be considered afterwards; if, after calculating the cost of the mere walling and other necessary parts of the structure, he finds he has sufficient to construct them in a substantial manner, and money to spare, let him then decide upon the amount of decoration. It is better to erect plain walling, so that it be solid and well-build, than to add enrichment upon enrichment upon walls which are scarcely able to support them. Let strength be the object sought to be attained, not show; mere ostentatious display is quite out of character in a sacred edifice. This leads us to the next rule:—let every material employed be real; if funds are not sufficient for the best materials, use the more common, but do not attempt to hide them, let them appear what they are in reality, in their true colours, and not stain or plaster them to resemble things of a superior description; the building may not appear so rich, but it will bear the stamp of reality and truth, which will carry a conviction of its superiority to minds perhaps unwilling to yield to its demands.

Of construction.—The best material for the walling is undoubtedly stone, and of this, we suppose, that which is dressed and squared should be preferred; we do not speak with certainty in this case, for there decidedly are advantages attached to undressed, uncoursed masonry; the very unevenness imparts a richness and variety of colour to the material, and a play of light and shade over the surface, which is not attainable in an even or smooth wall; but besides this, there is another superiority in the contrast which is afforded between the naked wall and the more finished dressings of the apertures. But even if this matter be left undecided, it will make but little difference in the present day, for few architects have funds at their disposal to allow them a choice between the two. The stone best adapted for the purpose, in the practice of the present time, is rag or rubble, which is inexpensive, and at the same time durable; it may be procured in most localities without much trouble. Whatever be the nature of the stone, it is not necessary nor desirable that it be quarried in large masses, the smaller the better, so far, at least, as is consistent with a due regard to the safety and expense of construction; when the stones are large, they are apt to catch the eye, and lead it away from the more detailed portions of the building, whereas, if the separate stones be of small size, and more especially if they be of irregular outline, and random-coursed, they will render the more important features distinct and effective. For this same reason, the finished stones of the apertures, and such like, should not all be of the same size, either in length or height, so as to form a regular line at their junction, with the rubble masonry, for, if so, they will divert the attention from the main outline and decoration of the windows, &c., which the eye ought to catch at the first glance; but besides this, if the jamb-stones be of different lengths, they will form a more efficient bond with the main wall. The latter remarks will apply to all buildings, whatever be the materials of which they are composed.

With regard to the selection and laying of stones, the best plan is to use them as they come to hand, studying neither their shape nor situation too closely; a wall, constructed in this manner, will look natural, and therefore far better, than when the stones are broken or placed in a peculiar manner for the sake of appearance. In no cases attempt to make the joints over close. The dressings will of course be formed of a stone which may be easy to work: Caen is a good stone for the purpose, but if this is not to be obtained, some kind of freestone may be discovered in the neighbourhood, available for such service. The nature of the stone required will vary of course with the degree of carved enrichment to which it is to be subjected.

Where flint is abundant and more readily procurable than other kinds of stone, it may be used with advantage, as is evidenced by many an old structure. Care should be taken that it be well bonded and cemented together, otherwise it will not be so secure as rubble masonry; in some cases, which we have before alluded to, the walls are formed of a sort of frame-work of freestone, the intermediate spaces being filled in with small squared flints. In new work the effect of flint is not so good as could be desired, but it improves by age; the contrast between it and the freestone being modified in process of time; old buildings of this material have a very pleasing effect.

If none of the above materials can be procured without much difficulty, brick is not to be discarded, although not to be recommended unless under peculiar circumstances. If you are compelled to use it, do not attempt to disguise it by stucco, a brick church is better than an imitation stone one; plaster may be used occasionally to preserve a wall, but, if so, let its nature and its purport be at once evident. Churches of red brick are to be found in Essex, but they are of a late period, and are not to be imitated unless absolutely necessary. In general cases, rag or rubble is preferable, not only in appearance, but even in economy.

Timber, though by no means a desirable material, may in special cases be employed. A church of this description has already been noticed and described, it will therefore be unnecessary here to enter into a consideration of its construction. While upon this subject we cannot conclude without again suggesting, whether churches built after the fashion of that at Greenstead, above described, would not be more appropriate structures for temporary churches, than those which at the present day pass under that denomination.

In all the above cases, let the walls be of considerable thickness, as this tends not only to the security of the structure, but also, as we have said before, to the preservation of an equable temperature in the interior.

Of the covering.—The best covering for the roof is lead, of sufficient thickness—7lb. lead is a good quality—but it has its disadvantages; in the first place it is expensive, and therefore not suitable for the present time; it also requires great care in laying, and unless pure, and of good quality, is liable to corrode. Slates are not objectionable if they be of a good colour, but the common blue slate does not harmonize well with the masonry; very fair specimens are to be procured from the north of England. Tiles and thatch are frequently found on old churches; the former may be employed, but the latter is objectionable, for reasons which will be obvious to every reader. Rag-stones may be used for the purpose, as may also shingles; the latter are eligible on account of their lightness, and other qualities, but they are not secure against fire.

Of the internal wood-work.—The roof, benches, screens, and other wood-work should be of oak, if expense is no obstacle; however, fir, walnut, and other inferior timber, are more generally employed now-a-days; but whatever is used, it should not be stained or grained, to resemble wood of a superior quality; it may be prepared in any manner which will tend to its preservation, and in this way its appearance may sometimes be improved. Deal may be employed when the funds will not admit of a better substitute. Varnish is now frequently used, but we think it better avoided; at least, allow it a sufficient time to dry, before the church is to be used for service.

Of the flooring.—The best materials for paving the floor are encaustic tiles, ornamented in appropriate-coloured devices; plain tiles, however, will answer very well for the nave, they should be placed diamond-wise, the alternate ones being of the same colour with a differently-coloured one between; red and black are the common colours. The enriched encaustic tiles may be judiciously reserved for the chancel; plain tiles are well introduced even here, for they serve as a contrast, as also to throw out the patterns of the richer sort.

Of metal-work.—The metals are used for a variety of purposes, the more costly in the furniture of a church, but we shall here confine ourselves to the ornamental iron-work, used for hinges, locks, bars, and such like, many beautiful specimens of which are preserved to us in our old churches. We must, at starting, lay down, as a rule, that iron, for these purposes, should be wrought, not cast; the latter class of iron-work is always a failure. These ornaments should not be painted, but, to preserve them from rust, it is recommended that they be dipped when red-hot in grease, and left to cool; the same purpose will be answered by coating them with some incorrosive metal.

Of style.—The best style for adoption in parish-churches is undoubtedly the Decorated, from the middle of the thirteenth to the middle of the fourteenth century. During this period Christian art was at its perfection, and soon after began to lose its character for genuine simplicity; the introduction of the depressed arch, and the excessive embellishment of the later style, was the commencement of its downward course. We would not, however, confine the architect to a single style; Early English is well adapted for large churches, and may occasionally be made available for smaller ones, while Perpendicular is appropriately employed for churches in cities and large towns, sometimes even with greater advantage than Decorated, which is particularly the case when a church, being closely surrounded with other buildings, requires large windows on those sides which are more open to the light. For the generality of churches, however, the Decorated is by far the most suitable, it is equally adapted for a plain, as for a more highly-finished structure, and has a natural grace which ensures its perfection, in whatever situation it be placed; it will admit of the highest elaboration, so far at least as is consistent with purity, or of the plainest construction, without sacrificing any of its inherent beauties; on the other hand, the Perpendicular style must be highly enriched, or otherwise it will appear meagre, and is therefore unsuitable, except for an expensive edifice. We have said nothing of Norman, but we must not pass it over in silence; it is decidedly not so appropriate as any of the above-mentioned styles for parish-churches, and yet we should be sorry to see it entirely discarded; it must not be recommended, but it has its peculiar beauties, which doubtless will always secure to it some share of public favour.

Of the plan.—The amount of money at the disposal of the architect, as it determines the material to be employed, will likewise, to a certain extent, govern the size, and therefore the plan and arrangement of the building. The ground-plan will also depend, in a great measure, on the site allotted for the building. For very small churches, the best arrangement is the most simple, viz.; that of the parallelogram, divided into nave and chancel, which division need not be shown on the exterior, although it is very desirable that it should be so, and in this case the chancel is marked by its smaller dimensions in height and breadth; the chancel should always be separated from the nave in the interior by an open screen of wood-work, as also by being elevated on one or more steps. An important and inexpensive addition may be made to this plan in the shape of a porch, which may be either of wood or stone, and should be placed, unless there be any strong reason to the contrary, towards the western end of the south side. A further improvement will consist in the erection of a bell-turret, or gable, either on the western gable, or on that between the nave and chancel; this again need not be expensive, in some cases it may be made of wood, in which material we have a sufficiency of ancient examples; but it is best, of course, of stone; of whichever material it be constructed, it always forms a very marked and beautiful feature in a small church. We should be rejoiced to see a larger number of such small structures as the above erected at the present day, when all seem to aim at an edifice of much greater pretensions, even though they have, it may be, scarcely sufficient funds for the erection of one of the more simple structures in an efficient manner. Towers placed between the nave and chancel are not unfrequent in some parts of England.

If accommodation for a larger number of worshippers be required, one or more aisles must be added to the nave. A nave with two aisles is the perfect form, but both aisles need not be built at the same time, unless the number of the congregation require it, and there are ample funds for its erection. At the same time, never build only one aisle for the sake of appearing extraordinary, nor unless there is an intention of erecting a corresponding one at some future period; for this reason, when a single aisle is adopted, let the opposite wall of the nave be built with arches of construction, so that when the second aisle is added, it may be necessary only to remove the masonry between the arches. This last method might be adopted with advantage in the first class of churches. We may remark here, once for all, that it is by no means necessary that the opposite sides of a church should exactly correspond.

This last is the most eligible form of structure for ordinary churches, to contain, say from two hundred persons and upwards. For churches of this capacity the first-mentioned form is not adapted, as, when so large accommodation is required, you would be compelled to extend the nave to an inconvenient breadth; twenty-five feet is the greatest dimension allowable in a small church without aisles; when aisles are added, their breadth, as a general rule, should be to that of the nave in the proportion of two to five, but this ratio is not fixed, it varies in different examples.

If still greater accommodation be required, it may be obtained by continuing the aisles on one or both sides of the chancel, from which they should be shut off by parcloses of open work; but this addition is not a desirable one, and should be adopted only in such places as the architect is cramped for room. A more legitimate method of obtaining greater space in general instances is by annexing a tower, which should open into the church by a lofty arch. This, though not essential to a church, forms one of the most striking and picturesque features, and when the means will admit of it, should never be omitted; though, on the other hand, the essentials should in no case be sacrificed to obtain it.

Of the position of the tower.—The standard situation of the tower is at the west end of the nave, although there are very many exceptions to this position, amongst which are the following, instances of which are given by the Ecclesiological Society:—west end of either aisle; middle or east end of either aisle; north or south of chancel; north side of a second north aisle; north or south side of nave; north-west and south-west angle of nave; north-east or south-east of nave; middle of nave and western end of the chancel. All these positions are allowable, when circumstances require the tower to be so placed; as a general rule, however, we think it advisable to retain it at the west end of the nave. At one time architects restricted themselves entirely to this rule, however more eligible any other situation might have been; now, on the contrary, it is the exception to see the towers in this position. We think both at fault, the former following one arrangement too closely, simply it would appear for the sake of preserving an exact correspondence in both sides of the building, even at the risk of losing other advantages; while the latter seek out extraordinary positions merely for the sake of their novelty, and for the purpose of exciting surprise. The nature and shape of the ground, as well as the internal arrangement, should decide the question. In cruciform churches the proper location of the tower is over the intersection of nave and transept, but in addition to other positions, the following are satisfactory—at the north end of the north, and the south end of the south transept. Sometimes, though rarely in this country, we find the tower detached from the church, similarly to the campaniles of the Continent.

A tower can scarcely be said to be perfect without a spire, and in churches in which the earlier styles are adopted, this feature should never be omitted; in the Perpendicular it is not of so great consequence, though even then desirable. Spires need not always be carried up to a great height, although the loftier the better, nor need they be invariably of stone, those made of shingles are very beautiful objects in rural districts, and those covered with lead or slates are not to be despised; in some counties we find both tower and spire constructed of weather-boarding. In passing, we cannot help noticing, that in many of our modern churches, the towers have not sufficient breadth, which gives them an appearance of poverty and meagreness. We suggest, whether it would not be better, where towers are deemed necessary, to lay the foundation of a more substantial structure, and to leave it incomplete until the requisite funds are provided. Our old church-builders always went to work on this principle, which accounts for the single aisle, and many other irregularities, as, for instance, difference of style in the different portions of a church. This plan might be carried out with advantage in the present day, not only in the larger parts of the structure, but also in the finishing of details, &c. The plan of the tower is generally square or rectangular, supported at its angles by massive buttresses, which add greatly to its appearance; not unfrequently a turret, containing a staircase, is added at one angle, which affords a picturesque irregularity, especially if it be carried up above the main building; this is particularly the case in the later styles.

Another addition which will be required, is the sacristy or vestry; its position should be on the north side of the chancel, with which it should communicate by a door: it should never be of large dimensions or imposing design. This is the only part of a church where a chimney is allowable.

Up to this point we have made scarcely any mention of cruciform churches, not because we do not think this a beautiful form, but rather because it is ill adapted to present circumstances. Such a plan is doubtless the most expressive of any for a Christian church, but it is not the most economical; it does not economize space. It is true the cross arms may be used for the accommodation of worshippers, but not without great inconvenience; persons placed there will not be, as it were, with the rest of the congregation, they must look a different way, and not only so, but must be hid from the altar and the greater portion of the performance of the services; in fact, transepts were not intended for this purpose, as is evident by there being seldom found any seats in this position, and even when such are seen, they are mostly subsequent additions. Besides all this, the cross form is more expensive in construction. When funds are ample, transepts may well be added, but not otherwise.

Of apertures.—These consists of doors and windows, and to both of them one remark will apply: do not make them too large; for with respect to the former, it may be said that they are seldom made an important feature in English architecture, not even in our cathedrals; and as regards the latter, small windows are advantageous on many accounts, not only are they more unassuming than larger ones, but they answer the present times—when stained glass throughout the building is scarcely to be looked for—by admitting less light, and if stained glass is to be inserted, they require but a small quantity. A great mistake, in our opinion, is very generally made in the present day, in allowing too great an area for lighting a church, either by making the windows too numerous, or too large; a glare of light is not desirable in a church, it interferes with people's devotion; we want a subdued tone, that "dim religious light" which was admitted of old through the stained windows, and this is to be procured rather by diminishing than increasing the area admitting light. With reference to the position of doors, there should be one small one for the priest in the south side of the chancel, another at the porch, and a third, generally speaking, opposite the last; in transeptal churches, there may be one at the west end, and another on the west side of one of the transepts.

We have previously hinted, that it is not at all necessary that the corresponding parts of the building should be in every respect uniform: the same remark holds equally true as to detail, as it does in respect of the main features of construction; the windows and other apertures need not be placed at exactly the same distances apart, nor is it necessary that the windows on both sides of the church should in every particular correspond; a buttress should not be placed between every two windows, or at every corner of the building, merely for the sake of appearance, nor indeed should they be employed at all, unless requisite. The governing principle in such matters, should be to use nothing more than is wanted, and place things just where they are required; if this rule were attended to, it would save a vast deal of unnecessary trouble, and produce in the end a far more satisfactory, because more natural, appearance. "How often do we see," says a writer for the Ecclesiological Society, "a simple village church, consisting of low and rough stone walls, surmounted, and almost overwhelmed, by an immense roof, and pierced with some two or three plain windows, between as many bold irregular buttresses on each side; or having a short massive tower placed at one angle, or in some seemingly accidental position, which nevertheless every one confesses to be as picturesque, and beautiful, and church-like an edifice as the most critical eye could wish to behold! while a modern design, with all its would-be elegancies of trim regular buttresses, parapet, and pinnacles would cost twice the money, and will not look like a church after all. Here perhaps one half of the money is laid out first in procuring, and then in smoothing and squaring great masses of stone, or in working some extravagant and incongruous ornament; whereas the small and rude hammer-dressed ashlar or rubble work of the ancient model, has a far better appearance, and allows a larger expenditure where it is most wanted, in the arrangements of the interior."

This leads us to remark, that the interior should be the main object of consideration, and should never be sacrificed to make way for a showy exterior, although this is too frequently the case with modern churches; it was far different with our ancestors. Of the interior, the chancel is that part on which the architect's best attention should be given. The interiors of our old churches, as we have previously stated, were enriched in the most splendid manner, all the finest productions of art were lavished upon them, the sculptor and painter vied with each other in their decoration—and why should it not be so now? Surely paintings in fresco would be preferable to yellow-ochre and whitewash, nor do we see any moral objection to pictorial representations in our churches, there can be no fear of people worshipping pictures now-a-days, the greater fear is for the want, not the excess, of reverence; they are the books of the unlearned, and serve not only to instruct the ignorant in matters which they would not otherwise know, but also bring before the attention of the more learned, things of which otherwise they might be forgetful. But if objections still be urged against the employment of the painter's highest branch of art, surely there can be no exception brought against such decoration as we have described as occurring at Luton Church. The employment of texts of Scripture delineated on the walls, is sanctioned by the order of the church, when she enjoins in her eighty-second canon—"That the ten commandments be set up on the east end of every church and chapel, where the people may best see and read the same: and other chosen sentences written upon the walls of the said churches and chapels, in places convenient." Passages of Scripture well selected and appropriately arranged, would form at the same time, a very useful and beautiful appendage to the walls of our churches; though, as we think, scarcely equal to the more pictorial illustration advocated above. We should be glad to see the interior of our places of worship relieved from the coldness which ever hangs about bare walls; let at least some coloured decorations be introduced into the chancel, if nowhere else.

Of the roof.—Open roofs, those in which all the beams and rafters are visible, should of course be adopted, the use of ceiling is now almost quite exploded; roofs of this kind not only afford an appearance of greater height to the building, but also have a perspective effect, by the repetition of the same parts, which adds to the apparent length of the church; indeed, the same building covered at one time with an open roof, and at another with a flat ceiling, would present two such very different aspects, as scarcely to be recognized as identical. Various forms may be used, of which, whether rich or simple, beautiful ancient examples are to be found; in small churches, where the span is inconsiderable, the arched form may be used with advantage; the amount of trussing increases of course with the span. Tie-beams are scarcely admissible, as they detract from the aspiring principle developed in church architecture, and arrest the eye in its progress upwards; they have in a small degree the same effect as a flat ceiling; there is, however, seldom occasion for their employment, they are not requisite in a high-pitched roof, especially where the walls of the building are of considerable thickness; the thrust is rather vertical than horizontal.

Of pews.—Let all the seats be low open benches with low backs, the lower the better, as far as convenience will allow; for as the height increases, so must the distance from each other; if this circumstance be not attended to, the high back will be found to be in the way: a convenient height is two feet six, preserving the same measurement between every two seats. The benches must be arranged across the church so as to face the east, and in such a manner as to allow of easy access to every part of the church; for this purpose, there should be a main passage running along the centre of the nave, five or six feet wide, and another of the same measurement across the church, connecting the north and south doors; smaller passages are necessary along the aisles, and at the east end of the nave. In small churches, the standards at the ends of the seats should be of a plain character, but in the larger ones they may be carved and finished at the top with poppy heads, &c.

Of galleries.—Galleries should on no account be admitted into a church; they entirely spoil its appearance, cutting up windows, and sometimes pillars, into two or more pieces, hiding the roof, marring the proportions, and obstructing a fair view of the interior: they are noisy, ill-ventilated, and clumsy, and not only are they ill-ventilated themselves, but they interfere with a proper circulation of air in the aisles beneath them, and by their principle of over-crowding a church, assist materially in vitiating the air throughout the building. And what is the advantage proposed to be effected by them?—the economizing of space, that is, the obtaining an increase of accommodation at a small expense: but do they effect this object? decidedly not; the additional space obtained by their adoption is very trifling, for from the total area of the gallery must be deducted, not only the main passage leading at the back of the seats throughout its length, but also the numerous cross passages branching from it to afford convenient access to the different parts of the gallery, so that, in fact, in the majority of cases, a full third, and in some instances nearly one half of the area obtained, is lost in passages of communication; add to this the space occupied in the aisles, by the piers or other supports, and it will be evident that the advantages in point of accommodation are very small. When, bearing all this in mind, we consider that the walling is frequently carried up to a greater height than otherwise necessary, for the sake of introducing a gallery, we shall scarcely be prepared to defend such *excrescences* on the score of economy.

Of the principal furniture.—The first object which needs a few remarks is the font; it should invariably be of stone, as ordered by the church, and of a size sufficient for the immersion of infants; there should be a drain leading from the bottom of the bowl down into the earth, to carry off the water used in the service, and the bowl, when not in use, should be protected by a cover. The situation of the font must be near the entrance in the nave, and should have sufficient space left round it for the priest, sponsors, and others immediately concerned in the rite. The pulpit, which may be of wood or stone, should be at the south-east or north-east end of the nave, either detached or built up with the wall or pier, and should not be elevated at too great a height: if there be a choice of situation, the north side of the nave is the preferable position. We need say nothing in this place respecting the furniture of the chancel, as it has already been described under that title; we may only add that we should be glad to see the whole of it introduced into our modern churches, even to the rood screen, which is so much objected to by some, on account of its being, as they say, a Romish invention, whereas in fact it has been employed in the Eastern as well as the Western church, from the very earliest period.

Of the lighting, warming, and ventilation of churches.—The best method of lighting a church is by candles, which may be held either in standards fixed or moveable, or in chandeliers made after the pattern of the ancient *coronæ lucis.* Gas is cheaper than wax-lights, we are aware, but a trifling additional expense should scarcely be a consideration in such a matter; besides, amongst other disadvantages, the glare of gas-lights is but ill adapted to the solemnity of a church, and the heat emitted from them is oppressive and somniferous. A fire-place is hardly admissible into a church, and stoves, hot air or water pipes, should never be attempted, they are unsafe, as well as unhealthy. The best method of regulating the temperature of a church, is by building substantial walls, and efficient drains, allowing a free circulation of air, and keeping the whole building in good and proper repair. If low benches, and high-pitched open roofs be adopted, while galleries and gas-lights are at the same time discarded, there will be little difficulty as to ventilation.

Of the restoration of churches.—Little need be said on this head, the main point to be attended to is, the reducing the building as nearly as possible to its original state, in structure, arrangement and decoration; it most frequently happens, that the minutiæ of the old structure are not traceable, and in such cases the judgment of the architect is called into action, but where the old arrangement is perceptible, it should always be followed in the restoration. The first thing to be attended to is the drainage, many old churches being destroyed by damp; in very many cases the earth of the church-yard will be found to have accumulated to a considerable height above the floor of the church, and this of course should be at once removed, and a proper ventilation given, to dry the foundations. The interior walls should be carefully cleansed of the many coats of whitewash, so that, in case any vestiges of painting remain, they may not be destroyed for want of proper caution; the same care should be taken in removing the plaster and whitewash from the ornamental details; flat ceilings likewise should be removed with caution, as they were frequently added merely to hide existing defects in the roof. Structural restoration should be first attended to, after that the arrangement, and lastly the decoration.

Of the enlargement of churches.—Architects are not unfrequently called upon to afford increase of accommodation in old churches; it may therefore not be out of place to point out as briefly as possible how this may be best effected. The first step is to calculate how much additional accommodation may be obtained by a proper re-arrangement of the seats, and a substitution of low benches in the place of the modern pews, and to regulate for further additions accordingly. Churches in which additions are advisable, are the following: those which consist only of nave and chancel, which may be enlarged by the addition of one or more aisles to the nave, and of a tower, if requisite;—those consisting of nave, chancel, and one aisle, where accommodation is naturally increased in completing the church by the addition of an aisle on the opposite side of the nave, an addition frequently contemplated by the founders, as is manifested by the existence of arches of construction in the nave-wall;—those again consisting of a nave and chancel, with tower between the two, may be enlarged by adding transepts, which, in cases of necessity, may be used for worshippers. Of churches comprising a nave with two aisles, a chancel and a tower, increased space may be obtained by a continuation of the aisles to the extremity, or nearly the extremity, of the chancel, or by adding another aisle to the nave. Either of these plans may be adopted in cases of great need, but they are by no means to be recommended; in both cases the same objection holds, that the people are packed into situations which are not convenient for public worship; in the first case they are made to look in a different direction from those in the body of the church, which interferes with the apparent unity of the worshippers, and, in the latter, a great portion of them are excluded from a proper view of the chancel. In such cases it would be much more advisable to erect a new church or chapel, however small or unimposing, but this necessitates other expenses, and is not always practicable; where it is possible, it should be adopted in preference. The Rev. J. L. Petit, in his Remarks on Church-Architecture, recommends additions to the chancel to be made in almost all cases where enlargement is required; but we must differ from him in this matter, for, be it remembered, that in our old churches, these projections were not used by the congregation, but were employed as side-chapels; in fact, their existence is attributable to the corruptions of the church of Rome: such additions may be used for the location of the organ, or such like purposes, but not, if avoidable, for the accommodation of worshippers. In other churches where none of the above methods are available, it is better not to attempt enlargement; the lengthening of the nave is a poor expedient, which may at once destroy the proportions and mar the unity of the original design.

We here take leave of a subject which we are rejoiced to say is daily receiving increased attention. Some few years since, our ecclesiastical structures were looked upon as remnants of by-gone days, to be wondered at for their associations and antiquities, but scarcely to be imitated in modern times; but of late a new light has appeared, infusing spirit and animation into the old buildings, and we no longer look at them as the relics of a barbarous age, but as examples most fitting to be followed in all sacred structures; they formed once the lore of the antiquarian, they are now the models of the architect. It is a matter of wonder how rapidly knowledge, on this subject, has been acquired; it is as yet imperfect, but is progressing satisfactorily; fresh discoveries are being made continually, and ere long we shall have a goodly number of useful text-books on the subject. We must not forget, that the first impulse in the right direction was afforded by the Cambridge Camden Society, to which the gratitude of every lover of our old parish-churches will be readily accorded. We have now Architectural Societies of a similar kind established all over the country, to which, in conjunction with the labours and researches of private architects, we look for a great increase of information. An additional incitement to this study has been given by the erection of so many churches in various parts of the country, in most of which a vast improvement may be observed on buildings of a similiar kind erected in previous years; it is true they are not all, perhaps but few, without faults, many of them are faulty in numerous respects, yet, as a whole, they are very satisfactory; we cannot do better in concluding this article, than repeat the remarks of Mr. Petit on the progress of church-architecture, and the impediments which the professional man has to encounter in its advancement. "So great," says he, "are the actual and inherent difficulties of his art, and so grievously are they multiplied by external causes, so limited and restricted is he by the perverseness of others, so many conflicting tastes and opinions has he to consult, so beset is he on every side by the ostentatious views of one, the parsimony of another, the private interests of a third, and the overweening ignorance of the greater number, that it is a marvel his work should ever be respectable; and we cannot deny that many of our modern churches are extremely creditable to the taste and skill of their designers. Let those who speak of the labours of the architect with flippancy, or censure them with unkindness or severity, reflect upon the difficulties he has to encounter; of no other art are the principles and beauties more deeply hidden in the treasury of nature, and to be searched out with greater toil and diligence."

CHURCH-HOUSE, a building in which meetings were held for the transaction of church matters and parish business; it was sometimes a room situate over the porch.

CHURCH-YARD, the space of ground surrounding the church, used as a cemetery or burial-ground. The entrance to our old church-yards was frequently through a gate covered with a projecting roof, called the lych-gate, under which the coffin was rested before entering the ground; and opposite the porch, was a lofty stone cross elevated on one or more steps, and frequently adorned with the emblems of the Evangelists, and other enrichments. Near the cross was planted a yew-tree, whose boughs were carried in procession on Palm Sunday, and used at other times to decorate the interior of the church.

The unwholesome practice of interment in towns is being discontinued, and consequently the church-yard in such cases is in a great measure dispensed with; where practicable, however, the church should be contained within a walled enclosure. The best model for an extra-mural cemetery, is that lately planned at Oxford: cemeteries are usually objectionable, on account of being made the subjects of speculation and pecuniary profit.

CIBORIUM, in ecclesiastical antiquity, the covering of an altar; being an insulated edifice, consisting of four columns supporting a dome. The ciborium was used during the lower and middle ages; but was afterwards superseded by the baldachin. *See* BALDACHIN.

The most magnificent ciborium ever known, was that erected by Justinian, in the church of St. Sophia, at Constantinople. It consisted of four large red marble columns, supporting a silver dome, surmounted with a globe of massy gold, weighing 118 pounds, and surrounded with lilies of gold, falling in festoons, weighing 116 pounds; and in the middle was a cross of the same metal, weighing 75 pounds, covered with the most rare and precious jewels.

CILERY, the drapery or foliage on the heads of columns.

CILL. *See* SILL.

CIMA. *See* SIMA, MOULDINGS.

CIMA-INVERSA. *See* SIMA-INVERSA, MOULDINGS.

CIMA-RECTA. *See* SIMA-RECTA, MOULDINGS.

CIMBIA, a fillet, string, list, or cincture.

CIMELIARCH, in English churches, the room where the plate, vestments, &c. are kept.

CINCTURE, or CEINCTURE, an annular fillet, of a cylindric surface, at the ends of a column, connected to the shaft by the apophyge, or scape. The cincture at the top of the column, is named also collarino.

CINQUEFOIL, an ornament in the pointed style of architecture, consisting of five cuspidated divisions, or curved pendants, inscribed in a pointed arch, or in a circular ring, applied to windows and panels. The cinquefoil inscribed in a circle, is a rosette of five equal leaves, with an open space in the middle; the leaves being formed by the open spaces, and not by the solids or cusps.

CIPPUS, a small low column, sometimes without a base or capital, and most frequently bearing an inscription. The cippus was used for various purposes among the ancients: when placed on a road, it indicated the distances of places: in other respects, the cippi were employed as memorials of remarkable events, as landmarks, and for bearing sepulchral epitaphs. Also the prison of a castle.

CIRCLE, (from the Latin, *circulus*), a plane figure contained under one line, called the circumference, which is such that all lines drawn to it, from a certain point within the figure, are equal; and the point from which the lines may be thus drawn, is called the *centre of the circle.*

A circumference may be thus described: if the end of a right line be placed upon a fixed point, and kept upon that point while the other end is carried progressively forward, or round, until it comes to the place whence the motion began, the moveable extremity will thus trace out the circumference of a circle.

In order to obtain the measurement of angles, the circumferences of all circles are supposed to be divided into 360 equal parts, called *degrees;* each degree is supposed to be divided into 60 equal parts, called *minutes;* each minute is divided into 60 equal parts, called *seconds;* each second is supposed to be divided into 60 equal parts, called *thirds;* which are again divided and subdivided *ad infinitum.* Any denomination, whether of degrees, minutes, or seconds, &c. is known by a peculiar character, written over the right-hand figure of that denomination; thus, °, written over the right-hand figure of a number, shows that number to represent degrees; the character thus, ′, written over the right-hand figure of a number, shows the number thus distinguished to represent minutes; *e. g.* $136° 24' 48'' 57'''$, &c. represents 136 degrees, 24 minutes, 48 seconds, 57 thirds, &c.; and, as similar arcs are such as are contained under the same, or equal angles, they contain the same number of degrees, &c., the number of parts of the arc of a circle, described from the meeting of two lines forming an angle, and comprehended between them, is the true measure of the angle; for the number of parts is still the same, whatever be the radius of the arc, or of the circle, the parts being greater as the radius is greater. The arc of the circle being supposed to be divided into 360 equal parts, the radius will be found to be equal to the chord of 60; because the circle contains six equilateral triangles, whose bases are chords to the circle, whose summits meet in the centre, and whose sides are radii to the circle. And since the sixth part of 360°, or of a whole circle, is 60°, the chord of 60 is therefore equal to the radius. The parts of the arc may be measured by parts of the radii, which are always supposed to contain the same number: for if there be two arcs described from the angular point of an angle, between the legs, these arcs may be measured in parts of their respective radii.

The circle is the most capacious of all plane figures; that is, it contains the greatest area under equal perimeters, or has the least perimeter enclosing the same area.

The area of a circle is equal to the area of a triangle, the base of which is equal to the circumference, and the perpendicular equal to the radius, and consequently equal to a rectangle, whose breadth is equal to the radius, and the length equal to the semi-circumference.

Circles, like other similar plane figures, are to one another as the squares of their diameters.

The ratio of the diameter of a circle to its circumference, has never been exactly ascertained. Archimedes was the first, in his book *De Dimensione Circuli*, who gave the ratio in small numbers, being that of 7 to 22, which is still the most useful for practical purposes. Vieta carried the approximation to ten places of figures, by means of circumscribed and inscribed polygons of 393,216 sides, showing the ratio to be as 10,000,000,000 to 31,415,926,536 nearly, the circumference being greater

than 31,415,926,535

but less than 31,415,926,537

Van Colen carried the approximate ratio to 36 places of figures; which number was recalculated and confirmed by Willebrod Snell. Mr. Abraham Sharp extended the ratio to 72 places of figures, which was afterwards extended to 100 places by the ingenious Mr. Machin; and, lastly, M. De Lagny, in the *Memoires de l'Acad.*, 1719, has carried this ratio to the amazing extent of 128 places of figures.

In approximating the circumference or area of a circle from the diameter, the first authors had recourse to inscribed and circumscribed polygons; since it was found that the circumference of the circle was greater than the perimeter of the inscribed polygon, but less than that of the circumscribing one; and, that when the polygon contained a great number of sides, the circumference of the circle did not differ materially from either, it would be still more nearly equal to the arithmetical mean of the two. And, to give the reader an idea how very near the circumference obtained by this means is to the truth, the circumscribed and inscribed polygons may be taken of such a number of sides, as that their perimeters will be each expressed by any given number of figures of the same value, from unity, either taken individually, or as a whole number, and consequently the circumference of the circle may be expressed, or carried to any degree of accuracy required.

But the method of obtaining the circumference by this means, being found extremely laborious, other methods, by a series of fractions, have been invented, so as not only to be much more easy in the calculation, but also to show how the terms may be continued at pleasure, by inspection only. Dr. Wallis was the first who expressed the area of a circle, in terms of the diameter, by an infinite series, and showed that, if the square of the diameter was 1, the area would be

$$\frac{3 \times 3 \times 5 \times 5 \times 7 \times 7}{2 \times 4 \times 4 \times 6 \times 6 \times 8}, \text{\&c. or } \frac{9}{8} \times \frac{25}{24} \times \frac{49}{48}, \text{\&c.}$$

Other series were also found by Lord Brounker, Sir Isaac Newton, and Dr. Gregory. The most convenient forms of expressing the circumference, are shown in the following statement, where c represents the circumference, the diameter being unity:

$$c = 4 \times \left(1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \frac{1}{9} - \frac{1}{11} + \frac{1}{13} \; \frac{1}{15}, \text{\&c.}\right)$$

$$c = \sqrt{12} \times \left(1 - \frac{1}{3.3^1} + \frac{1}{5.3^2} \; \frac{1}{7.3^3} + \frac{1}{9.3^4}, \text{\&c.}\right)$$

$$c = 8 \times \left(\frac{1}{1.1.3} + \frac{1}{1.3.5} \; \frac{1}{3.5.7} + \frac{1}{5.7.9} \; \frac{1}{7.9.11}, \text{\&c.}\right)$$

$$c = 8 \times \left(\frac{2}{3} - \frac{1}{5} - \frac{1}{4.7} - \frac{1.3}{4.6.9} \; \frac{1.3.5}{4.6.8.11}, \text{\&c.}\right)$$

$$c = 4\sqrt{2} \times \left(2 \times \frac{1}{3} - \frac{1}{2} \times \frac{1}{5} \; \frac{1}{4.2^2} \times \frac{1}{7} - \frac{1.3}{4.6.2^3} \times \frac{1}{9} - \frac{1.3.5}{4.6.8.2^4} \times \frac{1}{11}, \text{\&c.}\right)$$

$$c = 4 \times \left(1 - \frac{1}{2} \times \frac{1}{3} - \frac{1}{2.4} \times \frac{1}{5} - \frac{1.3}{2.4.6} \times \frac{1}{7} - \frac{1.3.5}{2.4.6.8} \times \frac{1}{9} \text{\&c.}\right)$$

One of the most useful properties of a circle is that when two straight lines, or chords, cut each other, the rectangle of the segments of the one line is equal to the rectangle of the segments of the other line. This property may be very conveniently applied to finding the centre of the segment of a circle, or the length of the radius, the chord and the versed sine of the arc being given. The rule is as follows: Divide the square of the half chord by the versed sine, add the versed sine to the quotient, and half the sum is the radius of the circle.

The diameter of a circle being given, to find the circumference: say, As 7 is to 22, so is the diameter to the circumference nearly. This rule will be sufficiently accurate for the most practical purposes; but if greater accuracy be required, multiply the given diameter by 3.1416, and the product will be the circumference, or very near. When the circumference is given to find the diameter, divide the circumference by 3.1416, and the quotient will be the diameter. Or, say, As 22 is to 7, so is the circumference to the diameter.

To find the length of an arc, the radius and number of degrees being given, say, As 180, the number of degrees in a semi-circle, is to the number of degrees in the arc, so is 3.1416 times the radius to the length of the arc. When the chord of the arc, and the chord of half the arc are given;—Subtract the chord of the arc from eight times the chord of half the arc, and divide the remainder by 3, which will give the length nearly. When the chord and versed-sine are known;—Firstly, find the diameter, from which subtract the versed-sine multiplied by .82, and divide the remainder by $\frac{2}{3}$ of the versed-sine; add 1 to this quotient, and multiply by the chord, which will give the length of the arc.

The area of a circle, whose diameter is unity, has been found to be .7854 nearly; and since the area of a circle is as the square of its diameter, the areas of all circles will therefore be ascertained by the following rule: Multiply the square of the diameter by .7854, and the product will be the area of the circle.

But it may sometimes appear, that the circumference only can be ascertained, the diameter being inaccessible: in this case, also, the areas of circles are as the squares of their circumferences. It has been found, that when the circumference of a circle is unity, the area of the circle is .07958. Therefore the rule may be thus: Multiply the square of the circumference by .07958, and the product will be the area of the circle nearly.

Though either the diameter or the circumference is sufficient to find the area of the circle, yet, if the dimension of each can be easily ascertained, the operation of finding the area is much shorter. This may be done by multiplying the radius into the semi-circumference; the product will be the area.

By this rule, the standard area, when the diameter or the circumference is unity, as in the two preceding rules, will be easily ascertained, by halving the ratio of the diameter 1 to the circumference 3.1416: for,

2)3.1416

1.5708 half the circumference.
.5 half the diameter, or the radius.

.78540 the area of the circle by the last rule, when the diameter is unity.

Again, when the circumference is unity, the diameter will be found to be .31830 nearly.

Then, .31830 ÷ 2 = .15915 the semi-circumference,
and 1. ÷ 2 = .5 the radius.

Therefore .15915 × .5 = .079575 or .07958 nearly.

To find the area of a sector, when the number of degrees in the arc are known; say, As 360, the number of degrees in the whole circle, is to the number of degrees in the arc of the sector, so is the area of the circle to the area of the sector. When the radius, and the whole or half the length of the arc are given; multiply the diameter by the arc of the sector, and divide the product by 4; or multiply the radius by half the length of the arc; in either case, the result will be the area of the sector.

To find the area of a segment. Having found the area of the sector, subtract from it the area of the triangle, when the segment is less than a semi-circle, and add, when greater, or; Divide the cube of the versed-sine by twice the chord, and add the quotient to two-thirds of the product of the chord and versed-sine.

As we must necessarily frequently recur to the subject of this article hereafter, we think it convenient to refer the reader for further information thereon to GEOMETRY, PERSPECTIVE, &c.

CIRCULAR ROOFS, are those roofs whose horizontal sections are circular.

CIRCULAR WINDING STAIRS, are such as have a cylindrical case, or walled enclosure, with the planes of the risers of the steps tending to the axis of the cylinder.

CIRCULAR WORK, a term applied to all work with cylindrical surfaces.

CIRCULAR-CIRCULAR, or CYLINDRO-CYLINDRIC WORKS, whatever work is formed by the intersection of two cylinders, whose axes are not in the same direction. The line formed by the intersection of the surfaces, is called by mathematicians, *a line of double curvature.*

CIRCUMFERENCE, the curve-line by which the area of a circle is bounded.

CIRCUMFERENTOR, (Latin, *circumferre*), an instrument used by surveyors in taking angles; it consists of a brass circle and index, in one piece, commonly about seven inches in diameter, an index about fourteen inches long, and an inch and a half broad. On the circle is a card, or compass, divided into 360 degrees; the meridian line of which answers to the middle of the breadth of the index. There is also soldered on the circumference a brass ring, on which screws another ring with a flat glass in it, so as to form a kind of box for the needle, suspended on a pivot in the centre of the circle. There are also two sights to screw on, and slide up and down the index, as also a ball and socket screwed on the under side of the circle, to receive the head of the tripod or stand.

CIRCUMSCRIBE, to draw a figure round another; the one being rectilinear, and the other either rectilinear or circular, with the sides of one touching all the angles of the other.

CIRCUMVALLATION, a round enclosure of trenches, or fortifications.

This word, from the Latin *vallo*, or *vallum*, denotes properly the *wall*, or rampart thrown up, but as the rampart is formed by entrenching, and the trench makes a part of the fortification, the word is applied to both.

CIRCUMVOLUTION, (from the Latin, *circumvolutus*) the act of rolling round. In architecture, this term is applied to the spirals of the Ionic capital; every term of which is called *a circumvolution*. In the most ancient examples of the Ionic order, the volute has three circumvolutions, or *revolutions*, as they are otherwise called; but that of the temple of Minerva Polias, at Priene, has four. *See* VOLUTE, SPIRAL, and IONIC ORDER.

CIRCUS, in antiquity, a large enclosed space, adapted for chariot-races, an amusement to which the Romans were passionately attached. The name Circus does not convey an exact idea of the form of this building, which both in its outline and its use resembled the Greek stadium.

There were many circi in Rome, of which the Circus Maximus, and the Circus Agonalis, were perhaps the largest. The former may still be distinctly traced; the latter retains its external form only in the Piazza Navona of Rome. This species of edifice appears to have been very early introduced among the Romans, and, like many of the first public edifices, was of a temporary character, and constructed of wood.

The first permanent circus, at Rome, was said to have been built by Tarquinius Priscus, and was situated in a valley between the Palatine and Aventine hills. On this side was afterwards erected the Circus Maximus, which was enlarged by Julius Cæsar, and rebuilt and richly ornamented by Augustus. In the time of Nero it was burnt down; Trajan repaired it, and increased its dimensions so much, as to contain the whole Roman people. The exterior of the circus, except at the *carceræ*, consisted of two stories, adorned with columns, and finished with a terrace. The ground-floor was occupied by merchants, except on the days appointed for the games. Augustus brought an obelisk from Egypt 126 feet high, and placed it in this circus. Constantine also erected in it the obelisk now called the Lateran, which is the largest of all the Roman obelisks.

The Flaminian circus was of considerable magnitude. Its only remains are ruins beneath the present pavement of the city. There are several other circi, the ruins of which may be traced; but that which demands our attention most, is the circus of Caracalla, as very considerable traces of its ancient form are yet to be seen.

Several of the circi in Rome, were exteriorly surrounded with magnificent porticos, except on the side where the carceræ were placed. Others were simply enclosed with a wall, pierced with doors and windows, as in the circus of Caracalla. The lower part of the circumference of the circus, beneath the seats, together with the porticos, formed long galleries of arcades, or *fornices;* serving in part for an access to the staircases leading to the seats, and in part for the shops of various traders. The staircases of different circi were variously distributed, according to the judgment of the architect. The principal staircases led to a number of little doors in the podium, which was a long open platform, or passage, encompassing the edifice at an elevation of some feet from the area of the circus. The persons of the imperial family, the principal magistrates, and the pontiffs, only were admitted into the podium. Behind the podium there was a little wall with a precinctum, in which small doors were distributed. The seats rose one above another, their whole height, in the manner of steps, and were supported on the inclined vault of the gallery or portico beneath them, and ascended from the podium to the top of the external wall.

The great circi, as well as the theatres and amphitheatres, were divided into several ranges of seats, for the purpose of placing the spectators according to their condition. The seats began from the wall at the back of the podium, and after setting off a sufficient number for persons of the first rank, the staircase of seats was interrupted by the omission of two or three, which formed an ambulatory, or via, similar to the podium, at every certain number of seats. Separate staircases led to each via, through doors in the precinctum; these apertures were called *vomitoria*. As the spectators entered by these passages at the top of the ranges of seats, they would have to descend to occupy the first rows of each mœniana, and since the seats themselves were too high to serve as steps, staircases, called *scalares*, formed by cutting down a seat into two steps, were provided. The scalares were placed opposite the vomitoria, beginning from the via, and descending to the lower seat of each range; by this means the ranges were divided into a number of compartments, called *cunei*, as in the theatres and amphitheatres; in the latter they obtained this name from their radial direction, and though the sides of the circus were straight, and the compartments consequently of a rectangular form, they were called cunei, from usage.

Over the seats was a portico, or covered gallery, for the accommodation of the lower class of people. The place for the emperor was called *pulvinar*, the situation of which is not known: it is supposed to have been a magnificent logia. To render the seats more comfortable, they were covered with wood.

The extremity of the circus, opposite to the semicircular end, was called *the oppidum*, and consisted of a series of thirteen arcades. The centre arch, of the same height, but wider than the rest, served as an entrance to the circus. At each extremity of the oppidum, was a tower, which surmounted every other part of the edifice. This combination of arches and towers, seen at a distance, gave the idea of a castle, whence was derived the name of oppidum. To what purpose these towers were appropriated, is not known. The twelve remaining arcades were the carceræ, whence the chariot-race began. These carceræ were placed six on each side of the entrance, which was intended for the use of the processions, and are so disposed, by the inclination of the chord-line of the segment on which they may be said to be set off, that the starting of the twelve chariots was equalized. The divisions of the arcades within, on the front, were ornamented with Hermes supporting a cornice, in the manner of Caryatides: the carceræ were closed with grated doors, to the height of the springing of the arch, and the semicircular opening above was filled with a marble lattice. Two of these lattices, very elegantly ornamented, are at present to be found in the court of the palace Mattei, which is founded upon a part of the Flaminian Circus. The top of the carceræ formed a terrace, upon which was placed the tribune of the consul.

The spina, as being dedicated to the gods, was the most sacred place in the circus. It consisted of a platform, nearly two-thirds of the length of the circus, and, running down the middle of the arena, divided itself nearly into two equal parts, resembling the spine of a fish, whence it took its name. At the extremities of the spina were placed the metæ, or goals, which consisted of three cones placed in a triangle. On the summits of these cones was placed a large egg, in memorial of the eggs of Castor and Pollux. The metæ rested upon the vault of a semicircular temple or chapel, a little wider than the spina. The circular part of these little chapels was at the first goal, turned towards the triumphal gate, and their entrances were in passages between them and the spina. The long extent of the spina was ornamented with columns, statues, and altars. It is remarkable that the spina was not situated in the middle of the arena, nor parallel to the sides of the circus, but in an inclined direction, so that the course was wider on the right side of the circus, where it began, than on the left, and diminished gradually all the way. The reason seems to be this, that the chariots, starting all together, required more room in the first course, than when they came in separately.

In several of the circi, the arena was surrounded at the foot of the podium with a canal, called *euripus*, which was 10 feet wide, and probably of the same depth, for the defence of the spectators, in cases where the podium was not sufficiently elevated: it does not appear, however, to have been absolutely necessary, since Nero had that of the Circus Maximus covered over, in order to enlarge its area; neither is there any euripus in the circus of Caracalla.

The following description of the games exhibited in the circus may be interesting. These games, according to tradition, were instituted by Romulus, under the name of Consulia, in honour of the god Consus (Neptune). They were exhibited on various occasions, and for various purposes, sometimes by the magistrates, sometimes by private citizens. The games were opened by a grand procession from the capital to the circus, in which the images of the gods were borne in carriages, followed by dancers, musicians, combatants and others; and, last of all, by the priests, to perform the sacred rites. The exhibition consisted chiefly of chariot and horse races; the charioteers were divided into four classes, distinguished by the colours of their dresses. The order in which the chariots stood was determined by lot; and the signal for starting was given by dropping a cloth. The chariot which first ran seven times round the course, was victorious, and the driver, after being proclaimed by the herald, was crowned by a palm-wreath, and received a sum of money. Besides these races, were contests in running, leaping, boxing, wrestling, and throwing the discus. Wrestlers were anointed with ointment by slaves; boxers used gloves strengthened with lead or iron, to give force to their blows; the combatants were almost entirely naked, and all underwent a preparatory training and dieting—sometimes sea-fights (*naumachia*) were represented, and Julius Cæsar revived the exhibition of mock-fights by young noblemen on horseback.

The most attractive of these public entertainments, however, were the combats of wild beasts, either with one another, or with men. Great expense was incurred to provide the beasts for this exhibition, and they were collected for the purpose from the most remote parts of the empire. The men engaged in such contests, were either forced to the combat as a punishment, or induced to enter it by sums of money. The beasts were kept in inclosures (*vivaria*) till the time appointed for the show. So passionately fond were the people of these games, that the expression *Panem et Circenses*, 'Bread and the Circensian Games,' was commonly used to signify the two prime necessaries of life to the Roman populace. The splendour of these exhibitions increased in the latter days of the republic, and the number of rare wild animals that were exhibited but to be destroyed, is almost incredible. It is said, that on one occasion, Pompey exhibited five hundred lions, which were all despatched in five days.

CISOID, or Cissoid, in geometry, a curve line of the second order, invented by Diocles, an ancient Greek geometrician, for the purpose of finding two mean proportionals between two given lines, of such property, as that if on the extremity, B, of the diameter, A B, of the circle, A O B, the indefinite perpendicular, C B D, be erected, and if from this, several lines be drawn to the other extremity, A, to cut the circle in I, O, N, and if upon these lines be set the corresponding equal distances, viz. H M = A I, F O = A O, C L = A N, &c., then the curve line drawn through all the points, M, O, L, is the cisoid. Other methods of constructing this curve may be seen in Newton's *Universal Arithmetic*, and Emerson *on Curve Lines*.

CISTERN, an artificial reservoir or receptacle for holding water, beer, or other liquor, as in domestic uses, breweries, and distilleries.

Cisterns of earth must be lined with good cement, to make them retain the water, and the bottoms should be covered with sand to keep it sweet.

Water for the use of a house, may be preserved in the cellar, where a cistern or cisterns may be constructed in the following manner: first lay a good bed of sound well-tempered clay, for a bottom, on which place a flooring of bricks, or impervious stones, cemented with plaster-of-paris, or terras-mortar. The sides should then be built up, leaving a space between them and the walls of the house, which is afterwards to be filled up with clay, well rammed down; this will keep the water from oozing, and effectually preserve the foundation of the house. As a substitute for plaster-of-paris, or terras-mortar, a composition of slacked lime sifted, linseed oil and tow or cotton, will be found very serviceable. A cistern of this kind, viz. of clay lined with bricks, will answer in any shady place, as well as in a cellar, provided it be kept covered. And though the cistern be not always full of water, the clay will not lose its requisite degree of moisture.

When a cistern is to be made above ground, it may be constructed of planks, plain or straight jointed, put together with white lead, and pinned to bearers and uprights. If the cistern be large, suppose 10 feet in altitude, and 20 feet square, the planks may be $2\frac{1}{2}$-inch yellow deals, the joists and uprights may be 4 inches thick, and 6 inches deep, placed about 2 feet 6 inches distant from each other. There should be two pins at each intersection of a board and upright, or bearer; every pin may be three-fourths of an inch thick, and wedged again with a small pin at the narrow end, to prevent the possibility of its drawing: the pins should all have a draught, to bring the joists as close as possible. This cistern, placed upon a firm well-tempered bed of clay, should be surrounded with a stone or brick wall, at 8 or 12 inches distance, and the cavity filled in with clay, as above described. This will retain the water, and answer extremely well for the supply of a city or village.

If the cistern be to be raised on high, where walls cannot be constructed around, it may be made of timber, in the foregoing manner, and lined with lead: but as this lining tends to contaminate the water, the casing of the exterior with stone or brick, with puddle between it and the wooden cistern, should be adopted when practicable.

A cistern may be constructed for watering cattle, by excavating the ground where there is a descent, and covering the bottom and sides with two coats of tough clay, each coat about six inches thick, well rammed; the bottom being covered with flag-stones, the clay will remain moist, and free from cracks, though not covered with water. But this is troublesome; for, should the clay happen to crack in any part, it would be necessary to go over the work again.

In a chalky soil, a cistern may be formed by digging a hole, and covering the bottom smoothly with chalk rubbish, which, when wetted by the rain, should be rammed well. Afterwards cattle may be turned in to tread it till quite firm, and then it will be impervious to the water.

CITADEL (from the French, *citadelle*, a diminutive of the Italian, *citta*) a small city.

Citadel, is also a small fortification, consisting of four, five, or six sides, with bastions, by which it is distinguished from a castle, and usually joined to towns, and sometimes erected on commanding eminences within them.

Citadels may be either square, rectangular, pentagonal, hexagonal, or, indeed, of any figure; but the pentagonal is most commonly adopted. The hexagonal is generally considered as too large, and requiring too great an expenditure for the advantages to be derived from it; and the quadrangular is incapable of making a sufficient defence. Citadels are also sometimes made in the form of a star fort.

The exterior sides of the citadel, when its plan is regular, are generally, each about 150 toises, or fathoms; but this extension may be varied according to circumstances.

When the citadel is erected on a hill, or eminence, within the fortifications of the place, it is well calculated to keep the inhabitants in awe, if the garrison be sufficiently provided; but it is of little use against an enemy, when once in possession of the town itself.

The citadel will require a stronger fortification than the town, to prevent its being attacked first by the enemy, who, getting possession of it, will soon become masters of the town. A citadel has, for the most part, two gates, the one for communicating with the town, and the other with the country; the gate communicating with the town, is used in case of an insurrection or sedition, or after the town has capitulated, for the garrison to retire into the citadel; the other gate, which communicates with the country, is for receiving assistance and succours when placed under extremities. The citadel generally takes up two sides of the fortification of the parts which adjoin to it, and should be so constructed that the ditch of the place may be defended as directly as possible, either by the faces of its bastions, or by ravelins, that the enemy may have no greater advantage in attacking in one place than they would have in another. It may be farther observed, that in an extensive fortified city, a citadel may be formed by uniting two adjoining bastions, by a good retrenchment, with flanking defences: the expense of making such is very trifling, compared with that of adding another fortification to the place.

CIVIC CROWN, in Roman antiquity, a garland of oak-leaves and acorns, or ground oak, given as a reward to such as had saved a citizen's life in battle.

CIVIL ARCHITECTURE, that which embraces the erection of edifices destined for civil purposes; the term is used in contradistinction to military and naval architecture.

CLAIR-OBSCURE, or Chiaro-Oscuro (from the Italian *chiaro*, light, and *oscuro*, dark) the proper distribution of light and shade in a picture, both with respect to the eye, and the effect of the whole composition. The term is also used for a design wherein only two colours are used, most usually black and white.

CLAMP, a small piece of wood, fixed to the ends of a board, to prevent it from warping, the fibres of the clamp being transverse to those of the board. The manner of clamping a board, is either by grooving the edges of the clamp, and tonguing the ends of the board into it with brads and glue, or by grooving the end of the board, and tonguing the edge of the clamp. Sometimes the end of the clamp is mitred to the side of the board, for the sake of neater workmanship. In the best clamping, the clamp is fixed to the board with a mortise and tenon.

The flaps of shutters, small doors, lids, and kitchen-tables, which consist only of boards glued together, are most frequently clamped.

Clamp, in brick-making, a pile of bricks built upon a rectangular base, for the purpose of burning them.

Clamps are built of unbaked bricks, after the manner of a kiln, with a vacuity between the breadths of the bricks, for the fire to play through; but, instead of arching, as in kilns, the flues are gathered in, by making the layers project one over another. The place for the fuel is carried up straight on both sides, till about three feet high; it is then nearly filled with wood, which is covered with a stratum of small sea-coal, or breeze, after which the flue is overspanned. The sea-coal is also strewed between every row of bricks, and the top of the clamp covered with a thick layer of it. The wood is then kindled, and the fire is thence communicated to the coals. When the fuel is exhausted, the brick-makers conclude that the bricks are sufficiently burned.

The operation of burning bricks is attended with considerable difficulty, and requires workmen of experience, to maintain an equal degree of heat throughout the mass. If the heat be too low, the bricks will be weak and crumbly, and if too strong, they will vitrify and run together. The operation is much better performed in kilns, than in clamps; as in the former, the fire can be kept up, and regulated at discretion; while in clamps, as the whole of the fuel must be put in at once, the manufacturer is tempted to use too little, and the outside bricks are consequently under-burnt. These are called *samel-bricks*, which are sold at an inferior price. *See* Brick.

Clamp Nails. *See* Nails.

CLAMPING, in joinery, the act of securing a board with clamps. *See* Clamp.

CLASP NAILS. *See* Nails.

CLASSICAL ARCHITECTURE, such as was practised by the Greeks and Romans.

CLATHRI, in Roman antiquity, bars of iron, or wood, used for securing doors and windows.

CLAY, in common language, any earth which possesses sufficient ductility to admit of being kneaded with water.

Common clays may be divided, with regard to their utility, into three classes, viz., unctuous, meagre, and calcareous.

The unctuous contains, in general, more alumine than the meagre, and the silicious ingredient is in finer grains. When burnt, it adheres strongly to the tongue, but its texture is not visibly porous. When charged with little or no oxide of iron, it burns to a very good white colour, and is very infusible; it is therefore employed in the manufacture of Staffordshire ware. When it contains oxide of iron, or pyrites, sufficient to colour it when baked, it becomes more fusible, and can only be employed in the coarser kinds of pottery.

Meagre clay does not take a polish with the nail, when dry, by rubbing it; feels gritty between the teeth; contains sand in visible grains; and, when burnt without additions, has a coarse granular texture. It is employed in the manufacture of bricks and tiles.

Calcareous clay effervesces with acids, is unctuous to the touch, and always contains iron enough to give it a red colour when baked. Being much more fusible than any of the preceding, it is only employed in brick-making; and, by a judicious burning, may be made to assume a semi-vitreous texture. Bricks thus made are very durable.

CLAYING, the operation of spreading two or three coats of clay, in order to keep water within a vessel, or to prevent its transmission to some place or apartment where it would be injurious. This operation is also called *puddling*. Claying is necessary in the construction of canals, cisterns, vaults, &c.

CLEAM, a word used in some countries, to signify *to stick*, or *glue*.

CLEAR, in building, the distance between any two bodies when no other intervenes; or between the nearest surfaces of two bodies; as, binding joists may be placed five feet *clear* of each other, or apart.

CLEAR-STORY, the upper story of a church rising clear above the adjoining parts of the edifice, and containing a range of windows, thereby affording an increase of light to the body of the building; some indeed derive the term from the French, *clair*, light, from that circumstance; while others consider the term to have been applied from this story of the building being clear of joists, rafters, or flooring: the derivation, however, implied at the commencement of this article, seems to be the most reasonable. In some cases, this story is made of great importance, pierced with windows of greater size than those below, in the body of the edifice, as at Exeter and other cathedrals, Henry VII.'s chapel, Westminster, and some of the larger churches; in others the windows are of very small dimensions, consisting merely of trefoils, quatrefoils, or small arched foliated apertures. Very small churches seldom have clear-stories, the roof being carried over the body and aisles in a single span. There is no clear-story to the choir of Bristol cathedral.

CLEAVING, the act of severing one part of a piece of wood from another, in the direction of the fibres, either by pressure, or by the percussion of a wedge-formed instrument.

CLEETA, an ancient Greek architect and sculptor, who built the palæstra, or large court, near Olympus, in which the horse and chariot races were performed at the celebrated Olympic games. It was magnificently decorated with porticos and other ornaments; and the author was so vain of his performance, that he introduced the following inscription under one of his statues:—"Cleeta, the son of Aristocles, who invented the palæstra of Olympus, did this." *See* PALÆSTRA.

CLEOPATRA'S NEEDLES, in Egyptian antiquity, two obelisks towards the eastern part of the palace of Alexandria, constructed of Thebaic stone, and covered with hieroglyphics; one has been thrown down, broken, and lies buried in the sand: the other stands on a pedestal. The dimensions of the two are pretty nearly the same; the whole height of the erect one, including the pedestal and three steps, is about seventy-nine feet. When the French examined the base of this obelisk, the accumulation of earth around it was about sixteen feet deep. These two obelisks formed the entrance to the temple or palace of Cæsar, as it is called, though probably they were moved from some of the ancient cities of Egypt by the Ptolemys.

CLINCHING, when a nail is driven to the head through a piece of wood or board, of less thickness than the length of the nail, the driving of the point of the nail backwards, flat into the wood, while a hammer is pressed against its head, is called *clinching*.

CLINKERS, bricks impregnated with a considerable quantity of nitre or saltpetre, and placed next to the fire in the clamp, or kiln, that they may be more thoroughly burnt.

CLOACÆ, large arched drains, formed under the streets of some ancient Roman cities. The most remarkable were the cloacæ of Rome, large portions of which still remain in excellent repair. These cloacæ extended under the whole city, and were divided into numerous branches: the arches, which supported the streets and buildings, were so high and broad, that a waggon loaded with hay might pass under, or vessels might sail in them. At proper distances, in the streets, there were openings, for the admission of dirty water, &c. These branches ran in the low parts between the hills, and fell into one large arched drain, constructed of solid blocks of stone, called the Cloaca Maxima, said to have been built by Tarquinius Superbus, and repaired in later times by Cato the Censor, and his colleague in office. The Cloaca Maxima is fifteen feet wide, and thirty high, with three arches in contact one within another; in some parts there were raised paths along the sides of the cloaca; and in the walls were stone brackets to support the ends of the waste pipes of the fountains. In the year 1742, a part of the Cloaca Maxima was discovered in the Forum, at the depth of thirty feet from the surface. *See* SEWER.

CLOAK-PINS AND RAIL, a piece of wood attached to a wall, furnished with projecting pegs, on which to hang hats, great-coats, &c.; the pegs are called *cloak-pins*, and the board into which they are fixed, and which is fastened to the wall, is called the *rail*.

CLOCHARIUM, CLOCHIER (French, *clocher*,) a building, more usually a tower, in which the clock and bells were contained.

CLOGHEAD, a name applied to the curious round towers of Ireland. *See* TOWER.

CLOISTER, (Latin, *clausum*, enclosed, shut in;) a covered range of building attached to a monastic or collegiate establishment, forming a passage of communication between the various buildings, more especially between the church and chapter-house. Cloisters were employed as places of meditation and recreation by the inmates of the etablishment; and sometimes of retirement and study, for which purpose we occasionally find them arranged with cells on one side, as at Gloucester Cathedral, and also at Durham, where such cells were termed carrols: they appear to have been used likewise as places of sepulture. Cloisters are invariably found contiguous to the church, ranged round three or four sides of a quadrangular area, having on the outer side a series of windows with piers and columns looking into the quadrangle, and in the inner side, which was in other respects plain, a number of doorways communicating with the surrounding buildings, the chapter-house, refectory, schools, and such like. The windows in our English cloisters are glazed, and the whole length of the ambulatories arched over with a vaulted ceiling; in some cases, a stone seat or bench is carried round the wall opposite the windows. Attached to the cloister is usually a lavatory or conduit, at which the monks washed previous to entering the refectory; the remains of one such are to be seen in the centre of the quadrangle at Durham, as also at Wells; lavatories also exist in the cloisters of Norwich, Gloucester, and Worcester. *See* LAVATORY.

In England cloisters seem to have been appended to all cathedrals, and to the majority of collegiate and monastic establishments, in short, to all the larger religious houses. Frequent examples are also to be found on the continent, in Italy, France, and Germany, and in some cases of great magnitude; they are in the main similar to those in England, though of different styles, and therefore varying in detail; one difference consists in the windows being unglazed, on account, no doubt, of the difference of climate; in some instances are found specimens of painting in fresco on the walls.

Of the continental cloisters, Mr. Hope says, "Those of the Latin church are all of them in the Lombard style; some, such as those of San Lorenzo and Santa Sabina at Rome, and of San Stephano at Bologna, are small and rude, and more like the courts of a mean habitation; others, as those of San Giovanni Laterano at Rome, and those of San Zeno at Verona, are spacious, and formed of columns of the most fantastical shapes; some coupled, twisted, and with spiral flutes; and glittering—those at Rome with white marble inlaid with porphyry, with serpentine and with gilt enamel; and those at Verona with the gold-coloured marble of the Euganean mountains. The cloisters of the cathedral church of Zurich, and of the monastery of Subiaco, in the papal states, are amongst the most elegant of continental examples. The latter was erected in 1235, and that of San Zeno, at Verona, in 1123."

The following account of the Campo-Santo at Pisa, one of the most famous cloisters in Europe, is given by Britton:—"Its form is an oblong square, or irregular parallelogram, measuring 430 and 415 feet in its longest extent, by 136 and 139 feet at its ends. The width of each walk is about 32 feet. It was commenced in 1278 by Giovanni de Pisa, and a chapel, adjoining its east end, was completed in 1464. Between the covered walk and the enclosed area, is a series of sixty-two windows, having semi-circular arches, and adorned with varied tracery, supported by tall light columns which divide each space into four lights. Some of these were formerly glazed, but the others were left open. The floor is paved with white marble having bands of blue, and the inner roof is formed of timber. On the walls are numerous old paintings of great interest, being some of the first productions on the revival of that art at the beginning of the fourteenth century. There is also a fine collection of marble sarcophagi, fragments of sculpture, &c."

Amongst many other of the more noted cloisters of the continent, may be mentioned that belonging to the monastery of Batalha in Portugal. It is extensive and highly enriched, the length of each ambulatory being 182 feet, and the width $17\frac{1}{2}$ feet; in the centre of the enclosed quadrangle is a cistern, and in one of its angles a large fountain.

Attached to the collegiate chapel of St. Stephen, Westminster, are the remains of one of the most highly enriched and beautiful cloisters in England, which was erected by Dean Chambers in the time of King Henry the Eighth. It is the only example remaining of a cloister of two stories; it has two oratories, or chantry-chapels, projecting into the quadrangle, and approached respectively from the upper and lower western avenues. The roof is vaulted, covered with fan-tracery, and adorned with finely-sculptured bosses and shields. The dimensions are added to the following table.

The areas at the entrance of some continental churches partake of the nature of cloisters, but are more particularly styled atria. *See* Ecclesiastical Architecture.

The annexed is a table giving the dimensions and some other information relative to the cloisters attached to our English cathedrals. The particulars are collected from Britton's works, and other similar sources.

List of Cloisters of the English Cathedrals.

	Length.	Width of avenue.	Height to vaulting.
	Feet.	Feet.	Feet.
[a] Canterbury	132		
Chester	110 108		
Chichester	198 S. 121 E.		
[b] Durham	145	15	
[c] Gloucester	147	from 12 to 14	17
[d] Hereford	143 115		
[e] Lincoln	118 N. and S. 90 E. and W.	13	
[f] Norwich	from 175 to 177	$14\frac{3}{4}$	15
[g] Salisbury	$181\frac{3}{4}$	18	$20\frac{3}{4}$
[h] Wells	162 E. and W. 158 S.	13	
[i] Worcester	125 E. 120 W. N. & S.	16	17
[k] Old St. Paul, London	91	10	
S. Stephen's Chapel, Westminster	89 E. and W. 75 N. and S.	$12\frac{1}{2}$	14 lower. 13 upper

Remarks.

[a] On north side of cathedral.

[b] Date about 1400; had octagonal lavatory in centre of area. On south side of cathedral.

[c] Completed 1390; has recesses or carols in the south walk, and in the north a spacious lavatory; the roof covered with elaborate fan-tracery.

[d] In ruins.

[e] Has timber vaulting with ribs and bosses; on north side of cathedral; date about 1300.

[f] Commenced in 1299, completed in 1430; has two lavatories at the south-west angle.

[g] Date about 1250; situate on south side of cathedral.

[h] Erected between 1407 and 1465; on the south side of cathedral. It has only three avenues, the fourth side being the wall of the nave; the eastern and western sides are of two stories; there is a lavatory in the area.

[i] Date 1380.

[k] Consisted of two stories; the chapter-house was enclosed within the avenues. Destroyed.

CLOISTER-GARTH, the quadrangular area enclosed within the four avenues of a cloister; it was laid out as a grass-plot, and had frequently in its centre a stone conduit, or reservoir of water.—The cloister-garth was used as a place of sepulture.

CLOSE STRING, in dog-leg stairs, a staircase without an open newel.

CLOSER, in masonry, the last stone laid in the horizontal length of a wall, of less dimensions than any of the others in the same row. Closers should never be admitted in good work, nor indeed in any other, for they deprive it of uniformity, and destroy the bond also: nor would they ever be found necessary, were due attention paid to the dividing of the stones in proper lengths. In brickwork the term is applied to a bat used in the same manner. When the bat is a quarter-brick, it is called *queen-closer*. When a three-quarter, inserted at the angle of a stretching-course, it is called a *king-closer*.

CLOSET, a small apartment, frequently made to communicate with a bed-chamber, and used as a dressing-room. Sometimes a closet is made for the reception of stores, and then it is called a *store-closet*. However unfashionable closets may be in the rooms of large houses, they are essential in those of small ones.

Closet. *See* Water-Closet.

CLOUGH, or Cloyse, a kind of sluice for letting off water gently, employed in the agricultural operation of improving soils by flooding the land with muddy water, the same with *paddle*, *shuttle*, *sluice*, *pen-stock*, &c., a contrivance for retaining or letting out the water of a canal, pond, &c.

Clough Arches, or Paddle-Holes, in the construction of canals, crooked arches by which the water is conveyed, on drawing up the cloughs or paddles, from the upper pond into the chamber of the lock, when it is to be filled.

CLOUT-NAILS. *See* Nails.

CLUB-CHAMBERS. As the building we are about to describe is the first attempt to provide a superior kind of accommodation for gentlemen who are accustomed to reside in chambers, by the erection of an edifice especially planned for, and adapted to the purpose; we think a notice of the extensive and elegant institution known as the Club-chambers in Regent Street, not inappropriate in a work devoted to architecture.

In consequence of the scarcity of chambers for residence in the vicinity of the Clubs and Houses of Parliament, an association was formed for the purpose of supplying the want. An eligible site having been procured in Regent Street, between Pall Mall and Piccadilly, the association engaged Mr. Decimus Burton to make designs for a new building. These designs being approved of, contracts were made, and the result was the present handsome and commodious mansion.

The elevation of this edifice is of the Italian style of architecture; it occupies a frontage of 76 feet, and consists of a ground-story, rusticated, and terminated by an enriched lace-band or string-course, enriched with the Vitruvian scroll. This story forms a basement to the upper part, containing the principal story, and a second and third story, surmounted by a bold and enriched cornice, the main characteristic feature of the Italian style. Between the principal story and the ground-floor, an entre-sol is introduced, the windows of which are placed between the panelled pilasters supporting the consoles of the bold projecting balconies in the windows above. The ground-floor is approached in the centre by a portico, projecting forward with coupled Doric columns on each side, and recessed back to give depth: this opens into a grand entrance-hall, the height of the ground-story, and entre-sol. The four upper stories are divided in the same way as the ground-floor, except that on all the stories above the entre-sol there is an apartment over the entrance-hall.

The building contains 77 chambers; 27 are provided with alcoves or recesses for the bed, and 50 without; some of the rooms are so planned, that two or three may be formed into one suite, if required. The basement-story—occupied as servants' rooms and domestic offices—is arched over with flat brick arches, supported by iron girders. The two staircases are of stone, all the corridors have stone floors, and every precaution has been taken throughout the building against the extension of fire.

The ingenuity displayed by the architect in providing for the warming and ventilation of the building deserves a particular description—it is thus effected:—On each side of the principal staircase, on the basement-story, is a furnace, with an iron pipe or flue 12 inches diameter, fixed in the centre of a vertical brick-chamber, rising through the several stories and roof, where it is terminated by a cowl. On each story these vertical chambers communicate with horizontal ones, formed between the floor and ceiling of the corridors. Each room being furnished with a ventilator near the ceiling, opening into the horizontal chamber; when the fire is lighted in the furnaces, it heats the iron flue, rarefies the air within the vertical chambers, and causes it to pass off with considerable rapidity through the cowl at the top. The air within the rooms then flowing through the ventilators and horizontal chambers into the vertical ones, supplies the partial vacuum created by the escape of the rarefied air, and thereby keeps up continuous and healthy circulation.

The warming of the building is effected by the patent hot-water apparatus of Mr. H. C. Price, erected under the superintendence of Mr. Manby. The apparatus is erected on the basement-story, on the north side of the principal staircase; the hot-air chamber is immediately behind, the top being nearly on a level with the ground-floor; a supply of cold air flows through a trunk—the mouth of which is furnished with gauze-wire to filter the air—into the vault, where it passes upwards between the vertical iron chambers filled with hot-water, and becomes heated, the warm air then escaping through apertures in the top of the vault, is distributed throughout the principal staircase and corridors. The corridors and water-closets are lighted with gas, the light being enclosed in glazed lanterns, provided with tubes leading to the external part of the building. On the basement-story, a well has been sunk, by which the premises are supplied with pure spring water lifted to the top of the building by means of a small steam-engine, which is also employed for raising coals, furniture, &c., up the well-hole of the back staircase. Every alcove or recess for the bed is provided with hot and cold water, and pipes trapped, and communicating with the drains for a water-closet, if the tenant should wish to have one.

We have been thus particular in describing this establishment, because the very perfect arrangements made in it for the comfort and convenience of its numerous occupants reflect the highest credit on the architect, whose taste and ingenuity have been so eminently displayed; and because we would bespeak for so valuable an association the patronage and support its liberality so fully deserves.

CLUB-HOUSE. Under this term are designated the splendid establishments which have sprung up at the west-end of the metropolis within the last few years. Called into existence by the requirements of a highly refined state of society, the clubs of London represent an assemblage of gentlemen composed of all that is eminent in rank, wealth, and talent; the *elite* of the gentry and nobility of the kingdom.

The clubs of the present day must not be confounded with those of a past age, they are essentially institutions of modern creation. Of the clubs of former days, the earliest described in our popular literature date about the end of the sixteenth, or the beginning of the seventeenth century. About that time was established the famous club at the Mermaid Tavern in Friday Street, amongst whose members were Shakspere, Beaumont, Fletcher, Raleigh, Selden, Donne, and others.

Another celebrated club, founded by Jonson, held its meetings at the well-known Devil Tavern. For this club Jonson wrote the "Leges Convivales," which are printed among his works. In the Spectator, Addison describes an association of a political character, called "The Club," or rather the Confederacy of the Kings. "This grand alliance," says he, "was formed a little after the return of Charles II., and admitted into it men of all qualities and professions, provided they agreed in this surname of king, which, as they imagined, sufficiently declared the owners of it to be altogether untainted by republican and anti-monarchical principles."

The great age of clubs, political, literary, and of every other description, was the early part of the last century. Amongst the most celebrated of these was the *first* Beef-steak club, of which Mrs. Woffington, the popular actress, was the president, being the only female member; and

Estcourt, the comedian, *provisor*, wearing in that character a small gridiron of gold hung round his neck with a green silk riband. Still more celebrated, perhaps, was the famous Kit-Cat club, said to have been instituted at the time of the trial of the seven bishops in the reign of James II., but in its greatest glory in that of Queen Anne.

In 1735 was established the *second* Beef-steak club, which is still in existence, and which has numbered among its members the most eminent public characters that have appeared since its institution. This club originated with Rich, the pantomimist, and the Earl of Peterborough, and has continued to the present day to maintain its high celebrity, as the chosen resort of good-fellowship and conviviality.

The modern clubs are associations of gentlemen of similarity of political feeling, literary or professional pursuits—as the Reform, the Carlton, Athenæum, United Service, &c. These are, in no other respects, clubs, according to the ancient English understanding of the term, except that every member must be balloted for, or admitted by the consent of the rest. They might perhaps be more correctly described houses as combining the characters of restaurants and reading-rooms, for the use of a selected number of associated persons, who agree to make an annual payment for their support, whether they resort to them little or much; and pay besides for whatever refreshment they may require, at a cost free of profit. Originating within the present century, and concentrating a large proportion of the men of fortune, station, and political note in the metropolis, these establishments have certainly had a striking effect upon the manners, not only of the departments of society from which the members are drawn, but upon society in general. They have, indeed, given a new direction to the habits of certain classes, and the change has been decidedly for the better.

Although it is our province more especially to describe the buildings in which these institutions are domiciled than the institutions themselves, a slight account of the origin and progress of the latter, abbreviated from an interesting sketch in Chambers' Edinburgh Journal, may not be uninteresting.

It appears that to the military we are indebted for the origin of these establishments. The officers of the army, whether in camp or quarters, have always experienced the advantage and economy of *clubbing* for their provisions. They have found that the pay of each individual, spent separately, would scarcely procure him ordinary necessaries; whilst, by adding it to a general fund, to be judiciously disbursed by an experienced caterer, he would obtain for his subscription not only requisites, but luxuries.

At the peace of 1815, a reduction of the army withdrew a number of officers from the "*messes*" to which they had been accustomed. Thus a great many gentlemen of comparatively limited means were thrown into private life, subjected to all the expenses and inconveniences of hotels, taverns, and lodging-houses. In many instances long and continued absence from home had severed these brave men from domestic ties; yet having always lived among a congenial brotherhood-society, it was essential to their happiness. In these circumstances, the *mess-system* was naturally thought of, and the late General Lord Lynedoch, with five brother-officers, met for the purpose of devising a plan by which a similar system might be made applicable to non-professional life. So effectual were their deliberations, and so well-grounded their preliminary measures, that a club was formed during the same year, (1815,) intended, in the first instance, for military men only, but naval officers, as well as military, were afterwards brought within the scope of their design, and an association enrolled, entitled the "United Service Club."

A building fund was formed; a neat edifice,—from the designs of Sir Robert Smirke,—was erected at the corner of Charles Street, St. James's, and in the year 1819 the first modern club was opened for the reception of its members. Candidates for admission, however, increased so rapidly, that a larger habitation was rendered necessary. A building, on a grand scale, from the plans of Mr. Nash, was erected at the east corner of the new entrance to St. James's Park from Pall Mall, and taken possession of in 1828, while the residence in Charles Street, vacated by the "United Service Club"—now generally called the "Senior United Service"—was taken by a new association, under the title of the "Junior United Service Club."

The establishment of the "United Service Club" was speedily followed by that of others, and the number of these institutions, which is daily increasing, now amounts to above thirty. The principal club-houses are situated in Pall Mall and its immediate neighbourhood, and a person re-visiting London, after an absence of several years, would be surprised to see here clustered together a number of mansions exhibiting every order of architecture, from the severest Doric to the most florid Composite. The following description, subject, of course, to modification in particular instances, will give a tolerably correct idea of the *general* arrangement of a modern club-house.

The visitor, on entering one of these palace-like edifices, finds himself in a lobby, in which are the hall-porter, who is seated at a desk, and his assistants. The duty of these officials is to see that none have access to the club but members, to receive letters, &c. Close to the hall is a reception-room for strangers wishing to see members, and beyond this a hall, or vestibule, from which doors open on the various apartments on the ground-floor. Of these there is, first, a "morning room," which is used for reading newspapers and writing letters. And to give some idea of the liberal scale on which these morning-rooms are supplied, and of the profusion of periodicals taken in by the large clubs, it may be stated, that at the Athenæum, in the year 1844, the sum of £471 2s. 6d. was expended for English and foreign newspapers and periodicals. Stationery also is supplied to an unlimited extent.

The "coffee-room" is furnished with rows of small tables projecting from each side, with an avenue up the middle. These tables are laid for breakfasts and luncheons till four o'clock in the day, after that hour they are arranged for dinners. For the accommodation of members who may feel inclined to form themselves into parties to dine together, in preference to the *detached* mode of dining at the small tables of the coffee-room, a dining-room, handsomely furnished, is provided on the ground-floor, in which they can do so—these dinners are termed, in club-parlance, "house-dinners."

The principal apartment above stairs is the drawing-room, in which members take their evening coffee or tea. In some clubs a great display of luxury and expensiveness is made in this room, and, notwithstanding that it is perhaps less used than any room in the house, the finest taste of the decorator and upholsterer is called into requisition to adorn it. Near to the drawing-room is the library, fitted up with every convenience for reading, consulting maps, &c. The books are accumulated by donations, and by a sum set aside from the general funds for their purchase. These libraries are generally well supplied with books, and that of the Athenæum is said to contain near 30,000 volumes. Five hundred pounds is annually expended by this club for increasing its library. Near the library is, in some clubs, a card-room, but gaming is as much as possible discouraged in these institutions.

The next story contains at least one billiard-room, some club-houses have two; in many clubs also there is a smoking-room: on the upper story are sleeping chambers for the servants, who reside on the premises. The basement contains the usual domestic offices; and, as may be supposed, every detail connected with the important department of the "*cuisine*" is most perfect.

The above sketch will give the reader some idea of the general arrangements of a club-house; we shall now proceed to describe more particularly a few of those splendid edifices which have been, by some, compared to the *Palazzi* of Italian cities.

The "United Service," though first in seniority as a club, deserves a very brief notice on the score of architectural beauty. It is a plain unpretending building, which may be called Italian, because it cannot be described as being of any other style, but it is Italian of an impoverished and enfeebled character, exhibiting, remarks Mr. Leeds, "incontestable evidence of insipidity and poverty."

The building consists of two stories, the ground-floor being rusticated, and having windows on each side of the portico. The upper story contains an elegant *suite* of rooms, having seven lofty windows, with pediments, over which, and running through the whole building, is an entablature, the whole being surmounted by a balustrade. The south front is similar to the one described, but the north, facing Pall Mall, has a portico the whole height of the structure, and is in two divisions; that of the ground-floor being composed of eight fluted Doric columns in pairs, having an entablature with triglyphs. This is surmounted by a balustrade, over which are eight Corinthian columns arranged in the same order as those below, and crowned by an entablature and pediment. The internal arrangements are exceedingly well contrived, and furnish every convenience for the accommodation of the members. There are some remarkably fine portraits of distinguished military and naval officers, and the apartments are furnished with great luxury and elegance.

The "Athenæum," is situated at the opposite angle of Carlton Place, and is remarkable for the elaborate sculptured bas-relief frieze continued along its three sides. This club ranks as one of the very first in the metropolis, and the magnificent mansion belonging to its members, is worthy to occupy a similar prominent position.

The building is from the designs of Mr. Decimus Burton, and displays that gentleman's usual ability and good taste. The east elevation has a rusticated basement with a portico, the ends of which are filled up and perforated with windows; the angles are finished by a square pilaster and fluted column of the Doric order; the space between being divided by four columns of the same order in pairs. The frieze is ornamented with triglyphs, and the cornice surrounded by a balustrade, the space over the centre intercolumniations being filled up and crowned by a pedestal supporting a figure of Minerva.

Over the ground-story, and on a line with the cornice of the portico, is a balcony running through the three elevations, and terminating at the angles by pedestals. The principal story is lighted by seven lofty windows with sashes, by which there is access to the balcony, and which are ornamented with cornice and trusses; above this, and continuing through the entire building, is the beautiful frieze we have already mentioned, the figures, in basso-relievo, being copied, it is said, from the Elgin frieze deposited in the British Museum. Over this is a cornice of very bold projection, the whole being crowned by a balustrade.

Adjoining the Athenæum, is the "Travellers'," of which it is scarcely possible to speak in terms of sufficient commendation. "Could there," says a talented writer and able critic, "be any question as to the possibility of reconciling the seemingly antithetical qualities of richness and simplicity, this building might be allowed to determine it, since the design is no less remarkahle for the attention bestowed upon all its details, than for the simplicity of its composition." We have many others far more ambitious in decoration, yet not one so beautifully finished up in every part, or exhibiting so perfectly that *integrity of finish* which is displayed in this work of Mr. Barry's. For here, indeed, we behold the full beauty of the Italian style purified from its defects, and stamped by a serene kind of dignity that renders it truly captivating.

In the treatment of his design, Mr. Barry has bestowed equal pains on both fronts, that towards the garden being as carefully studied as the one facing Pall Mall; and it is well worthy not only of observation, but of imitation, that there is more nicety of detail and greater elegance here bestowed on parts sometimes considered of very secondary importance, than is often expended upon a whole design. If, again, we lift our eyes to the upper extremity of the building, we instantly perceive what attention has been bestowed on that also; for it is not the cornice alone, but the cornice and roof together which constitute its decoration; the latter being treated as belonging to the elevation itself, and the former giving richness and majesty to the whole façade.

The interior of the building is arranged with great ability, both with regard to convenience and picturesque effect, for which latter it is not a little indebted to a small but elegant internal court, of strictly architectural character.

The position of the entrance, which a regard to exact symmetry would have required to be in the centre, has been sometimes objected to, but we are of opinion that the architect exercised a sound judgment in placing it where he has, rather than sacrifice a portion of the interior accommodation.

The following description of this elegant structure, is extracted from an excellent work, "The Public Buildings of London," edited by Mr. W. H. Leeds:—"The hall, which has a screen of two columns in antis,—behind which is the porter's desk,—includes the window next to the entrance-door. Although small in itself, it does not by any means look confined, there being a vista from it along the corridor, which is lighted by three windows looking into the court, and to which there is an ascent of four steps through an open arch. The ceiling of both hall and corridor are arched; that of the former coffered, of the other panelled. A door to the left, immediately after ascending the steps, leads into the morning-room, (44 feet by 23 feet 9,) which has three windows towards the street, and a fire-place at each end. From this, a door facing the farthest window, opens into the house dining-room, which is 27 feet by 28 feet 9 inches, and occupies all the space to the east of the court. Beyond the principal staircase, which is seen at the end of the corridor through an open arch, is the coffee-room, occupying the whole extent of the garden front. This room is divided by piers and antæ into three compartments, in each of which is a fire-place, namely, one at each end, and another facing the windows in the centre division.

"The libraries form a single apartment, divided by double screens of Corinthian columns on a pedestal stylobate in continuation of the dado of the room, leaving a passage through the centre intercolumn six feet clear. Owing to the contraction of the opening, to the depth of the screen, and the duplication of the columns one behind another, the perspective appearance acquires a high degree of pleasing complexity, and the larger or inner library is not so much exposed to view, on first entering from the staircase. Above the entablature is a deep frieze, forming a continued subject in bas-relief. Over the libraries are billiard and smoking-rooms, which are lighted from above in the slope of the roof towards the court."

The drawing-room and card-room are loftier than the libraries, and have a deep cove with coffers between the ceiling and the top of the cornice. The design of the drawing-room ceiling is exceedingly tasteful, combining finished simplicity with richness in a very striking manner, and all the details exhibit proofs of the most refined taste and the most careful and elaborate design.

The dimensions of some of the principal apartments are as follows:—

	Ft. In.		Ft. In.		Ft. In.	
Coffee-room	68	by	24 9	and	18 6	high.
Principal Staircase...	45	by	16			
Corridor	27	by	11			
Court	27	by	25 6			
Drawing-room	39	by	23 9	and	24 0	high.
Card-room	28 9	by	23 9			
Libraries	48	by	24 9	and	17 6	high.
Reading-room	29 9	by	19 6			

We cannot close our notice of this elegant building, without again expressing our admiration of so great an ornament to our metropolitan architecture. The Travellers' club-house will bear the most critical and scrutinizing examination; and the more closely it is scanned, the more apparent will be its beauty; nor is it till then that we perceive how carefully every part is elaborated, and yet so subdued to the general effect, that the eye never rests on particular points thrust obtrusively forward, but embraces the perfect ensemble, in a structure replete with chaste and refined simplicity.

Immediately adjoining the Travellers' is another magnificent example of architectural genius—the "Reform Club." The instructions issued to the competing architects, by the spirited members of this association, when seeking a design for their new dwelling, were—to produce a club-house which should surpass all others in size and magnificence; one which should combine all the attractions of other clubs, baths, billiard-rooms, smoking-rooms, with the ordinary features, besides the additional novelty of private chambers or dormitories. The manner in which Mr. Barry responded to these instructions, may be seen in the edifice we are about to describe; an edifice on which public opinion and professional criticism have united to bestow the highest praise; pronouncing it unsurpassed in grandeur of design, and perfection of taste, by any building in the metropolis. The distinguishing characteristic of the Reform Club, is its grand and imposing appearance; produced, not only by its greater extent and loftiness, but by the circumstance of its being detached from other buildings on three of its sides. These are made to constitute as many façades, two of which may be beheld together from the same point of view, producing, from their uniformity in design, a continuous, rich architectural mass; and thus securing a completeness and fullness of effect which a mere façade on the same scale could never give.

In the Reform, as in the Travellers', Mr. Barry has avoided the too common fault of cutting up a composition into distinct divisions, finishing, and then commencing again; on the contrary, the ensemble is made consistent throughout, crowned by a magnificent cornicione, proportioned not to a part, but to the whole; while sufficient decoration, in other respects, is derived from essential features and members, windows, string-courses, &c. These display themselves with a boldness and effect hardly attainable where windows are introduced between straggling columns, and other like incongruities offend the judicious observer. In this building richness combined with simplicity is diffused throughout, and the eye dwells with unmixed satisfaction and delight on the harmonious result.

The entrance to the club-house from Pall Mall, is several steps above the ground, and in the centre of the building. On this side, the frontage presents only three floors from the ground, though consisting of six from the basement; the basement and mezzanine below ground, and the chambers in the roof being unseen. There are four windows on each side of the entrance; nine windows equidistant on the first floor, and the same number on the second. The pediments surmounting the windows in Pall Mall, are supported by Ionic pilasters; and at the back, overlooking Carlton Gardens, by Ionic pilasters rusticated. The height of the ground and first floor is on the same level as the Travellers'.

An Italian court (34½ feet by 29 feet,) is placed in the centre of the quadrangle. Corridors, on the first and ground floors, 9 feet wide, lighted from this court, lead to the apartments on these floors; but on the second floor, the corridors leading to the lodgings are contracted to 5½ feet. On the basement, every sort of culinary office seems provided, and located with singular judgment and convenience. The number of apartments here exceeds thirty. In the mezzanine or entresol, are the butler's, housekeeper's, and still-rooms, dressing and bath rooms, and 16 servants' rooms. On the ground floor is the coffee-room, of noble proportions, having a view into the gardens; writing-room, newspaper or reading-room, house dining-room, steward's, waiting, porter's, and two audience-rooms—in all nine rooms on this floor.

On the first floor, above the coffee-room, is the drawing-room, supported by Corinthian pillars, and so constructed, that if required, it may be divided into two or three rooms; two libraries, both supported by Corinthian pillars; two billiard-rooms; and several other rooms.

On the second floor are twenty-six chambers or lodgings, the dimensions of each varying from 22 feet by 14 feet, to 12 feet by 10 feet.

On the attic floor there are about thirty rooms, intended for servants. The following are the dimensions of some of the principal apartments :—

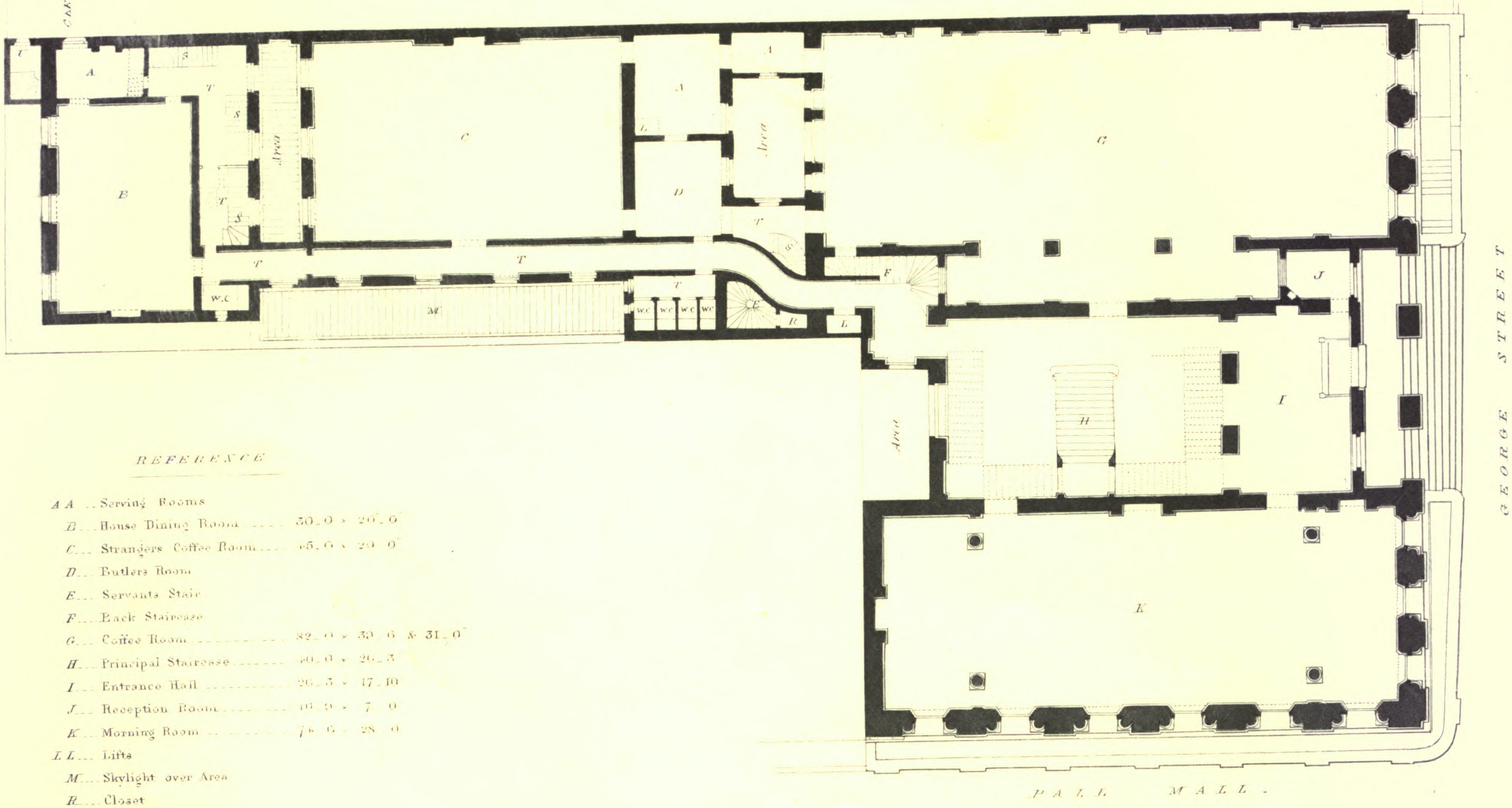
		Ft.		Ft.		Ft.		Ft.
Basement....	Kitchen	29	by	22				
"	Steward's room......	26	by	18½				
"	Butler's pantry	16½	by	14				
"	Scullery	20	by	14				
"	Cook's room.........	17	by	12				
Ground Floor	Coffee-room	117	by	28				
"	Writing-room........	40	by	27				
"	Reading-room	28½	by	27				
"	House dining-room ...	29	by	18				
First Floor ..	Drawing-room	117	by	28				
"	Libraries............	40	by	27	and	28½	by	27
"	Billiard-room	32	by	18	and	23	by	17½
"	Committee-room	33½	by	17½				

In the whole building, there are upwards of 130 several apartments, arranged with the greatest ingenuity, and with the utmost attention to convenience, and showing that, however great may be our admiration of the beautiful exterior, the interior is not less deserving of our approval and commendation.

The "Carlton" adjoins the Reform, and adds another to the fine structures we have been describing. The committee of this club, after examining a number of designs submitted in competition by various architects, none of which seem to have met with approval, agreed to elect an architect by the votes of the members. The ballot resulted in the election of Mr. Sydney Smirke and Mr. G. Basevi, who had arranged to act conjointly; but the death of the latter gentleman preventing this being carried into effect, Mr. Smirke was retained by the committee to complete the work.

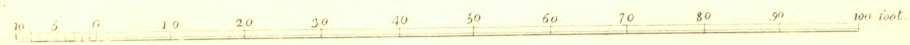
ARMY & NAVY CLUB HOUSE.

PLAN OF GROUND FLOOR.



REFERENCE

A A ... Serving Rooms
B ... House Dining Room .... 30.0 × 20.0
C ... Strangers Coffee Room .... 45.0 × 29.0
D ... Butlers Room
E ... Servants Stair
F ... Back Staircase
G ... Coffee Room .... 82.0 × 30.6 & 31.0
H ... Principal Staircase .... 40.0 × 26.3
I ... Entrance Hall .... 26.3 × 17.10
J ... Reception Room .... 10.9 × 7.0
K ... Morning Room .... 78.6 × 28.0
L L ... Lifts
M ... Skylight over Area
R ... Closet
S.S. ... Stairs
T.T. ... Corridors
W.C. ... Water Closets
U ... Entrance to Kitchen depart.t from Lane.



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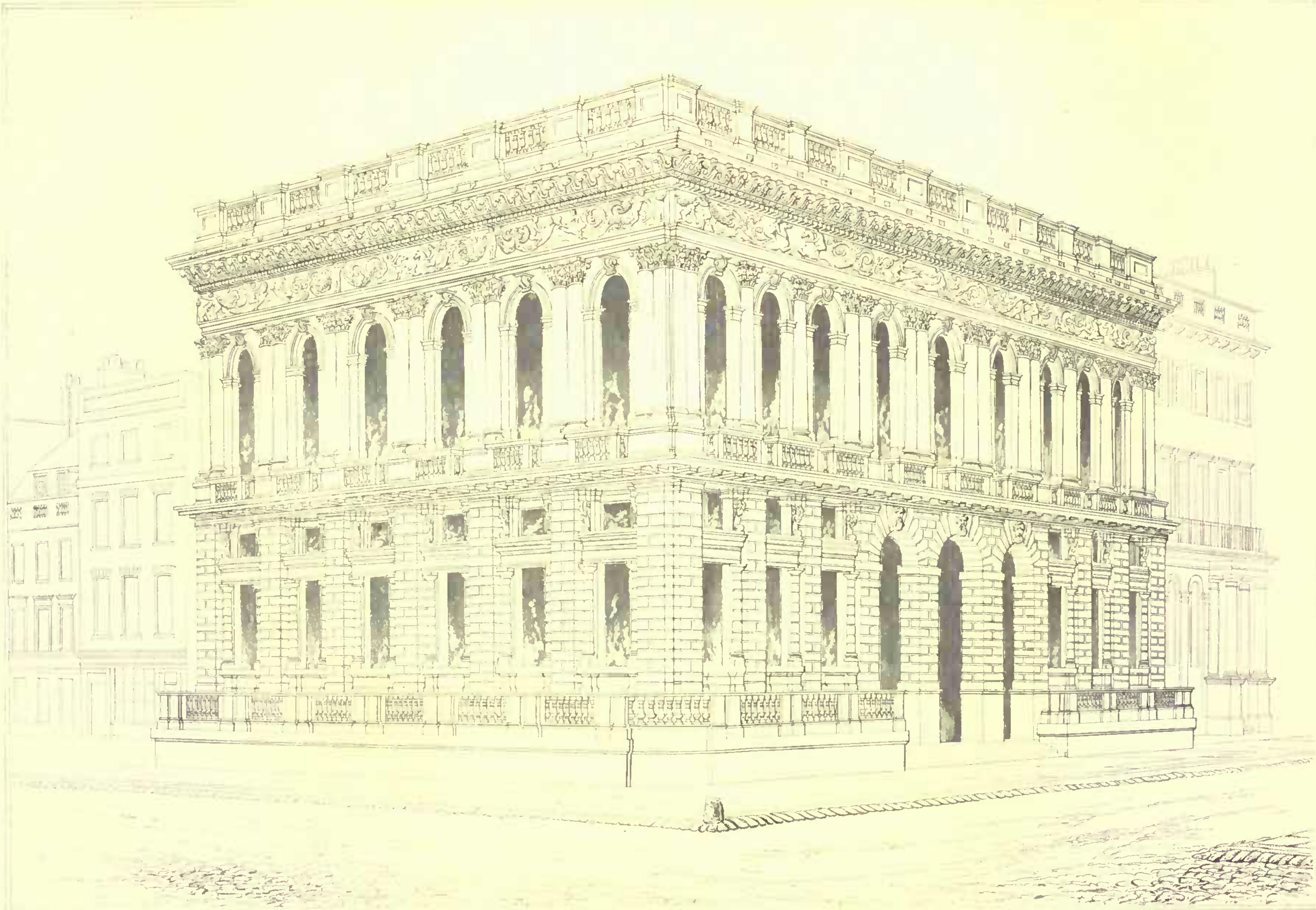


ARMY AND NAVY CLUB HOUSE. LONDON.

The general design of the building is adopted from that of the library of St. Mark, at Venice. The extent of the frontage in Pall Mall, is 133 feet, and the height is about 70 feet. The fronts are of Caen stone; the shafts of all the pillars and pilasters, of polished Aberdeen granite; and the contrast made by the red tint of the latter, has a novel and pleasing effect. The decorations of the interior, furniture, &c., are of the most tasteful and splendid description, and the coffee-room, 90 feet by 36 feet, is an exceedingly handsome apartment. The whole building presents an imposing elevation, designed with judgment and good taste. The rooms are of good proportion, and arranged with every attention to comfort and convenience; and the important details of domestic and culinary matters, as cellars, kitchens, larders, and servants' rooms, have not been neglected.

The splendid building belonging to the "Oxford and Cambridge University Club," erected from the designs of Sir Robert and Mr. Sydney Smirk, adjoins the Carlton. The front of the University club-house extends 87 feet in width, and the height from the ground line to the top is 57 feet. An entablature, marking the separation of the ground story from the principal floor, and projecting forward in the centre of the building over four Corinthian columns, divides the front horizontally into two equal parts. The centre space on the ground-floor is occupied by the portico, which projects to the front line of the area; the entrance to the hall being formed by the centre intercolumniation, which is wider than the rest; the four columns stand upon pedestals, four feet high, with base mouldings and cornice. The upper part of the building is terminated with a delicate Corinthian entablature and balustrade, breaking forward with the centre of the building, which corresponds in width with the portico: the front being thus vertically divided into three compartments, the side ones assuming the appearance of wings, while the effect of a centre, indicated by the projecting portico on the ground-floor, is maintained throughout the whole height of the building. The angles of the centre division, on the principal story, are formed of rusticated pilasters; the principal window occupying the space between these pilasters. Similar rusticated pilasters also divide each wing on the principal floor into three equal oblong recessed spaces, containing windows similar to the window above described. A balcony, projecting 3 feet, continues throughout the whole line of front, the parapet being formed of pedestals with intervening panels of richly designed foliage, cast in metal in high relief, and the landing supported by elaborately enriched consoles. The frieze of the entablature over the ground-story is filled with convex panels, enriched with laurel leaves, and over each column of the portico are shields bearing the arms of the Universities. The whole of the ornamental detail throughout, is designed to correspond in richness of effect with the Corinthian capitals of the columns, which have their central volutes entwined. Below the ground-story are mezzanine and basement stories.

In the panels above the windows of the principal floor, are bas-reliefs illustrating those exalted labours of the mind, which it is the peculiar province of the Universities to foster. We have not space to describe these beautiful ornaments more minutely, but they are well worthy a careful examination, and reflect credit on the taste of the architects, and on the liberality of their employers. The arrangements of the interior are planned with great judgment, and afford every accommodation to the members of the club; but as a great similarity must necessarily exist in all establishments devoted to similar purposes, it is unnecessary to describe them.

On the opposite side of Pall Mall, is the new building erected for the "Army and Navy Club," an engraving of which, with a plan of the ground-floor, is here given. The architects are Messrs. Parnell and Smith. The following description, principally taken from that very useful publication, "The Builder," gives a good idea of the structure:—

"Although the design is based on the Cornaro palace on the grand canal at Venice, it differs materially from that building. The palace has three stories above the basement, Doric, Ionic, and Corinthian, and shows the roof, terminating on the modillion cornice of the upper order, as at the Reform club; the frieze being devoid of sculpture, and having oval openings to light an attic story. In the club-house, the general arrangement of the ground and first floor elevation of the palazzo has been adopted, but coupled Corinthian columns have been substituted for the Ionic of the latter, and the building terminates with the entablature of the order, highly enriched with sculpture and a balustrade.

"The entrance to the building is from George-street, by a flight of steps leading to a recessed portico. On the left of the entrance-hall, is a morning-room corresponding to a coffee-room on the opposite side; there is also a reception-room. The coffee-room is lighted from each end, and an elliptical dome in the centre: the dome has an exterior covering of glass, between which it is proposed to light the room at night by a gas device encircling the whole circumference. By this arrangement, the necessity for any gas-burners will be avoided, and a hot-air chamber provided, which, by the aid of flues, will afford a system of ventilation. Between this room and the strangers' coffee-room, lighted and ventilated in the same manner, and communicating with each, is placed the serving-room, connected with the kitchen by a lift, and the butler's serving-room: from this last is a direct communication to the dispensing cellars, while the room will be fitted up with ice-bins, hot and cold water, and presses for the reception of glass: there is also a separate entrance from the still-room. At the extremity of the building is placed the house dining-room, which has a separate communication with the kitchen.

"The mezzanine floor is appropriated to the members' bath and dressing rooms, and the housekeeper's department. The first floor is approached by a flight of steps, one branch of which leads to the secretary's room, and upper floor, the latter containing billiard, card, and smoking rooms—the other to the evening-room, library, and writing-room. The evening or drawing-room, is 76 feet by 28 feet; the library, 40 feet by 32 feet; writing-room, 33 feet by 18 feet. There are besides the rooms we have mentioned, a great number of others of the usual description in similar establishments."

It would be impossible, without occupying more space than can be allotted to this article, already extended beyond its due limits, to describe in detail the several handsome mansions in which other clubs, under various designations, have located themselves. The "University" in Suffolk-place —the "Union," one of the oldest and most select of London clubs—the "Conservative," lately erected in S. James's-street, on the site of the well-known Thatched House Tavern, and a host of others, are all deserving the study of the architectural student. In some, beauties of the highest order command his attention; in others, defects, he should mark, in order to avoid; in all, much may be learnt as to arrangement of apartments, and those details of convenience on which so much of the comfort and economy of a large establishment depends.

In conclusion, we would observe only, that whatever may be the faults of some of these buildings, the formation of the present club system has been the means of adorning the west end of London with a number of splendid houses, designed by eminent architects, decorated by artists of reputation and taste; and completed at an expenditure of the most liberal and extensive character. Nor has this been confined to London alone, the example has been followed in the country; and in many of the provincial cities and towns, clubs have been formed, and club-houses built on a scale of magnitude and splendour rivalling those in the metropolis. It is scarcely within our province, to remark on the effect the rapid extension of clubs may have on the usages of society in general; but we may be permitted to say that any system which tends to the adornment of our cities with magnificent structures decorated in the most expensive manner, and filled with costly furniture, and luxurious productions in every department of art, cannot but have a refining influence on the taste of the rising generation, while affording employment to professional talent, and to hundreds of skilful artisans.

CLUMP, in ornamental gardening, a detached portion of ground, raised in the form of a mound, in lawns or other parts of pleasure-grounds, for the reception of trees or shrubs on the top, while its sides are covered with flowers or small plants. Clumps differ from borders, in being detached and separate, as well as in being much more elevated.

CLUSELLA (Latin, *clusum*, enclosed,) a small castle within a close or inclosure.

CLUSTERED, in architecture, denotes the coalition of two or more members, so as to penetrate each other.

Clustered Column, in the pointed style of architecture, a column composed of a number of slender pillars attached to each other, but having each a distinct base and capital. Clustered columns were frequently divided in their height by moulded bands, which gave them the appearance of being bound together. They are sometimes attached to the shaft throughout their length, and sometimes only at the capitals and bases.

Clustered Column, in the Roman style, is said of two, or four columns, which seem to intersect or penetrate each other, either at the angle of a building or apartment, that they may answer each return; or under an entablature, when a single column would be too weak; or at the intersection of two transverse architraves: in the latter case, there may be four columns.

COATING, in a general sense, denotes the covering of a body in one or several plies or thicknesses; thus, walls are spread over with one, two, or three separate coats of plaster; the interior apartments of houses are covered with several coats of paint; works in wood are covered with paint, pitch, lead, copper, &c.; baser metals are covered with the richer, as copper with gold or silver, and silver with gold; for culinary purposes, copper is covered with tin, as is iron also, to prevent rust.

COB-WALL, a wall built of straw, lime, and earth.

COCHLEARE, or Cogla, a lofty round tower, ascended by means of a winding staircase; from the Latin, *cochlea*, winding stairs.

COCKING, a method of securing beams to wall-plates, by notching each beam at the end on the under edge, across its thickness, nearly opposite to the inner edge of the wall-plate, and cutting two reverse notches out of the top of the wall-plate, leaving the part whole which is opposite to the notch in the beam; then laying the beam to its place, it will slide down, and the corresponding parts will fit into each other. This method prevents any possibility of the beam drawing longitudinally out of the wall-plate, even though the timbers should afterwards shrink.

COCKLE-STAIRS, a winding staircase. *See* Stairs.

CŒMETERIUM. *See* Cemetery.

COFFER, a recessed panel, of a square or polygonal figure, anciently used in level soffits, and in the intradoses of cylindrical vaults.

In the remains of Grecian and Roman architecture, the coffers sometimes recede in one degree, but more frequently in several degrees, like inverted steps, around the panel, each internal angle being filled with one or more mouldings. In Roman works, the surface of the panel at the bottom is mostly covered with a rosette. Sometimes the bands between the framing are divided into two equal parts, by a groove or canal of a rectangular section.

Coffers are also employed in the soffits of the cornices of the Corinthian and Roman orders, between the modillions. For the farther use of coffers, and other matters relating to them, *see* Ceilings and Cylindrical Vaults.

Coffer, in inland navigation, a large wooden vessel, open at the top, with movable ends, of sufficient capacity to receive a barge or vessel from the pond of a canal, in order to be raised into a higher, or let down into a lower pond. This coffer is a substitute for a lock.

COFFER-DAM, a hollow dam, constructed of a double range of piles, with clay rammed between, for the security and convenience of the workman while digging out and building the foundation of an entrance-lock to a dock, basin, or canal, when it cannot otherwise be laid dry.

In bridge-building, the term is applied to a case of piling fixed in the bed of a river, without any bottom, for the purpose of building a pier dry. Its sides must, therefore, reach above the level of the water, and, after it is fixed, the water must be pumped out by the engines, which, unless the work is very carefully done, must be kept constantly at work, to prevent leakage as much as possible. Coffer-dams are made either double, or single. In the double one, the space between the inner and outer rows of piles is rammed with clay or chalk; the piles are driven as closely as practicable to each other by means of a pile engine, till fixed firmly into the earth; sometimes they are grooved and tongued; sometimes they are grooved in the sides, and fixed at a distance from each other, with boards let into the grooves.

The first writer on the use of coffer-dams was Alberti, who, chap. vi., book 2, gives the following directions: "Make the foundation of your piers in autumn, when the water is lowest, having first raised an enclosure to keep off the water, which may be done in this manner: drive a double row of stakes close to that side of the row which is next to the intended pier, and fill up the hollow between the two rows with rushes and mud, ramming them together so hard, that no water can get through; then, whatever you find within the enclosure—water, mud, sand, or whatever else is an hindrance to you—throw them out, and dig till you come to a solid foundation." To this we may add, where the river is rapid and deep, and the bed of solid earth or clay, the coffer-dam must be constructed with three, four, five, or even six rows of piles, according to the rapidity and depth of the stream. Due care must also be taken to brace the sides well from fixed points, as well as to make the whole water-tight, by ramming in chalk or clay, as above directed.

Where the river is rapid and deep, and the bed of a loose consistence, though the sides be never so firm, the water will ooze through the bottom in too great abundance to be taken out by the engines, recourse must therefore be had to a caisson. *See* Caisson.

The following is a description of the very large coffer-dam made at the New Houses of Parliament, for building the embankment, or river-wall. This dam was 1,236 feet long, and 10 feet wide, constructed in the following manner:—a trench was first made by dredging in the bed of the river of the form of a segment of a circle, 27 feet wide, and 8 feet deep in the centre, to allow the piles to drive more easily; two parallel rows of guide or main piles were then driven about 5 feet apart, leaving a width of 9 feet between them transversely: to these piles were fixed three tiers of waling of whole timbers, cut down and bolted together, one tier being fixed at the top on a level with high-water mark; another level with the bed of the river: and the third midway. The piles and waling were then bolted across with iron bolts 12 feet long, forming a carcase for the inner or sheet-piling; the inner main piles being also firmly braced to resist the pressure at high water. Horizontal struts of whole timber, also, at the back of the brace piles abutted against other piles driven just within the inner edge of the foundation of the wall.

The piles were 36 feet long, driven through the gravel, and 2 feet into the clay, the top of which is 28 feet below high-water mark. Within the waling were two parallel rows of sheet-piling; the outer or river-side of whole timbers—the inner or land-side of half-timbers. After all the piles were driven, the gravel forming the bed of the river between the piling was dug out down to the clay, and the space filled in with clay, and puddled. For the purpose of pumping out the water, a ten-horse power steam-engine was erected, which was kept at work night and day; and considering the great extent of the dam, it is remarkably free from leakage. It occupied fourteen months in its construction.

COFFIN, (Greek κοφινος, a basket,) the chest or box in which dead bodies are deposited for burial. In ancient times coffins were usually constructed of stone, and sometimes highly ornamented, as is evidenced by the remains of Egyptian and other sarcophagi which have been brought to light. In England likewise stone coffins were anciently used, frequently formed of a single block hollowed out to receive the body; the shape was that of a trapezium, having the end where the head lay slightly wider than the other extremity; they were covered with a lid, which was either flat or coped, and often sculptured with crosses and other emblems. They were sometimes buried in the ground, though not deeply, sometimes only up to the lid, which was visible above ground, and sometimes placed entirely above ground.

COGGING, the same as Cocking, which see.

COIN, or Quoin, (from the French *coin*, a corner,) the angle made by two surfaces of a stone or brick building, whether external or internal; as—the corner of two walls, the corner of an arch and a wall, the corner made by two sides of a room, &c.

Coin, *Rustic*. *See* Rustic.

Coin, (from the Latin, *cuneus*, a wedge,) a block cut obliquely at the bottom, but level at the top, to rest upon an inclined plane, for supporting a column, or pilaster.

COLARIN. *See* Collarino.

COLLAR, a ring, or cincture.

COLLAR-BEAM, a beam in the construction of a roof, above the lower ends of the rafters, or base of the roof. The tie-beam is always in a state of extension, but the collar-beam may either be in a state of compression or extension, according as the principals are with or without tie-beams. In trussed roofs collar beams are framed into queen posts; and in common roofs, into the rafters themselves. Though trusses in general have no more than one collar-beam, very large roofs may have two or three collar-beams, besides the tie-beam. Collar-beams will support or truss up the sides of the rafters, so as to keep them from sagging, without any other support; but then the tie-beam would only be supported at its extremities. In common purlin roofing, the purlins are laid in the acute angles between the rafters and the upper edges of the collar-beams. *See* Truss.

COLLARINO, or Colarin, that part of a column which is included between the fillet below the ovolo of the capital, and the upper side of the astragal at the top of the shaft. The collarino is to be found in the modern Tuscan and Doric orders, but not in the three Grecian orders, except in the Ionic of the temple of Erechtheus, at Athens, and in some fragments of Ionic columns found in Asia.

The collarino, or colarin, is otherwise denominated the *neck*, *gorgerin*, or *hypotrachelion*.

COLLEGE, a public building, endowed with revenues for the education of youth and their instruction in the various branches of science and literature. An assembly of colleges constitute a university.

Our colleges consist, for the most part, of one or more quadrangular areas, surrounded by ranges of buildings, which comprise a house for the superior, and rooms or lodgings for the fellows, scholars, &c.; besides which there is always a chapel and refectory, or dining hall. Amongst our finest buildings of this class are those of Christ Church and Merton Colleges, Oxford, which, with many others at the same university, as also at the sister institution at Cambridge, are magnificent specimens of the architecture of their respective dates.

In writing on this subject, we must not pass over in silence the foundation and erection of St. Augustine's College, Canterbury, a building which may vie with many an older structure of the same kind, as well in its architectural, as its educational features.

This college comprises only one area, which is of a quadrangular form, three of its sides only being occupied with buildings, the fourth at present consists but of a wall; but the space is intended to be built upon as occasion demands. The three sides already occupied are the north, east, and west, the cortile on the southern side being enclosed by the wall; of these, the buildings on the two first, the northern and eastern sides, are elevated on a raised terrace, while those on the south are on a level with the entrance. The materials employed for the walling are for the most part flint, with dressings of rag-stone, and, in other cases, rag with Caen stone dressings. The style adopted is the Decorated of the fourteenth century; in the chapel are some parts of an earlier date, but in other respects the architecture of Edward the Third's reign predominates.

On entering under the fine old gateway on the southern side, the object which probably first attracts our attention is the long range of beautiful windows on our left. The long pile of buildings on this side of the quadrangle is raised, as we before mentioned, on a broad paved walk, or terrace, and consist besides of two stories, the lower presenting, on the exterior, a series of large, closely-set windows, with intervening buttresses; and the upper a row of nearly double the number of windows, but of much smaller dimensions, and with larger intervening spaces. The lower windows are divided by mullions into five lights, and their arched heads are filled with tracery of good design; while the windows of the upper story are of the most simple description, being but plain lancets of one light. This length of building is judiciously broken up into three parts by two stair-turrets, which give access to the apartments above; and by a door at the side, entrance is obtained to the lower story; one of the turrets is used likewise for a belfry. The doors on the terrace give entrance to a long covered ambulatory, 151 feet in length, lighted by eight fine windows, which we have noticed above, and covered with a flat roof showing the timbers, with arches spanning across at intervals where required. Out of this cloister open twenty apartments for the students, of which above thirty more open into a corridor in the upper story. The arrangement of these apartments is the same throughout: they measure 15 feet by 8 feet 6 inches, and are divided by a partition into two rooms. The furniture of the rooms consists of an iron bedstead, a fixed and compact washhand-stand, a fixed table, having on one side drawers for clothes, and on the other a drawer for writing materials, and above the table shelves for books fixed against the wall; an elbow-chair and two others complete the furniture. The rooms are well ventilated, and heated by hot water, one of the few arrangements which we have to find fault with.

Level with these buildings, but at right angles to them, on the eastern side of the area, and detached, stands the library, perhaps the most dignified building of the whole group. Raised upon a crypt, the proportions of which are old, and the details copied and of great simplicity, is a vast apartment 78 feet long by 39 feet broad, with massy buttressed walls, and large traceried and transomed windows, surmounted by a magnificent open roof of oak, the ridge of which is 63 feet high from the level of the terrace. A noble flight of fifteen steps, approached by an ample arch, and contained within a porched roof at right angles to the main pile, and lighted by four windows, affords a means of entrance at the southern extremity. This library is well lighted by thirteen large windows, six on each side, and one at the north end; they are each of four lights, being divided vertically by a mullion, and horizontally by a transom, and have trefoiled heads. The disposition of the windows naturally divides the interior into six compartments.

The crypt upon which this building is erected, is raised on the foundation of the great refectory belonging to the ancient establishment, and is to serve the purpose of a museum. It is lighted from the exterior by small lancets, and is divided internally by ten pillars into three aisles of equal width; the ceiling is groined, and the floor paved with red tiles.

The roof of this building, as also that of the last, is tiled and crested with ridge tiles; the materials of the walling, however, vary, the library being built of uncoursed rag, with dressings of Caen, while that of the northern range is of flint.

Descending from the terrace, the most important building of the western range is the chapel, but it will be well to leave this for the present, and starting from the southern extremity of the library, follow out the lucid description afforded to us in the *Ecclesiologist*:—

"Going from this point in a south-west direction, we come to a range of buildings containing the apartments for the fellows, each of whom will have two rooms and a gyp room, and the warden's lodge, a spacious and commodious family residence. These are of flint, in good middle-pointed, and in many respects show great ability. Still we confess we think them the least admirable parts of the design. Northward of these, and projecting considerably from their level eastward into the court, is the chapel to which we shall recur after speaking of the refectory and kitchen, which range northward of the chapel between it and the ancient gateway at the north-west corner of the quadrangle. The refectory is a fine room, with a roof the humbleness of which is redeemed by its being mainly original—no oriel, (the shell of the walls being ancient,) but with a dais and tables, and a cleverly contrived range of closets at its south extremity. Northwards it communicates with a common room, and a beautiful room, intended, we believe, for a muniment-room, or, for the present, a lecture-room, occupying the upper story of the ancient gateway. Below the refectory is the kitchen, with a fine chimney projecting eastwards into the quadrangle, while offices and a porter's lodge extend under the common room to the entrance gate. A steep and narrow flight of stairs between the chapel and refectory, the kitchen door being at their feet, reaches a small landing, from the right or north of which you enter the hall, while immediately opposite, on the left hand, is the entrance to the chapel.

"The chapel is entered at the north-west, through a small ante-chapel lighted by the restored western triplet of the ancient fabric, and parted from the body of the chapel by a bold arch, sustaining a double bellcote externally, and filled with a proper screen. Within the screen extends the solemn length of the chapel, the small dimensions being quite forgotten in the beauty of the proportions: returned stalls, with miserere seats and back panelling of unexceptional style and taste, with subsellæ to match, mark the choir. Eastwards the sanctuary, though small, is beautifully treated and sufficiently dignified. The measurements are as follows: length, 60 feet; width, 18 feet; height from floor to wall-plate, 14 feet 6 inches; from floor to ridge, 30 feet 6 inches. The lighting of the chapel is peculiarly effective: a five-light middle-pointed east window, and two adjacent couplets north and south of the sanctuary, concentrate the light on the altar. The side-walls are unpierced, and the choir is consequently religiously sombre, the windows of the ante-chapel, however, sufficiently removing it from gloom. There is no colour on the walls or roof; in fact, none but the stained glass with which all the windows are filled. The whole effect is one of real, unpretending, earnest effectiveness, and austere and unworldly beauty. The stained glass chosen throughout, with a depth of meaning, itself a homily, betrays a world of thought in its distribution.

"Mr. Butterfield is peculiarly successful, we think, in his treatment of encaustic tiles. Those used in the chapel appeared to us most judiciously chosen and arranged. The footpace of the altar in particular was a beautiful mosaic of bright colours and intricate design.

"The ante-chapel is furnished with a few open seats intended for the use of the family of the warden and of the servants of the college. The choir is thus appropriated exclusively to the use of the foundation and the students.

"We rejoice to add, that there are no fixed altar-rails, though there is movable railing for the use of the communicants. A litany-stool occupies the middle of the choir. The lessons will be read from letterns fixed one on each side in the upper ranges of stalls. A rather large hole, furnished with a shutter, near the wall-plate on the north side, for ventilation, deserves notice for the boldness and simplicity of the idea.

"We should mention that the chapel is raised on a crypt vaulted and designed to serve as a sacristy. The bells are rung from a western bay, open and vaulted, occupying the space under the ante-chapel, the ropes passing through the floor by the screen, and so reaching the bells in the bellcote before noticed, which is by the way one of the less successful parts of the design.

"It is with unfeigned pleasure we again congratulate Mr. Butterfield on his success in this most interesting work, which will, we really think, ensure him enduring and most deserved fame amongst English church-architects."

COLLEGIATE CHURCH, a church to which is attached an ecclesiastical establishment of deans, wardens, and fellows, which, before the Reformation, consisted of a number of secular canons living together under the government of a dean, warden, provost, or master.

COLOGNE EARTH, a substance used by painters as a water-colour, approaching to amber in its structure, and of a deep brownish tinge.

COLONELLI (from the Italian) truss-posts, or the posts of a truss-frame.

COLONNADE, (from the Italian *colonna*,) a range of attached or insulated columns, supporting an entablature. The interval between the columns, measured by the inferior diameter of the column, is called *the intercolumniation*, and the whole area between every two columns is called *an inter-column*. When the intercolumniation is one diameter and a half, it is called *pycnostyle*, or columns thick set; when two diameters, *systyle;* when two and a quarter, *eustyle;* when three, *diastyle;* and when four, *aræostyle*, or columns thin set. Columns are sometimes set two and two together, having half a diameter for the smaller interval, and three and a half diameters for the larger; this disposition is termed *aræosystyle*. A colonnade is also named according to the number of columns which support the entablature, or fastigium; as, when there are four columns, it is called *tetrastyle;* when six, *hexastyle;* when eight, *octastyle;* and when ten, *decastyle*. The intercolumniations of the Doric order are regulated by the number of triglyphs, placing one over every intermediate column; when there is one triglyph over the interval, it is called *monotriglyph;* when there are two, it is called *ditriglyph;* and so on, according to the progressive order of the Grecian numerals. The intercolumniation of the Grecian Doric is almost constantly the monotriglyph, for there are only two deviations from this to be met with at Athens; the one in the Doric portico, and the other in the portico forming the entrance to the Acropolis, or citadel; but these intervals only belong to the middle intercolumniations, which are both ditriglyphs, and became necessary on account of their being opposite to the principal entrances. As the character of the Grecian Doric is more massive and dignified than that of the Roman, the monotriglyph succeeds best; but in the Roman it is not so convenient, for the passage through the intercolumns would be too narrow, particularly in small buildings; the ditriglyph is therefore more generally adopted. The aræostyle is only applied to rustic structures of the Tuscan order, where the intercolumns are lintelled over with architraves. When the solid parts of the masonry of a range of arcades are decorated with the orders, the intercolumns necessarily become wide, and the intercolumniation is regulated by the breadth of the arcades and of the piers.

Buildings with a colonnade projecting at one end are termed *prostyle;* with a colonnade at both and opposite ends, *amphiprostyle;* with the same on all sides of the building, *peristyle;* and with a double range of columns, *polystyle*.

It does not appear that coupled, grouped, or clustered columns ever prevailed in the works of the ancients; though, on many occasions, they would have been much more useful; we indeed find, in the Temple of Bacchus, at Rome, columns standing as it were in pairs; but as each pair is only placed in the thickness of the wall, and not in the front, they may rather be said to be two rows of columns, one almost immediately behind the other. In the baths of Diocletian, and in the Temple of Peace, at Rome, we find groined ceilings sustained by single Corinthian columns; but such a support is both meagre and inadequate. Vignola uses the same intercolumniation in all his orders. This practice, though condemned by some, is founded upon a good principle, for it preserves a constant ratio between the columns and the intervals. Of all the kinds of intercolumniation, the eustyle was in the most general request among the ancients; and though, in modern architecture, both the eustyle and diastyle are employed, the former is still preferred in most cases: as to the pycnostyle interval, it is frequently rejected for want of room, and the aræostyle for want of giving sufficient support to the entablature.

The moderns seldom employ more than one row of columns, either in external or internal colonnades, for the back range destroys the perspective regularity of the front range; the visual rays coming from both ranges produce nothing but indistinct vision to the spectator. This confusion, in a certain degree also attends pilasters behind a row of insulated columns; but in this the relief is stronger, owing to the rotundity of the column and the flat surfaces of the pilasters. When buildings are executed on a small scale, as is frequently the case in temples, and other designs, used for the ornaments of gardens, it will be found necessary to make the intercolumniations, or at least the central one, broader than usual, in proportion to the diameter of the columns; for when the columns are placed nearer each other than three feet, the space becomes too narrow to admit more than one person conveniently.

COLISEUM, or COLOSSEUM, the amphitheatre at Rome, built by the emperors Vespasian and Titus. *See* AMPHITHEATRE.

COLOSSEUM. Although it scarcely falls within our province to describe places of amusement considered merely as such, the structure known under the name at the head of this article, deserves, from its peculiar form, and the extreme taste displayed in its interior decorations, something more than a passing notice. The Colosseum, designed by Mr. Decimus Burton, is, in external form, a polygon of sixteen sides, of which the diameter is 130 feet. In the attic, all the faces of the polygon are shown; but below, three of them are occupied by the portico, a Doric hexastyle of about 70 feet in width. This order is here exhibited upon a much larger scale than had previously been done in any building in the metropolis, with the advantage of an effect not attainable with fewer columns, and with the still greater advantage of its character not being impaired by the introduction of features irreconcileable with any aim at a strictly Grecian style, there being n other within the portico than a single lofty doorway. "In its general form," observes Mr. W. H. Leeds, whose criticisms are always entitled to attention, "this edifice must be referred to a Roman, rather than a Grecian prototype, namely, the Pantheon, which circumstance it probably was that led one writer, who has attempted to describe the building, into a ludicrous blunder, for he has not scrupled to assure his readers, that its portico is *copied* from that of the Pantheon at Rome, 'which, in the harmony of its proportions, and the exquisite beauty of its columns, surpasses every temple on the earth!' Had he said that it was copied from Canova's church at Possagno, he would have been some degrees nearer the mark, at least as far as resemblance in regard to the order adopted, and the application of a Grecian style to the plan of the Roman Pantheon."

Mr. Hosking, in his "Treatise on Architecture," objects to the combination of the square and circle in the plan; observing, "Irregular and intricate forms in works of architecture, whether internally or externally, will be found unpleasing. Few can admire the external effect of the Pantheon, or of the structure in London called the Colosseum, which has been subjected to the same arrangement, though certain features in both may be good." Yet, with due deference to the opinion of such an authority, we should be inclined to demur to it, even had we not Canova's own example to oppose to it. In itself irregularity is a fault; but then the question is, whether the slight degree of it thus produced can be fairly termed so; besides which, by pushing the doctrine a little further, we may contend that a parallelogram is an irregular square, consequently faulty, and the flank and front of a Grecian temple do not exhibit that uniformity which they might and ought to be made to do. But we need not resort to any argument of that kind, because, were it not for the irregularity censured by that writer, and caused by the addition of a portico to the circular part of their plan, both the buildings he mentions would appear heavy, lumpish masses, whatever decoration might be bestowed upon them.

The Colosseum was built for the purpose of exhibiting a panorama of London, on a scale of magnitude hitherto unattempted. The projector made his sketches from an observatory placed on scaffolding several feet above the top of St. Paul's cross; these sketches were afterwards transferred to the canvass, and in their finished state display the whole of this vast metropolis and its environs, as it would appear on the clearest day, and aided by the most powerful vision. To use the somewhat magniloquent language of a contemporary, the spectator " sees beneath the summer sunshine of a serene sky, divested of the usual canopy of smoke and vapour, this great metropolis, with its countless multitude of streets and squares, its churches, palaces, mansions, hospitals, theatres, public offices, institutions scientific and literary; its noble river, with its numerous bridges; and in the distance a rich and varied expanse of rural and sylvan scenery, extending from the woodlands of Kent and Essex in the east, to the forest and castle of Windsor on the western horizon. Recovering from the wonder created by this first view of the picture as a whole, he finds new cause of astonishment in examining it in detail; for not only may the prominent structures be discerned and known, but every private residence in town or country, which is visible from St. Paul's itself, be recognized in the representation; and the various objects in the foreground, as well as in the distance, will bear the test of the telescope. To increase the effect, improve the convenience for inspection, and, at the same time, to augment the means of judging of the merits of the performance as a work of art, there is a succession of galleries, the highest of which is constructed for the purpose of giving a more satisfactory view of the distant country; an easy ascent from the galleries leads to an esplanade, on the circle that crowns the exterior of the Colosseum, from which is beheld a real panorama formed by the Regent's Park and its elegant vicinity."

Since the above description was written, the Colosseum, as a place of amusement, has suffered many vicissitudes, and at one time had fallen very low in public estimation; in the year 1844, however, it fell into the hands of the present proprietor, who has expended very large sums in completely remodelling the whole establishment.

The alterations considered desirable were made from the designs and under the direction of Mr. William Bradwell, whose taste, skill, and judgment have, in this instance, as in many others, produced the most admirable results. The ability he has displayed has been seconded by the proprietor with the greatest liberality, and the unhesitating appropriation of whatever amount of capital might be required to carry out the conceptions of the talented artist.

There are two entrances, one in the Regent's Park under the portico, the other in Albany Street, at the back of the building. Entering by the former, the visitor proceeds down a handsome staircase to a vestibule, leading to a large saloon, called the Glyptotheca, or Museum of Sculpture. The roof of this apartment presents to the eye a lofty dome, of several thousand feet of richly cut glass, springing from an entablature and cornice supported by numerous columns. The frieze is enriched with the whole of the Panathenaic procession from the Elgin Marbles, and is continued without interruption around the entire circumference of the hall, above which are twenty fresco paintings of allegorical subjects on panels, the mouldings, cornices, capitals of columns, and enrichments being in gold. Beyond the circle of columns is another of as many pilasters, dividing and supporting arched recesses, in each of which, as well as between the columns, are placed works of art from the studios of many eminent sculptors. In the centre of the apartment is the circular frame-work enclosing the staircase leading to the panorama; this is hung with drapery tastefully disposed, from the summit of the arched dome to the floor, concealing the stairs, and harmonizing with the prevailing tints of the architectural decorations. Around this are seats covered with rich Utrecht velvet, raised on a dais, and divided by groups of Cupid and Psyche supporting candelabra in the form of palm-trees; the figures being white, and the draperies, leaves, plumes, &c., gilded. From this hall, the visitor ascends to the panorama by the staircase, or is raised in a small room, called the *Ascending Room*, which is elevated by means of machinery to the required height.

A panorama of Paris by moonlight has now succeeded to the panorama of London before mentioned, and seems to attract as much as the former picture.

Since the creation of what may be termed the original structure, a considerable addition has been made to it on the eastern side towards Albany Street. Here is a second entrance, leading by large folding doors into a square vestibule, and thence into an arched corridor, lighted during the day from above by circles of cut glass; and at night by numerous bronze tripods. Descending to the basement story by three flights of steps, the visitor enters a spacious saloon, supported by columns and pilasters, appropriated to the sale of refreshments; from this room ornamented glass doors lead to conservatories, aviaries, and other objects of interest. In the upper story of this part of the building a handsome little theatre has been formed, the decorations of which are of the most gorgeous character. In this theatre is exhibited a moving picture called the "Cyclorama," in which a representation is given of the great earthquake at Lisbon in the year 1755. As a work of art, the panorama is deserving of high praise, and aided by the labours of the machinist, and the inventive ability of Mr. Bradwell, the presiding genius of the establishment, a scenic illusion has been produced, which is really well worthy of admiration. Altogether the Colosseum is deserving the attention of the architectural student, as something beyond a mere place of amusement. In it he may learn how much may be done in the way of decorative art, by a tasteful arrangement of those materials which the sister arts place at his disposal.

COLOSSUS, at Rhodes, a celebrated statue of Apollo, made of brass, popularly supposed to have been erected over the entrance of the harbour in such manner that a foot stood on each pier, and ships passed through its extended legs. This statue, of which Pliny has left an account, was begun by Chares, a pupil of Lysippus, and completed by Laches; twelve years were employed in making it. Its height was 105 feet; the thumb was so large that few men could span it, and its fingers were much larger than those of ordinary statues. It was cast hollow, and filled with large stones to counterbalance its weight, and keep it steady on its supporters. Within was a winding staircase ascending to the top, where it is said, was hung a vast mirror, in which the country of Syria, and ships entering the ports of Egypt, might be discerned. The notion that its legs rested one on each side of the harbour does not, however, seem to be supported by any good authority, and modern travellers do not agree as to its site.

After standing upwards of sixty years, the Colossus was overthrown by an earthquake in the year 224 B. C., by which also the buildings of the city suffered greatly. So great at that time was the commercial importance of Rhodes, that the great princes of the day vied with each other in the munificence of their presents to repair its losses. The inhabitants of Rhodes sent ambassadors to all the states of Grecian origin, to solicit their assistance for repairing and re-erecting their statue, and obtained a sum more than five times equal to the damage. The principal contributors were the kings of Macedon, Syria, Egypt, Pontus, and Bithynia. But, instead of appropriating the money to the purpose for which it was given, the Rhodian priests pretended that the oracle of Delphi had forbidden it; and the money was converted to other uses. The Colossus, therefore, lay neglected on the ground for 894 years, when the Saracens, becoming masters of the island, sold it to a Jewish merchant, who broke it up, and loaded 900 camels with the metal: the weight of the brass, therefore, allowing 800 pounds for each load, after the diminution it had sustained by rust, and probably by theft, amounted to 720,000 pounds weight.

This enormous figure was not the only colossal statue that attracted notice in the city of Rhodes, for Pliny reckons near 100 others. From the Rhodian Apollo, it is supposed, that every statue exceeding in magnitude the size of a man, has been called a colossal statue.

COLUMBARIA, the holes left in walls for the insertion of timbers; also the recesses in ancient tombs, in which the urns containing the ashes of the deceased were deposited.

COLUMELLÆ, the same as balusters. *See* Balustrade.

COLUMN (Latin, *columna*, derived from *columen*, a post, or supporter) in a general sense, a vertical support of a body, or portion of a building.

The use of columns is of very early date, as we hear of their application both in the Temple of Solomon, and in the Palace of Ulysses; they do not seem to have been employed in the primæval erections of Babylon, where their place was supplied by piers, but are to be found in universal application in the ancient structures of Egypt, India, and Persia. The column is so important a feature in the construction of buildings, that its value must have been early known, and when known, must soon have formed a subject for ornamentation; its origin is to be found doubtless in the simple pier, and a very good specimen of its progress in improvement of form and in application of ornament, is to be seen at Amada, in Nubia, where, amongst other columns or piers in the form of a simple parallelopiped, with base and capital of a similar form, but projecting a little beyond the surface of the shaft, those at the corners of the building are both cylindrical and fluted, leaving, however, a square abacus or capital, and square base, similar to the others. The former is undoubtedly the primitive shape; the latter, previously of the same form, whether for convenience or otherwise, has been rounded off at the corners and somewhat ornamented. Such improvements both in form and decoration, gradually progress, until we arrive at the well-proportioned and tastefully enriched columns of the classic orders, or the still more beautiful pillars of the Gothic styles.

The columns of Egypt exhibit a great variety, both in form and decoration: the capital in the shape of a vase or inverted bell, is usually decorated with foliage, frequently with the leaves of the lotus, but is of less elegant form than similar capitals of Greece and Rome; the shaft is generally circular, but sometimes square or polygonal, and varies in diameter at different heights, the thickness, in some cases, diminishing both towards the capital and base; this last member, the base, is frequently absent in Egyptian examples, and when present is of the simplest kind, consisting of a square slab or plinth. The columns were of stone, not unfrequently of a single block, and, at other times, of gigantic masses placed one upon the other. "There is a peculiarity, however," says Mr. Hamilton, "in the columns of the portico of Ashmounein not found, we believe, elsewhere in Egypt. Instead of being formed of large masses placed one above another, they consist of irregular pieces fitted together with such nicety, that it is difficult to detect the lines of junction; and this illusion is aided also by the form of the columns. The bottom is like the lowest leaves of the lotus, after which we see a number of concentric rings, binding the column just like the hoops of a cask; and again above them the column is worked in such a way by vertical cuttings, to present the appearance of a bundle of rods held together by hoops; the whole has the appearance of a barrel; the columns are about 40 feet high, including the capitals. Their greatest circumference is about 28½ feet, at the height of 5 feet from the ground, for the column diminishes in thickness both towards the base and capital. These columns were painted yellow, red, and blue. Similar pillars are found in the temple of Gournon."

Reeded columns, which bear the appearance of a bundle of reeds bound together at intervals and set on end, are not uncommon, and are often surmounted with a bulging capital, which is of similar formation to the shaft, with a cincture at its lowest part, and square flat abacus on the top, bearing the entablature; the swell or bulging would appear to be caused by the pressure of the entablature. Square columns are to be found in the excavations at Thebes, and triangular ones are spoken of by Pococke; at Ypsambool are square columns or piers with caryatid figures in front of them.

The forms of columns found in India vary considerably. In the subterraneous temples, which are excavated out of the solid rock, they are generally of a massive character, and in proportions stunted; they are rather grand than graceful. The bases are frequently cubical, and of great height in proportion to the shaft, sometimes equal to it; they are at other times octangular: the shafts are circular, or multangular, and sometimes consist of both forms one above the other, surmounted by low, compressed capitals. Columns of a balustral form are to be seen at the Temple of Elephanta; they are about 9 feet high, supported on cubical bases about 6 feet in height; the capitals, of a semicircular profile, exhibit the appearance of compressed cushions, and with the shafts, are ribbed or reeded: the whole is surmounted by an abacus of the form of an inverted truncated pyramid. Some very curious columns are to be seen in a cave at Ellora, which consist of elephants bearing castles, and surmounted at the top by a capital or abacus.

In the pagodas, or constructed temples of the Indians, the columns are of an entirely different appearance, they are by no means so stunted, and are often of quite an opposite character, slender; such are those in that part of the pagoda of Chillambaram called the Nerta Chabœi; they are, in all cases, profusely enriched with sculpture. The capitals of the columns are frequently made more effective to the support of the entablature by extending them out in the shape of brackets, so as to leave but a small portion of the entablature unsupported. Sometimes a succession of brackets project from the adjacent columns one above another, and meet in the centre, so as to leave no portion unsupported.

Of Persian columns we have but few examples remaining, but from these we may conclude that they were of slender proportions, the height of some of the existing specimens being as much as 70 feet, while their diameter is but 5¾ feet. Some of the shafts are fluted with fillets intervening, and are raised upon a base 4 or 5 feet in height, finished with sculptured mouldings. We have specimens of two kinds of capitals, the one consisting of small scrolls, somewhat similar to the volutes of the Ionic capital, placed in rows one above the other on the sides at the top of the shaft; the others projecting from two opposite sides of the shaft, after the manner of brackets or corbels, and sculptured into the shape of the fore-part of an animal, which in some degree resembles a horse. These columns must have possessed a considerable share of simplicity and elegance.

Of the columns of the Grecian or Roman orders we need say nothing in this place, not only because their forms are so well known, but also because they are so fully and minutely described in other parts of this book, and amply delineated in its illustrations. Some few remarks as to their form, &c. is appended to this article.

In those styles of architecture which immediately succeeded the Roman, and were indeed but debased copies of it, the column followed the general form and character of the original; some were formed of portions of columns taken from Roman buildings, and piled together indiscriminately in the new structures, which destroyed their proportions, while it preserved their form and details. Out of this chaos arose the styles afterwards prevalent in Italy and that portion of the continent, and we may add in Greece, for doubtless Byzantine architecture, although in a certain sense a distinct style, borrowed largely, both in its general features and its details, from the edifices of the deserted capital; indeed a debased imitation of the Corinthian column was very prevalent in the buildings of Constantinople. The copy was more successful in some instances than others, the foliage being frequently of very inferior design, and only carved out slightly in relief above the surface. The more characteristic capitals of the Byzantine style consisted of mere truncated pyramids inverted and ornamented with a kind of basket-work in low relief.

In Lombardic columns the base is frequently but a simple square block, rounded off at the top, though it sometimes consists of a carved lion or other monster supporting the shaft on its back; such bases are frequent in porches and in smaller structures, as tombs, &c. The shafts, especially of the larger columns, are circular, and of the same diameter from top to bottom; the proportion between the height and diameter varies very considerably, according to the purpose of the column and its material; when the weight to be supported is great, or the material used but little compacted, the shaft is low and massive; but when the weight is inconsiderable, it becomes tall and slender, and is sometimes divided in its height by moulded bands. Columns are sometimes coupled together, standing either side by side, or one in front of the other, of both which arrangements we have examples in the cloisters of S. Lorenzo and Santa Sabina, at Rome, where either arrangement is copied in the alternate piers; quadrupled columns are to be met with in the church of Boppart. When columns are attached to walls or piers, they not unfrequently have smaller shafts either before or beside them, somewhat similar to the clustered columns of later date; these smaller shafts, however, are never prolonged in the shape of ribs of a vault. The shafts of the smaller columns are not unfrequently polygonal, fluted, or reeded, and are sometimes formed of small shafts twisted together in a spiral line. The capitals are, for the most part, barbarous imitations of the classic orders, more usually Corinthian, and are sometimes ornamented with spear-heads, and scroll or fret-work, while some again are formed of animals real and monstrous, and ornamented with grotesque designs of all descriptions.

We have now arrived at the period of Gothic art, when the forms, proportions, and ornamentation of columns became of infinite variety, subject to no law save that of beauty and utility; so that to attempt to describe them in this place would be futile. We have them of all proportions save the stunted, and of all degrees of decoration, some with simple mouldings, others with foliated capitals; some with single shafts, others clustered; some circular, others polygonal. These, as is necessary, will be considered in detail, for which we refer to the various subdivisions into which the Gothic style is usually distributed.

Column, in the orders of classic architecture, consists of a conic or conoidal frustum, called *the shaft*, tapering upwards in the manner of a tree, with an assemblage of parts at the upper extremity, termed *the capital*, and with sometimes another assemblage of parts at the lower extremity, called *the base*. The capital finishes with a horizontal table, either square on the plan, or capable of being inscribed in a square, called *the abacus*. The base, also, when there is one, most frequently stands on a table, square on the plan, and horizontal on the upper and lower sides, called *the plinth*.

Vitruvius directs the columns at the angles to be made thicker than the intermediate ones; the diameter of columns to be proportioned to the intercolumns; that the higher they are, their diminution should be less; that those on the flanks and angles have their inner faces toward the walls perpendicular, but those of the pronaos and posticum to be set perpendicular on their axes; that those in theatres and other works of gaiety, should not have the same proportion as those in sacred edifices; and that the two middle columns, opposite the entry, should have a wider interval than any two of the others.

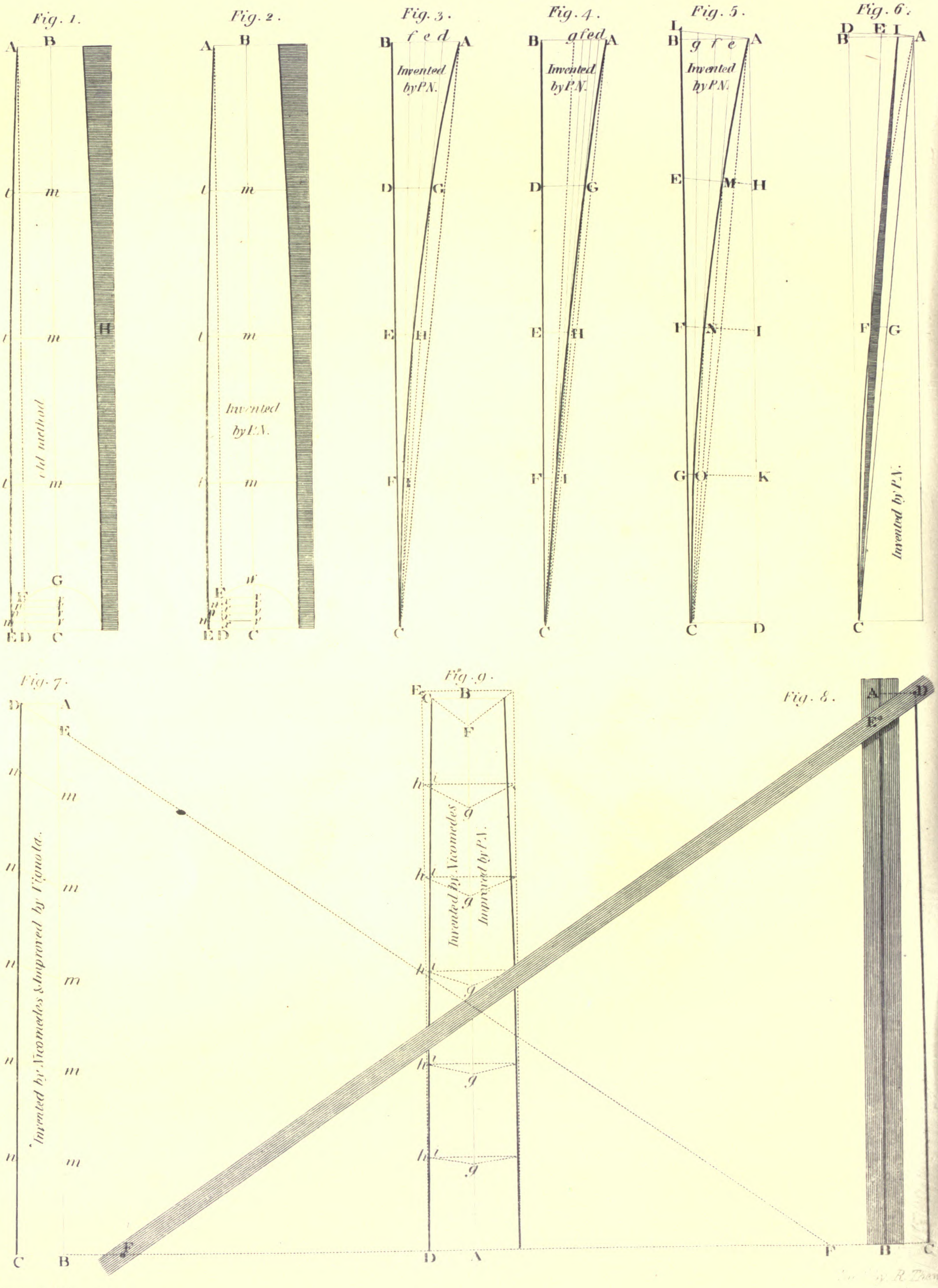
The Greeks seldom employed attached columns; the only instances of the kind in Attica, and indeed in all Greece, are the monument of Lysicrates and the temple of Minerva Polias, where the columns present something more than half their diameter. In the temples of Agrigentum and Æsculapius, in Sicily, the columns are also attached. The remains of Roman edifices show many instances of attached columns, as in the temple of Fortune, the triumphal arch of Titus, the Coliseum, and the theatre of Marcellus, at Rome, where the columns project only half their diameter; and this rule was strictly observed by the ancients, who generally tapered the shafts from the base.

The Grecian Doric is without a base, which is peculiar to the Ionic and Corinthian orders. Much has been said concerning the proportion of columns; but it must chiefly depend upon their situation, whether disposed on the exterior or interior, attached or insulated, on a level with the eye or raised above it; circumstances which will affect the proportion, and render all canonical rules uncertain. We also judge of the proportion of columns from the materials whereof they are constructed, as a column of iron will require a different proportion from one of stone.

Some columns have the lower third quite cylindrical, and the upper two-thirds only diminished, but the most beautiful diminish from the bottom.

In the preface to Stewart's third volume of *Antiquities*, speaking of the temple of Jupiter Olympus, at Athens, Mr. Reveley, who conducted that volume, observes, that "the columns diminish from the bottom by a beautiful curve line." In another part of the same preface, he farther observes, generally, that "the columns rise, with considerable diminution, in the most graceful sweeping lines." It is much to be regretted, that Mr. Stewart, who has, in general, been so particular in the measures of Grecian architecture, should have neglected a thing so important as the dimensions of the shafts of columns.

The columns of the Pantheon, of the temples of Vesta, of Jupiter Stator, of Antoninus and Faustina, of Concord, of the arch of Titus, of the portico of Septimius, and of the theatre of Marcellus, at Rome, are all diminished from the bottom.



Drawn by P. Nicholson.

Columns may be diminished by a curve, according to any of the following methods:

METHOD I.—*Figure* 1. Take the semi-diameter, A B, at the top of the shaft, and apply it from C to D on the semi-diameter, C E, at the bottom; with the radius, C E, describe an arc, E F. Draw D F perpendicular to E C, divide the arc E F into any number of equal parts (as four, in this example) E *n*, *n n*, *n n*, *n* F; also divide the representative axis, C B, into the same number of equal parts, C *m*, *m m*, *m m*, *m* B; through the points *m*, *m*, &c. and also through the points *n*, draw lines *m t* and *v n*, parallel to E C, of which the lines *v n* cut the representative axis at *v;* make all the lines *m t* equal to all the lines *v n*, beginning next to the base in succession, towards A B; then through all the points, *t*, draw a curve, which is the contour of the column. The edge of the diminishing rule H, shown upon the other side, is just the reverse, that is to say, it is concave, the contour of the column being convex.

METHOD II.—*Figure* 2. The points D and F, being found, as in Figure 1, instead of dividing the arc, E F, as in Figure 1, into equal parts, divide the straight line D F into the equal parts, D *x*, *x x*, *x x*, *x* F, and the representative axis C B, into the same number, and complete the other parts of the operation, as in Figure 1. The same letters of reference being fixed to the like parts, show the process to be similar.

METHOD III.—*Figure* 3. B C being the altitude of the shaft, and B A, at right angles to it, the quantity of diminution upon one side of it: divide C B into equal parts, at the points D, E, F; also divide A B into the same number of equal parts, at the points *d*, *e*, *f;* draw the lines D O, E H, F I, parallel to A B; again from the points *d*, *e*, *f*, to the point C, draw lines, *d* O C, *e* H C, *f* I C: and through the points A, O, H, I, C, draw a curve, which will give the contour required.

METHOD IV.—*Figure* 4. A B and B C, being the same as in Figure 3: now, suppose it were required to give less curvature to the contour of the column; between A and B take any intermediate point, *g*, nearer towards A, or B, as the curvature is intended to be flatter or quicker (in this example it is in the middle of A B); draw the line *g* C, divide A *g* into any number of equal parts, A *d*, *d e*, *e f*, *f g*, (as here into four); divide B C into the same number of equal parts, B D, D E, E F, F C; draw D O, E H, F I, parallel to B A, draw *d* O C, *e* H C, *f* I C, then through the points A, O, H, I, C, draw A G H I C, which is the curve required.

METHOD V.—*Figure* 5. Join A C, and draw A L at right angles to it, meeting C B produced at L; draw A D parallel to C L, and C D perpendicular to it; divide L C and A D, each into the same number of equal parts, the former at the points E, F, G, and the latter at H, I, K; also, divide A B into the same number of equal parts, A *e*, *e f*, *f g*, *g* B; join E M H, F N I, G O K; also *e* M C, *f* N C, *g* O C, and draw A M N O C, which is the curve required.

METHOD VI.—*Figure* 6. Join A G C, and bisect it by a perpendicular, F G; on the centre, C, with the radius, C A, describe the arc A D; divide A D into two equal parts in E; draw E F C, and parallel to G A draw F I; make an angle, C F I, upon the edge of a board or rule, put in pins at the points C and F, and with a pencil, upon the angular point F, while the rule is moved from F to C, keeping the side F I of it upon the pin at F, and the same side F C, upon the pin at C, the angular point F will describe the contour of the column between F and C. In like manner, by removing the pin out of C, and putting it in A, the part F A may be described.

The same curve might have been found by one continued motion from A to C, as follows: suppose the line D C to have been produced to a point, K; the supposed line, C K, to have been equal to C D; and an angle, having been made upon the edge of a thin board, equal to A C K; then the contour, A F C, would have been described in the same manner, between the points A and C, as each of the former parts shown by the figure. It is obvious, that by this last method, it would be requisite to have the machine twice the length of that in the first method; from which it would become more unmanageable in the formation of the curve, and inconvenient in many situations, for want of space to extend it to the necessary distance.

METHOD VII.—*Figure* 7. Let A B be the representative axis of the column; A D, B C, the semi-diameters of the top and bottom of the shaft; produce C B to F; on the point D, with a radius, C B, describe an arc, cutting A B at E; draw D E F; in A B, take any number of points, *m*, and draw the lines F *m n;* make each line *m n*, equal to B C; then draw D *n n* . . . C, which will be the curve required.

METHOD VIII.—*Figure* 8. The points E and F being found as in Method VII. place a rule with a canal, or groove, on the axis A B, and put a pin in F; take another rule, D F, having a groove on the under side, and lay this groove on the pin at F; put another pin through the rod at E, into the groove A B; then, with a pencil, through D, and moving the ruler D F, while the pin E slides in the groove A B, and the groove on the under side of D F on the pin F, the contour D C, will be described with one movement.

METHOD IX.—*Figure* 9, A B being the axis of the column; A D and B C the lower and upper diameters; draw D E parallel to A B; find the point F, as in Methods VII. and VIII., and draw E C F; divide A F into any number of equal parts, by the points *g;* also divide D E into the same number of equal parts, by the points *h;* join each corresponding *g h;* make every *g i* equal to A D, and the curve drawn through all the points *i*, will be that required. This mode is practised when room cannot be found for Figures 7 and 8, with which it is the same in principle.

Observations on the several methods.—By the First Method, the curvature of the shaft becomes continually less towards the superior diameter, and if the contour were extended beyond the shaft, it would meet in a point, of which its distance from B would be a fourth proportional to the length of the arcs E F, F G, Figure 1, and the axis C B; the semi-axal section of the whole thus produced, is a figure of the same nature as the figure of the sines.

By the Second Method, the curvature of the shaft is continually increased towards the superior diameter, and if the contour were extended above A B, Figure 2, it would terminate at a distance from C, which would be a fourth proportional to D F, C *w*, C B; the contour thus produced, would be an elongated semi-ellipsis.

By the Third Method, the curvature of the shaft is continually less towards the superior diameter, and if the contour were extended, the two sides would meet in a point, whose distance from the lower end of the shaft would be the second root of a fourth proportional to the quantity of diminution, the semi-diameter at the bottom, and the square of the altitude of the shaft. The shaft and the part thus produced, forms the half of a parabolic spindle; and the axal section is two equal semi-parabolas, joined together by a common ordinate, which forms the axis of the column.

By the Fourth Method, the curvature is likewise parabolic; but the axal section is two equal portions of a parabola, less than semi-parabolas.

By Methods V. and VI., the curvature is everywhere the same, and is consequently the arc of a circle: this contour would therefore meet in a point, which would be distant from the lower end of the shaft, by a quantity equal to the value of

$$\sqrt{\text{C M}\left(\frac{\text{B C}^2}{\text{A B}}+\text{A B}-\text{C M}\right)}$$ in which B C is the height of the shaft, A B the quantity of diminution, and C M the semi-diameter at the bottom.

By Methods VII., VIII., and IX., the contour of the shaft never terminates when continued. The curve is concave to the axis at the bottom, and after a certain distance, it changes into a convexity. The curve is called *the conchoid of Nicomedes*, who is the reputed inventor; the straight line, in which the moving point runs, is an *assymptote;* and the point over which the moveable rule passes, is called *the pole*.

As the curve may either fall upon one side or the other of the axis, it is distinguished accordingly: when it falls on the side of the axis opposite to that in which the pole is situated, it is called *the first conchoid;* and when the describing point is made to move on the same side of the axis with the pole, the curve so formed is called *the second conchoid.*

This last method of describing a column by continued motion, has been much praised in architectural works; but though the method be simple, the instrument is very cumbersome. It may be observed, that as all curves are nearly the same at the vertex, so small a portion as is required for a column, will be the same in practice, by any of the foregoing forms. The most useful method, therefore, of describing the contour of the shaft, is that of Figure 6; the instrument is much more simple, and takes less room, which, in many cases, would not admit of that for describing the conchoid; and even that of forming the curve by one motion, as shown at the end of Method VI., is much more convenient, as length or extension in one direction only, is required. But where space is wanting, Methods III. and IV. are recommended.

Columns are variously named, according to their materials, construction, formation, decoration, disposition, and destination.

1. Columns, according to their materials, are, *moulded*, *fusible*, *transparent*, *scagliola*, *masonic*, or *wooden*.

When a column is made by cementing gravel and flints of different colours, it is called *a moulded column.*

The art of moulding columns was known to the ancients, as would appear by some lately discovered near Algiers, in the ruins of the ancient city of Cæsarea; where the same inscriptions in antique characters, and even the same defects, are to be found repeated on every shaft, which is certainly a proof of their being moulded: the cement employed in the emplastation of columns, grows perfectly hard, and receives a polish like marble.

Columns of fusible matter, as metals, glass, &c., are called *fusible columns;* the secret of making them is said to have been known to the ancients, who are also said to have fused and cast columns of stone. Columns of this description may also be called *moulded columns.*

When the material of which a column is made is transparent, the column is called a *transparent column.* The columns of the theatre of Scaurus, mentioned by Pliny, were of crystal, and those in the church of St. Mark, at Venice, are of transparent alabaster.

When columns are constructed with a kind of plaster, so as to imitate marble in polish and colour, they are called *scagliola columns.*

Columns built of rough stone, or compass bricks, and cased with stucco, are called *masonic columns*, or *columns of masonry;* as are likewise those made in courses of stone, jointed, and cemented in the best manner, with a rubbed or smoothed surface. *See* Stone Column.

When the shaft of a column is constructed of wooden staves, glued together, and the interior angles strengthened with blockings, the column is said to be *a joinery column. See* the articles Base, Capital, and Wooden Column.

2. Columns, according to their construction, are *columns in bands* or *tambours*, *columns in trencheons*, or *banded columns.*

When the shafts of columns are formed of courses of stone of a less height than the diameter of the column, they are called *columns in bands* or *tambours.* This method is only practised in large columns.

When shafts of columns are formed in courses of greater height than the diameter of the column, they are said to consist of *trencheons;* this is practised in small columns, when the fewer the pieces, the more beautiful will the column be; but the difficulty of raising them from the quarry is greater, and the carriage more expensive.

When the shafts of columns consist of plain or ornamented cinctures, projecting beyond the general line of the shaft, the column is said to be *banded*, and is therefore called *a banded column.* Columns of this description were first introduced by De Lorme, in the chapel de Villers-Coherets, and at the Tuileries, who by this means supposed the joints would be concealed.

3. Columns, according to their formation, are *attic*, *conical*, *conoidal*, *cylindrical*, *cylindroidal*, or *polygonal.*

The *attic column* is an insulated pilaster, having four equal faces, of the highest proportion. Though this is commonly inserted among the number of columns, it should not be so deemed, but rather what we have already denominated it, an insulated pilaster. To prevent confusion, the use of the term *column*, in architecture, should be restrained to a body of circular horizontal sections.

A conical column has the superior diameter of its shaft less than the inferior, with its sides straight in every plane passing through the axis.

A conoidal column also has the superior diameter of the shaft less than the inferior, but its exterior sides are convex in any plane passing through the axis. This practice of making the shaft swell is ancient, being mentioned obscurely by Vitruvius, and has been generally followed by modern architects.

Cylindrical columns have the extreme diameters of the shafts of equal circles.

Cylindroidal columns are those whose sections are all similar and equal ellipses, alike situated. These are otherwise called *elliptic columns.* Instances of this form are rarely to be met with in the remains of antiquity; a few examples, of modern date, are to be seen at Rome.

Polygonal columns have the horizontal sections of their shafts similar to polygons, alike situated. The lower parts of the shafts of the columns of the portico on the Island of Delos and of the temple of Cora, are of this form; as are likewise the columns of several Egyptian buildings.

4. Columns, according to the decorations of their shafts, are *bark-formed*, *cabled*, *carolytic*, *fluted*, or *twisted.*

A bark-formed column represents the trunk of a tree, with the bark and knots. This is otherwise denominated *a pastoral column.*

Cabled or *rudented columns* have the flutings of the shaft filled with astragals, to about one-third of their height.

Carolytic columns have foliated shafts, decorated with leaves and branches winding spirally around them, or disposed in form of crowns and festoons. They were used by the ancients for supporting statues, whence the name. They are suitable in theatres, triumphal arches, &c.

Fluted columns have flutes cut in their sides, in planes passing through their axes, and are otherwise called *channeled* or *striated columns*.

Twisted columns make several circumvolutions in the height of the shaft, after the manner of a screw, and have sometimes several threads or screws following one another in the same circumference; they are otherwise called *spiral columns*. Vignola is said to be the first who discovered the method of drawing this kind of column by rule; but what has been presented to us by this author, is only an incorrect method of drawing the contour of the column on paper, by segments of circles, diminishing in altitude as they become more elevated in their regular succession: but the true principles of forming the shaft ought to be shown from the principles of the spiral, and described upon the conoidal surface. The barbarous practice of twisting columns has been much used by modern architects, particularly in the screens and altar-pieces of churches. The most celebrated example is the baldachin of St. Peter's.

Columns spirally formed may be seen in the temple of Spoleto, and are not unfrequent in sarcophagi and other ornamental works.

5. Columns, according to their disposition, are *angular*, *cantoned*, *coupled*, *doubled*, *engaged*, *flanked*, *grouped*, *inserted*, *insulated*, *median*, or *niched*.

Angular columns are insulated in the corners of a portico, or upon the corners of a building, (even though attached,) whether the angle be right, acute, or obtuse.

Cantoned columns are placed one at each corner of a square pier, for supporting the angular springings of groins, or intersecting vaults.

Coupled columns are disposed in pairs, in the same range or line, so as almost to touch at their bases; as those in the western portico of St. Paul's, and the peristyle of the Louvre.

Doubled columns, in any range of columns, or in peristyles, seem to have their shafts penetrating each other to about one-third of their diameter; as in the peristyle of the Louvre.

Engaged columns seem to penetrate a wall from between one-fourth to one-half of their diameter.

A *flanked column* has a semi-pilaster on each side of it, and is engaged from one-fourth to one-half its diameter, within the plane of the faces of the semi-pilasters.

Grouped columns stand in threes or fours on the same pedestal.

An *inserted column* is let into a wall.

An *insulated column* is free or detached on all sides.

Median columns are those two columns of a portico, which are placed in the middle of the range, at a wider interval than any other two of the same range, for giving a freer access to the principal entrance. The term is derived from *columnæ mediæ*, the name given by Vitruvius to the two columns in the middle of the colonnade.

A *niched column* is placed in a niche, with the axis of the column in the plane of the wall.

6. Columns, according to their destination, are *agricultural*, *astronomical*, *boundary* or *limetrophus*, *chronological*, *funeral*, *gnomonic*, *historical*, *indicative*, *itinerary*, *lactary*, *legal*, *manubiary*, *menian*, *miliary*, *military*, *phosphorical*, *rostral*, *statuary*, *symbolical*, or *zoophoric*.

Agricultural columns are raised for explaining the rules of agriculture.

An *astronomical column* is a cylindrical or conical observatory, built hollow, with a winding staircase ascending to an armillary sphere at the top, for observing the motions of the heavenly bodies. Such is the Doric order, erected at the Hotel de Soissons, at Paris.

Boundary or *limetrophus column* showed the limits of a kingdom, or conquered country. Such was that erected by Alexander the Great at the extremities of the Indies, mentioned by Pliny.

A *chronological column* bears an inscription of historical events, arranged in order of time. There were two columns of this kind at Athens, whereon was inscribed the history of Greece, digested into Olympiads.

A *funeral column* is placed over a tomb, supporting an urn, or bearing some inscription relative to the deceased. Its shaft is frequently covered with symbols of grief and mortality.

A *gnomonic column* is a cylinder, on which the hour of the day is represented by the shadow of a style. There are two kinds of gnomonic columns: in the one the style is fixed, and the hour-lines are projected on the cylindric surface; in the other, the style is moveable, and the hour-lines are drawn to the several heights of the sun in different seasons of the year.

An *historical* or *triumphal column* is usually adorned with basso-relievos, winding spirally upwards around the shaft, and showing the history of some great personage. The most celebrated ancient triumphal columns are those of Trajan and Antoninus Pius at Rome, and Pompey's Pillar, near Alexandria, Egypt; of modern ones we have three in London—the Monument erected in memory of the Great Fire, that erected in honour of the Duke of York, and another in memory of Lord Nelson, in whose honour there is an earlier one at Edinburgh; there is likewise a celebrated column termed Buonaparte's Column, in Paris.

Trajan's Column is of the Doric order, and constructed of marble; the face throughout its length is covered with sculptures arranged in a spiral line, running up the shaft, representing his martial exploits; its total height, including a base or pedestal of 19 feet, is 132 feet, and the diameter of the shaft at its junction with the base 13 feet.

The column of Antoninus is similar to that of Trajan both in its style and general character, though not equal to it in execution. Its height is 122 feet, including a pedestal of 26 feet, and the diameter of the shaft 11 feet 6 inches.

Pompey's Pillar at Alexandria is of the Corinthian order, and is 92 feet in total height. The shaft, which is 66 feet in height, is of a single block of granite, and polished.

Of the columns in London, the Monument is the most celebrated. It is of the Doric order, and has a fluted shaft; its total height is 202 feet, and the diameter of the shaft at its base 15 feet.

At Constantinople were two triumphal columns, similar to those of Trajan and Antoninus; that of Constantine is entirely destroyed, and of the other, erected to Arcadius, by Theodosius, only the pedestal and the first course of the shaft remain. Historical columns may also be called *memorial*, *honorary*, or *triumphal columns*.

An *indicative column* is placed on the sea-coast, for showing the rise and fall of the waters. Of this kind is the Nilometre, at Grand Cairo, which shows the rise and fall of the Nile.

Itinerary columns are constructed with several faces, and placed at the intersection of two or more roads, to point out the different routes by an inscription placed on each face.

The *lactary column* was erected in the herb-market at Rome, on a hollow pedestal, wherein young children, abandoned by their parents, out of poverty or inhumanity, were exposed to be brought up at the public expense.

A *legal column*, among the Lacedæmonians, was raised in a public place, inscribed with the fundamental laws of the state.

A *manubiary column* is built in imitation of a tree, and adorned with trophies taken from an enemy.

Menian columns support a balcony or meniana. This kind of column takes its name from one Menias, who having sold his house to Cato and Flaccus, when consuls, to be converted into a public edifice, reserved to himself the right of raising a column on the outside, to bear a balcony, whence he might see the public shows. We are informed of this circumstance by Suetonius and Ascanius.

Military columns were raised equidistantly on the highways from Rome to the several cities of the empire, and described their distance from the middle of the Roman Forum, as a centre, where the first military column was raised by order of Augustus. This column was of white marble, of a cylindrical form, and massive proportions, supporting a globe, the same as is now seen on the balustrade of the staircase of the Capitol at Rome. This column was called *miliarium aureum*, as having been gilt, or at least the ball, by order of Augustus. It was restored by the Emperors Vespasian and Adrian, as appears from the inscriptions.

A *military column*, among the Romans, was engraven with a list of the forces in the Roman army, ranged in order by legions, and intended to preserve the memory of the number of soldiers, and of the order observed, in any military expedition. Another kind of military column, used by the Romans, stood before the temple of Janus, at the foot whereof the consul declared war, by throwing a javelin towards the enemy's country. This column was called *columna bellica*.

A *phosphorical column* is a hollow column, built on a rock, or the tip of a mole, or other eminence, to serve as a lighthouse, or lantern, to a port.

A *rostral column* was a triumphal column, adorned with the beaks and prows of galleys, in memory of a naval victory. The first rostral column was erected in the Capitol, on occasion of the defeat of the Carthaginians by C. Duilius. Augustus constructed four columns with the prows of the ships taken from Cleopatra.

A *statuary column* supports a statue.

Symbolical columns represent some particular country, by appropriate attributes.

A *zoophoric column* is a kind of statuary column, bearing the figure of some animal.

There are also other columns, denominated *hydraulic*, or *water-columns*, used as fountains.

COLUMNIATED WINDING-STAIRS. *See* Stairs.

COMA (from the Greek κῶμα, *sleep*) in antiquity, a mound of earth over a grave.

COMITIUM (Latin, *an assembly*) in Roman antiquity, a large hall in the forum, in which comitia were ordinarily held. Prior to the period of the second Punic war, it was open at the top; but on account of the assemblies being often interrupted by bad weather, it was then covered over.

COMMANDERY; a religious house belonging to the Knights Hospitallers, the same as a preceptory with the Knights' Templars. Previous to their dissolution in the time of Henry VIII., there were no less than fifty such buildings subject to the priory of St. John of Jerusalem.

COMMISSURE (from the Latin, *commissura*) the joint between two stones, or the application of the surface of one stone to that of the other.

COMMON (from the Latin, *communis*) in geometry, a line, angle, surface, or solid, which belongs equally to two or more objects.

Common Centering, a centering without trusses, having a tie-beam at the bottom; or otherwise, that which is employed in straight vaults.

Common Joists, those beams in single naked flooring to which the joists are fixed; they might be properly called *boarding-joists*, and should never exceed one foot clear of each other.

Common Pitch, a term applied to a roof which has the length of the sides about three-fourths of the span.

Common Rafters, those timbers in a roof to which the boarding or lathing for slating is attached. Common roofing consists entirely of common rafters, which, in the strongest-framed roofs, bridge over the purlins.

COMMUNICATING-DOORS, or Doors of Communication, those which open or throw two apartments into one.

COMPARTED (from the French, *compartir*, to divide) a line, surface, or solid, divided into several parts; or a hollow space partitioned into several smaller spaces.

COMPARTITION, the distribution of the ground-plot of an edifice into apartments and passages.

COMPARTMENT (from the French, *compartiment*) a division of a picture, design, &c.

Compartment Ceiling, a name given to all ceilings divided into panels, surrounded with mouldings. There are many beautiful ancient compositions of this kind applied to the intradoses of cylindrical and spherical vaulting, and to the soffits of the porticos of temples; as may be seen in the Pantheon and the Temple of Peace. The compartment ceilings of the last century were extremely heavy, which has occasioned the epithet *pondrous* to be applied to them, in order to distinguish them from those in present use. These weighty compositions took their rise in Italy, under the first masters, who seem to have been led into that idea, from observations on the soffits of the porticos of antique temples. The ancients, with their usual skill, kept up a bold and massive style, proportioning their coffers to the strength, magnitude, and height of the building, and at the same time making an allowance for their being on the exterior part, adjoining to other great objects; all which served to diminish and lighten the effect of the compartments. From this mistake of the first modern restorers in Italy, all Europe has been misled. Michael Angelo, Raphael, Pyrro, Ligerio, Dominichino, Georgio Vasari, and Algerdi, with great taste and knowledge, threw off those prejudices, and boldly aimed at restoring the antique in due proportion. But at this time, the rage for painting became so prevalent in Italy, that, instead of following these great examples, every ceiling was covered with large fresco compositions, which, though extremely fine and well painted, were much misplaced, and would, from the attitude in which they were beheld, tire the patience of every spectator. Great compositions should be placed so as to be viewed with ease. Grotesque ornaments and figures are perceived with a glance of the eye, and require little examination. The heavy compartment ceilings were afterwards adopted in France; and Le Potre adorned them with all the trappings of his luxuriant imagination. Inigo Jones introduced them into England, with as much weight, but less fancy and embellishment. Vanbourgh, Campbell, and Gibbs followed too implicitly the authority of this great name. Kent has the merit of being the first who began to introduce grotesque paintings in ornaments of stucco, and to lighten the coffers of compartment ceilings. Mr. Stewart, with his good taste in the antique, has contributed greatly towards introducing the true style of decoration; but the completion seems to have been reserved to the present times, in which not only these, but every other kind, are executed in the highest degree of perfection.'

Compartment Tiles, an arrangement of white and red tiles, varnished, for the decoration of the covering of a roof.

COMPASS-HEADED, having a semicircular head.

Compass Roof, that which extends from one wall to the other the whole width of the building, having a ridge in its centre; the term is used in contradistinction to lean-to roof, and is peculiarly applied to the ancient open timber roofs. The term is applied by some to roofs with cylindrical or barrel vaults.

Compass Saw. *See* Saw.

Compass Window, a window which has a circular plan; a bow or oriel window.

COMPASSES, (from the French, *compas*) a mathematical instrument for describing circles and ellipses, or their arcs; also for measuring and proportioning distances.

Compasses for drawing are of four kinds: those with two legs, moveable on a joint, by which the extremities can be extended to any distance, not exceeding the sum of both legs, are called *common compasses.* Those with a beam having a fixed point at one of its ends, and a moveable collar carrying another point, which may be fixed at any distance from the fixed point by means of a screw, are called *beam compasses.* Those with three legs, so as to be set to any three points, of which the distance between any two may not be greater than the sum of any two legs of the compass, are called *triangular compasses.* Those for drawing ellipses, are called *elliptic compasses.*

Common compasses are of several kinds, and are furnished with fixed or moveable points, for carrying a pencil or ink foot.

Common compasses with sharp points, used for taking distances, are called *dividers.* Dividers, which have the lower point of one of the legs fastened to the upper part by a stiff spring, and by means of a screw will allow of slow motion in the legs, so as to extend or shorten the distance of the points to the smallest degree, are called *hair compasses.* Those with moveable ink and pencil feet, for describing circular lines, are called, in contradistinction, *compasses;* the ink or pencil foot is fitted into a socket in one of the legs of the compass. Besides the ink and pencil feet, there is sometimes another foot for dotting circular lines, but it is seldom used, as being apt to run two or more dots into one. Compasses for describing small circles with ink or pencil, and which shut into a bow, are called *bow compasses.*

Triangular compasses have two legs, which revolve on a folding joint, like common compasses, and the third leg is fixed to the bulb by means of a projection, with a joint, so as to be moveable in every direction. The three points of the compasses may be made almost to coincide with any three assumed points, to any distance within the reach of their extension.

Compasses with a joint between the extremities, and two sharp points at each end, forming a double compass, so that the two ends may always preserve the same ratio, however extended, are called *proportional compasses.* When the joint is fixed, the compass is said to be *simple;* but when moveable, it is called *a compound proportional compass.*

The simple proportional compasses, in most general use, have the two legs on one side of the centre always double those on the other, and are denominated *wholes-and-halves,* or *bisecting compasses.*

Compound proportional compasses have each branch cut with a long slit for a cursor to slide in; in the middle of the cursor is a screw, by which the ends may be set in any proportion to each other. One leg is generally graduated on either side of the slit, one side for the division of right lines into any number of equal parts from 2 to 10, and the other for inscribing polygons from 6 to 20 sides in a circle of any given radius within the greatest extension of the compasses. The other leg is graduated in a similar manner, one side into divisions, showing the proportion between the areas of similar plane figures, the other into parts showing the proportion between the contents of similar solid figures. This instrument is employed in the reduction of figures, and is extremely useful in the projection of dome departments, and in perspective.

Examples of the use of compound proportional compasses.—Let it be required to divide a straight line into four equal parts; push the cursor till the index be just on the figure 4, and fix it there; then take the length of the given line with the longer legs, and the distance between the points of the other legs will be one-fourth of the length of the line.

Again, let it be required to inscribe a heptagon in a circle: push the cursor till the index or zero be on 7; then, with the longer legs take the radius of the circle, and the distance between the two other points will be the side of the heptagon. *See* Projection.

To find a regular plane figure whose area shall equal one-fourth of that of a given similar figure; set the zero on the cursor to the line marked 4, take the length of one of the sides of the given figure with the longer legs, and the distance between the points of the shorter ones will give the side of a similar figure which shall contain an area equal to one-fourth of the area of the given figure.

By means of the same scale of divisions, may be found the square root of any given number, thus:—Set the zero of the cursor to the given number; open the longer legs so as to contain the same number from any scale of equal parts, then apply the points of the shorter legs to the same scale, and the distance measured between them will give the square root of the given number.

To find a sphere or cube whose solid contents shall be equal to one-fourth of those of a given square or cube: Set the zero to the division marked 4, measure the diameter of the given sphere, or the side of the given cube, with the points of the longer legs, and the points of the shorter ones will give the diameter of a sphere or side of a cube such as required.

The cube root of any number may be found by this scale in a similar manner to that by which the square root is found by the opposite one.

Compasses used in the description of ellipses, are called *elliptic compasses,* or *ellipsographs.* *See* Ellipsograph and Pentagraph.

COMPASSING (from the French, *compasser,* to encircle) in naval architecture, the act of bringing any piece of timber into the form of an arch.

COMPLEMENT (from the Latin, *complementum,* perfection) in a general sense, the full quantity, or completion of anything.

Complement, in geometry, whatever is wanting of any angle to make a right angle, or 90 degrees.

Complement of a Parallelogram, two lesser parallelograms, made by drawing two right lines parallel to the sides of the greater parallelogram, through a given point in the diagonal.

COMPLUVIUM (Latin) in ancient Roman buildings, is supposed by Newton to be the gutter of a roof; but by Dr. Adam (*Roman Antiquities*) to be the aperture at the top of the cavædium. *See* Cavædium.

COMPOSITE ARCH, the pointed or lancet arch.

Composite Base,
Composite Capital, } *See* Roman Order.
Composite Order,

COMPOSITION, the distribution and arrangement of the component parts of an architectural design.

Composition, in plastering. *See* Plastering.

COMPOUND ARCH, a term applied by Willis to those arches made up of a series of receding concentric arches, the dimensions contracting with each successive arch; or in other words, to those arches which may be resolved into a number of concentric archways, successively placed within and behind each other.

Compound Masonry. *See* Masonry.

Compound Pier, the same as Clustered Column.

Compound Proportional Compasses. *See* Compasses.

CONCAMERATE (from the Latin, *concamero*) to arch over.

CONCATENATE (from the Latin, *catena*) to chain or link together.

CONCAVE (from the Latin, *concavus*, hollow) an epithet applied to the interior side of a figure, or to the interior surface of a body.

Concavity of a Curve Line, the side next to a straight line, extended between the two points of a curve.

Concavity of a Solid, the curved surface of a solid, such that if any two points be taken in that surface, the straight line between them will be entirely in a void space, or will coincide with the surface in one direction only. This definition applies to cylinders, cones, spheres, and all other solids generated by the rotation of conic sections about an axis.

When the surface of a solid is such, that two straight lines may be drawn from any point in that surface to two other points, so that the one line may be entirely in the void, and the other pass through the substance or solid, the surface may be distinguished by the epithet *concavo-convex;* of which description are the surfaces of solids formed like a trumpet-mouth.

CONCENTRIC (from the Latin, *concentricus*) in geometry, a term applied to such objects as have a common centre. It is principally used in speaking of round bodies, or figures that have a circular or elliptic circumference; and may also be applied to polygons that have the same centre, and their sides parallel to each other, about the same diagonals, radiating from the centre.

CONCHA, the concave surface of a semicircular vault, more especially applied to that of a semi-dome, or hemisphere.

CONCHOID (resembling a shell.) This name was given by the inventor, Nicomedes, to a curve, by which he proposed the finding of two mean proportionals, and the duplication of the cube. It may be described as a curve line which always approaches to a straight line but never meets it, though the straight line and the curve be ever so far produced. It is thus generated: If A P and B D be two right lines intersecting each other at right angles; and if from a fixed point, P, a number of other lines, P F D E, P F D E, &c. be also drawn, and if D E be taken equal to A B, the curve drawn through all the points E, E, E, &c. will be the first conchoid, or that of Nicomedes. In like manner, if D F, D F, &c. be taken each equal to B C, the curve passing through all the points, F, is called the second conchoid. The straight line, D D, &c. by which the description of these curves is regulated, is called *the asymptote.* The inventor, Nicomedes, contrived an instrument for describing his conchoid by a mechanical motion, of which the description will be found under Column.

CONCLAVE (from the Latin) a room in the Vatican, wherein the cardinals used to meet to choose a pope. This room was, in fact, a range of small cells or apartments, standing in a line along the galleries and hall of the Vatican. The word was also used by the ancient Romans, to denote, generally, a room under lock and key.

CONCORD, *Temple of,* in Roman antiquities, a temple, built by Camillus at the foot of the Capitol, and seen from the Forum: the remains consist of a hexastyle portico, with two columns at the back, of the Ionic order; the entablature is very nearly entire; a large portion of the tympanum, and a small part of the pediment, remain at the spring of the level cornice. The weight of the tympanum is discharged from the entablature with arches. The columns are of granite, of one piece each, being 40 feet high, and 4 feet 2 inches diameter. The bases are without plinths, except those of the angular columns. The capitals are of a singular construction, and differ from all ancient examples of the same order, in having the four faces alike. The volutes are insignificantly diminutive, and the mouldings too large, compared with the other parts of the column. The architrave and frieze make only one course in height; and on the front, and at one return of the portico, are entirely plain, without any separation by mouldings. The cornice has both modillions and dentils. This is perhaps the only ancient example of the Ionic order, in which modillions are used: they are in number twenty-two in the front of the portico. An interval is placed over the axis of each column, and not a modillion; and the columns are very high, being above nine diameters and a half. This temple is supposed to have been pseudo-peripteral. The column on the right angle is less than the rest, and the middle intercolumniation greater than the others, by about one-third part of a module.

CONCRETE, the name given to a composition, variously made, but in general use among architects as an artificial foundation for buildings.

The convenience of obtaining a firm and solid bottom by the formation of a compact mass of concrete; and the facility with which this composition is made and used, have led to its almost universal adoption in all situations where the requisite materials can be procured. The proportions, and the species of material vary, of course, in different localities, and in the practice of different architects, but the principal ingredients, good lime, clean sharp river-sand, and pebbles well mixed, will not fail to make a good concrete.

Semple recommends to take 80 parts of pebbles—each about 7 or 8 ounces in weight—40 parts of sharp river-sand, and 10 of good lime; the last to be mixed with water to a thinnish consistence, and grouted in. The concrete used by builders in the neighbourhood of London, is made of Thames ballast, as taken from the bed of the river; this is found to consist nearly of 2 parts of pebbles to 1 of sand, and from one-seventh to one-eighth part of lime. Mr. Godwin says the best method of making concrete is to mix the lime, previously ground, with the ballast in a dry state; sufficient water being thrown over it to effect a perfect mixture; it should then be turned over two or three times with shovels, put into barrows, and wheeled away for instant use. It is advisable to employ two sets of men to perform this operation, with three men in each set, one man fetching the water, &c. while the other two turn over the mixture to the second set, and they, repeating the process, turn over the concrete to the barrow-men. After being put into the barrows, it should be wheeled up planks, so raised as to give it a fall of some yards, and thrown into the foundation, by which means the particles are driven closer together, and greater solidity is given to the whole mass. Soon after being thrown in, the mixture is observed usually to be in commotion, and much heat is evolved with a copious emission of vapour.

The concrete should be thrown on in layers, the first being allowed to set, before a second is thrown down. A barrow-load spreading over the ground in its fall, will form generally a stratum of from 7 to 9 inches thick, and a cubical yard of concrete will take about 30 feet cube of ballast, and $3\frac{1}{2}$ feet cube of ground lime, with a sufficient quantity of water.

Of the latter no more should be used than is absolutely necessary to effect a perfect mixture of the ingredients. Hot water accelerates the induration.

The expediency of using concrete as a substitute for stone, brick, and other materials for building, or constructions above ground, has been much discussed, and a great variety of opinion has prevailed on the subject. In the "*Prize Essay upon the Nature and Properties of Concrete and its Application to Construction*," Mr. Godwin has given much valuable information, but we think the opinions he has there ventured as to the use of concrete for walls, &c., will hardly be adopted by architects generally. "A prudent man," says Mr. Bartholomew, "will not heap up walls a second time, altogether of concrete. He will not exchange masonry of good strong mortar, and good strong stone or brick, for a heap entirely of mortar, and that "*très maigre*." A careful examination will discover that in every instance in which concrete walls have been used, more or less of instant ruin has occurred, the lintels over the apertures of the first story giving way before even those of the second story have been laid; and when those breaches have been repaired, they have reappeared; and even through the solid walls, rents have instantly occurred: experience proves that gravel lying in a bed, and there growing, as it were, without the means of flow or escape, is sufficient to support the most enormous weight of fabric; but the same gravel detached, cannot be piled up, so as to form either solid upright walls, or horizontal beams."

Concrete has been also used both as "rough concrete," and in blocks, in extensive works, as river-walls, breakwaters, &c., and has been recommended for such purposes by engineers of eminence. In the "Professional Papers of the Corps of Royal Engineers," Captain Denison describes some works of this kind, and, in the experiments he had the opportunity of witnessing, some very instructive results are obtained as to the practical application of concrete to the construction of river-walls at Woolwich and Chatham. In one instance at Woolwich, it has been applied in mass, the wall having been constructed in the same manner as the Brighton sea-wall; in both the other instances at Woolwich and Chatham, the concrete was formed into blocks, which were allowed ample time to set and harden before they were built into the face of the wall. At Woolwich, the river-wall is for the most part founded upon piles; its height above the piles is about 24 feet; the thickness at bottom 9 feet, at top 5 feet, with a slope or batter in front of 3 feet in 22. The face of the wall is composed of the blocks laid in cement, in courses 18 inches in height; the headers and stretchers in the course being each 2 feet 6 inches long: the former having a bed of 2 feet, while the latter have only 1 foot; behind the facing, the rough concrete was thrown in to complete the thickness of the wall and counter-forts. Both the blocks and the rough concrete were composed of lime and gravel, in the proportion of 1 to 7 and brought to the proper consistence with boiling water; but the blocks were, or ought to have been, made with Aberthaw lime, Dorking lime being used for the rest of the work. The blocks were cast in moulds, and were submitted to pressure while setting; a coating of finer stuff being given to the face for the sake of appearance. The whole of the wall was built by tide-work, and in the lower part therefore the backing of rough concrete had hardly time to set before it was covered with the tide; the water, however, in this instance, appeared to affect the *surface* of the mass only, the interior at the depth of a few inches appearing dry, and of a moderate degree of hardness, when examined after the retiring of the tide.

During the summer months, the action of the water from day to day was not perceptible; the surface still remained tolerably hard; occasionally portions of the fine facing separated from the rest of the block, owing, it was said, sometimes to want of care in the original construction, sometimes to injuries caused by boats or vessels striking the wall; in these cases, however, a new facing of cement was applied, and before the winter, the general appearance of the wall was to a certain extent satisfactory.

During a hard frost, however, evidences of failure began to show themselves; and as soon as the thaw allowed a thorough inspection of the face of the wall to be made, it was found that hardly a single block had escaped damage; in many instances, the whole face had peeled off to the depth of half an inch; at one spot, where a drain discharged itself into the river from a height of about six or eight feet, the back action of the water after its fall, had worn away the lower courses to the depth of some inches. These were the evidences of the action of frost and water combined, upon the best constructed wall at Woolwich. At Chatham, they were of the same character, but the damage done to the wall was much greater.

The portion of river-wall at Woolwich, which was built with rough concrete, was severely injured by the common action of the water before frost, and the same result was observed in the walls of a school near Blackheath, which were built of concrete some years ago: at the ground-line, where the drip of the water had acted, the concrete was soft, and yielded easily to any force applied, while the walls above were very fairly hard, and seemed to have stood very well. The results of the observations made at that time, on the use of concrete in constructions of a kind similar to those above mentioned, are summed up by Captain Denison in the opinion "that in climates like ours, in situations exposed to the alternate action of water and air, concrete cannot be advantageously used as a building material, the apparent economy, caused by the cheapness of the material employed, being more than compensated for by the frequency of repairs."

In the report (dated 1846) and evidence of the "Committee on the Harbour of Refuge to be constructed in Dover Bay," a great deal of valuable information is afforded on the use of concrete. Amongst the various plans submitted to the committee, Captain Denison, Colonel Jones, and Mr. Vignoles proposed to construct breakwaters of blocks of concrete. The first of these gentlemen recommended that the blocks should be manufactured at Dungeness, and thence floated to Dover by means of camels. The French adopted a similar plan in their works at Algiers, where large blocks of *bèton*, or hydraulic concrete, were floated out to the required spot, and then allowed to drop into their places from slings. These blocks were rectangular in form, and measured 324 cubic feet. At the works at St. Joilette, at Marseilles, also, immense blocks of concrete, 13 yards cubic measure in size, have been sunk for the foundation. The form suggested by Captain Denison was that of an hexagonal prism, and it was considered each block would weigh from 20 to 30 tons. The concrete would be made in the following manner:—the gravel of sea-beach to be mixed with the best hydraulic lime in the proportion of ten or twelve parts of gravel to one of lime; and with the view of causing it to set more speedily under water, a proportion of puzzolana should be added, varying in quantity according to its quality; half the quantity of puzzolana to that of lime would make very hard, sound concrete, which would set rapidly; but if desirable to make it set very quick, the quantity of puzzolana might be increased till it equalled that of the lime. The concrete used by Mr. Ranger at Woolwich was nearly the same, except that he used no puzzolana.

In the course of Captain Denison's evidence he refers to the works at Chatham and Woolwich, to which we have already alluded, and states that he had again examined the wall at Woolwich, and found the interior as hard as could be wished. Those parts, however, of the concrete facing, which were exposed to the mechanical action of the water, were injured by it; and therefore, though recommending concrete below low-water mark, he was bound to admit that it was not adapted to those situations where it must be exposed to such action.

The specific gravity of concrete, as compared with that of other materials, is as follows:—

Concrete weighs about 140 lbs. to the cubic foot.
Brick-work . . . 110
Granite . . . . 160 to 170
Portland stone . . 150.

We must refer to the report itself for more detailed information on this subject, only adding the conclusion come to by the committee, that "there is not sufficient experience of the use of concrete to warrant its adoption for the faces of works to be constructed in the sea."

The French engineers have made use of bèton in many of the extensive works on the continent; bèton sets very rapidly under water, and attains, after a time, a very considerable degree of hardness. M. Milet de Montville having filled a chest containing 27 cubic feet of bèton, sunk it in the sea, where it remained during two months, after which it was drawn up, to ascertain the consolidation it had acquired. On inspection it was found to be converted into so compact a body, that more difficulty was experienced in separating its parts, than those of a block of hard stone. The best manner of compounding the bèton, according to M. de Montville, is as follows:—"Take twelve parts of puzzolana, (*terrasse de Hollande, or Cendre de Tourney,*) of which form a circular wall of five or six feet in diameter, on which place six parts of sand, well sifted, free from earthy matter, and evenly spread. Fill the interior of this circle with nine parts of quick-lime, well calcined, and pulverized with an iron beetle; and to cause it to slack more quickly, (in maritime works) throw on sea-water in small quantities, stirring it from time to time with an iron spatula. As soon as it is reduced to a paste, incorporate the puzzolana and the sand. The whole being well mixed, throw in thirteen parts of unhewn stone, and three parts of iron dross, well pounded. If this latter ingredient cannot be obtained, sixteen parts of rough stones or pebbles must be added, of a size not larger than a pullet's egg. Let this composition be well amalgamated for the space of an hour, after which it must be left in heaps to coagulate; for this purpose the space of twenty-four hours will be sufficient in summer or in warm climates, but in winter it often requires the space of three or four days. Observe to keep it protected from the rain, and not to use it until it has sufficiently hardened to require breaking with a pickaxe."

The method of using the bèton is either in blocks, or by means of a coffer or chest filled with the composition, lowered to the required depth, and there emptied.

CONCRETION (from the Latin, *concresco*) the act of concreting; the process by which soft or fluid bodies become thick, consistent, solid, or hard; the act of uniting, by natural process, the small particles of matter into a mass. The word is used indifferently for induration, condensation, congelation, or coagulation.

CONCURRING, or Congruent Figures, or Solids, such as will cover each other exactly, or will fill the same space. All plane figures will do this, when their corresponding angles and sides are equal.

CONDUIT (from the French) a canal, or pipe, for the conveyance of water, or other fluid matter; an aqueduct.

The earth is full of natural conduits, for the passage of waters, which give rise to springs, and of vapours which generate metals and minerals.

Artificial conduits for water are made of lead, cast iron, stone, potters' earth, &c. *See* Plumbery.

Also the reservoir or erection where the waters are conducted and distributed for use. Previous to the formation of the present water-companies, these conduits were frequent in the different parts of London, and were the only means by which the inhabitants were supplied with water; the first conduit erected was one near Bow Church, Cheapside, in the reign of Henry III.; and among the latest was one of large dimensions, erected in 1655, at Leadenhall, which served likewise for an ornamental fountain. Conduits of this kind of an early date were usual in our large ecclesiastical establishments, and where cloisters existed, there was frequently one in the centre of the quadrangle; which custom has been observed in the quadrangle of S. Augustine's, Canterbury, lately erected, where the conduit, of excellent design, forms an imposing feature.

The first attempt to carry water into the houses of London was made by Peter Morris, A. D. 1582, who established the waterworks constructed under two of the arches of old London Bridge, but their supply extended only as far as Gracechurch-street; soon after, in 1594, similar works were erected near Broken Wharf, which supplied the houses in Westcheap and around S. Paul's, as far as Fleet-street. It was not until the reign of James, that any enterprise of this kind on a large scale was undertaken, when the formation of the New River was commenced by Sir Hugh Middleton in 1608, and completed in 1613.

CONE (from the Greek, κῶνος) a solid, bounded by two surfaces, one of which is a circle, called *the base*, and the other a convexity, ending in a point, called *the vertex;* and of such a nature, that a straight line applied to any point in the circumference of the base and to the vertex, will coincide with the convex surface.

The straight line drawn from the centre of the base to the vertex of the cone, is called *the axis.*

When the axis of the cone is perpendicular to the base, the cone is called *a right cone*, but when otherwise, it is called *an oblique cone.*

If a cone be cut by a plane through its vertex, the section will be a triangle.

If a cone be cut by a plane parallel to its base, the section will be a circle, or similar to the base.

If a cone be cut by a plane, so as to make the portion cut off similar to the whole cone, the section will be a circle, or similar to the base.

If a cone be cut by a plane parallel to a plane passing through the vertex, meeting the plane of the base produced without, the section is an ellipsis, except the part cut off be similar to the whole cone, as in the last position.

If a cone be cut by a plane parallel to a plane in contact with its side, the section will be a parabola.

If a cone be cut by a plane parallel to a section of the cone passing through the vertex, the section will be an hyperbola.

Every cone is one-third part of a cylinder of the same base and altitude (Euclid., b. xii., prop. 10.), and cones of equal altitudes are to each other as their bases (Euclid., b. xii., prop. 11); therefore any cone whatever is the third part of a cylinder of equal base and altitude with the cone.

The curved surface of a cone is equal to the sector of a circle, the radius of which is equal to the slanting side of the cone; and the arc-line of the sector is equal to the circumference of the base of the cone.

To find the solidity of a cone, multiply the area of the base by the altitude, and one-third of the product will give the solidity. Or, multiply one-third of the area of the base, which is the mean area, by the altitude of the cone, and the product will give the solidity. *See* CIRCLE.

To find the curved surface of a cone, multiply the slanting side of the cone by the semi-circumference of the base, and the product will be the area of the curved surface.

If the diameter of the base be given, the circumference must be found as directed under the article CIRCLE.

If the perpendicular altitude be given, the slanting side of the cone will be ascertained by the 47th prop., Book i., Euclid. But if the cone be given, it will be much easier to take the slanting side and the circumference of the base, than its altitude and diameter; the operation will also be much shorter by taking the former dimensions than the latter. *See* CONIC SECTION, ELLIPSIS, ENVELOPE, HYPERBOLA, and PARABOLA.

CONFESSIONAL, or CONFESSIONARY, in churches, a place usually under the main altar, wherein the bones of deceased saints, martyrs, and confessors were deposited.

CONFESSIONAL is also used in the Romish church, to designate a little box, or desk, in the church, in which the priest receives the confessions of the penitents.

Few confessionals, if any, are to be found in England, although it is a common practice to set down all niches, for which no other use can be immediately discovered, under this title.

CONFIGURATION, (from the French) the exterior superficies of a body, from which it receives its particular figure.

CONGE, a concavity at the extremity of a vertical surface, where it bends off in a tangent, and projects forward until it meets a fillet, or other vertical surface, at an external angle. Thus the shaft of a column bends forward at the upper and lower ends, until it meets the fillet. The conge, when applied to a column, is part of the interior surface of a cylindrical ring, and its section is generally a quarter of a circle.

The term is derived from the French, *conge*, a curve; the Greek appellation is *apophyge;* and the Latin, *scapus*, from which the English word *scape* is derived. *See* APOPHYGE.

CONGERIES, a collection or heap of several bodies, united in one mass or aggregate.

CONGRUITY, in geometry, a term applied to lines, angles, figures, and solids, which exactly cover each other, or coincide. Figures that are equal and similar have a congruity; as have solids, the figures of whose sides are congruous with the planes of the corresponding side at the same inclination.

CONIC, relating to a cone. *See* CONE.

CONIC SECTIONS, the curves formed by the intersection of a circular cone and a plane, the former being either oblique or right. The works of Apollonius and Archimedes are the first in which these sections were treated of; and their history is nothing but that of the addition of a few remarkable properties, till the discovery that the path of a projected body in an unresisting space is a parabola, and that of a planet round the sun an ellipse. Though the name, therefore, of conic sections still remains, the interest which attaches to these curves, and the method of treating them, has no longer any reference to the accident from which they derive their name. The Greek geometers, in pure speculation, occupied themselves with the different methods in which a cone may be cut, simply because the conical (with the cylindrical and spherical) came within the restrictive definitions under which they had placed geometry;—but since the discovery to which we have alluded, we might as well attempt to write the history of mathematics and physics, as that of conic sections in their results and consequences.

Some sections of a cone are considered in elementary geometry, for a plane may meet a cone in a point, or in a single straight line, in two intersecting straight lines, or in a circle. But the curves, which are peculiarly conic sections, are the oval made by a plane which cuts the cone entirely on one side of the vertex, called the ELLIPSE; the indefinitely extended modification of this when the plane becomes parallel to any one slant side of the cone, called the PARABOLA; and the curve, which is partly on one side, and partly on the other of the vertex, formed by a plane which cuts both surfaces of the cone, called the HYPERBOLA.

Below is appended some convenient methods of forming the sections upon a plane, without any reference to the cone.

If each end of a string of greater length than the distance E F, *Plate* 1, *Figure* 1, to be tied to the points E and F, and any intermediate point B, be taken in the string, then the point B being carried round the line E F, so as to keep the parts, E B, B F, always stretched till it come to the point whence it began to move, the point B will trace out a curve, A B C D, which will be *an ellipsis.*

If the end of a straight inflexible line, or rod, of a greater length than the distance E F, *Figure* 2, be fixed to one extremity, E, of the line, and one end of a string of greater length than the difference between E F and the length of the rod, be fixed to F, and the other end to the other end of the rod at N; then, if any point, B, be taken in the string, and the rod moved round the point E, so as to keep the parts N B, B F always stretched, the point B will trace out a curve, which will be *an hyperbola.*

And if the end of the rod be moved from E, and fixed at F, and one end of the string moved from F, and fixed at E, the curve described after the same manner, is called *an apposite hyperbola.*

In the ellipsis and hyperbola, the points E and F are called *the foci;* the line, A C, passing through the foci, joining the opposite parts of the curve, or curves, is called *the transverse axis;* and the point, C, in the middle of the transverse axis, is called *the centre.*

In the ellipsis, any line drawn through the centre, and terminated by the opposite parts of the curve, is called *a diameter;* if another right line, terminated by the curve, be drawn parallel to a tangent at one extremity of the other diameter, such line is called *a double ordinate;* and if it pass through the centre, it becomes *a diameter;* then the two diameters, thus situated, are called *conjugate diameters.*

When the conjugate diameters are at right angles to each other, they are called *the axis of the curve.*

If there be a diameter, and a double ordinate to that diameter, the two segments of the diameter are called *the abscissæ.*

Concentric ellipses are such as are similar, and have the same centre with the greater axis of the one upon the greater axis of the other, and the less upon the less.

Most of the above definitions apply also to the hyperbola.

If the side, A B, *Figure* 3, of a right angle or square, A B C, be applied to the straight-edge, A D, of a rule, and a thread, equal in length to B C, be fastened to the end, C, of the right angle, with the other end to the fixed point, F; and if any point, E, be taken in the line, then if the edge, A B, of the square be moved along the straight-edge, A D, keeping the variable point, E, upon the side, B C, of the square, and the two portions C E and E F stretched, the point E will trace out a curve, which is a parabola.

The point F is called *the focus.*

The line A D is *the directrix.*

The line L K passing through the focus perpendicular to the directrix, is *the axis.*

The point I, where the axis cuts the curve, is *the vertex.*

Any line parallel to the axis, terminated at one extremity by the curve, and on the concave side of it, is called, *a diameter.*

Any line parallel to a tangent at the limited end of a diameter, is called *a double ordinate* to that diameter.

The limited part of a diameter, contained by the curve and a double ordinate, is called *the abscissa* of that double ordinate.

Figures 4, 5, 6. *An abscissa, the ordinate, and the diameter being given, to describe the ellipsis or hyperbola.*

Let A B be the diameter, A C the abscissa, and C D the ordinate. Draw A E parallel to C D, and D E parallel to C A. In D C take any number of points, F, G, H, and divide D E in the same proportion at *f, g, h.* Draw B F I, B G K, B H L; likewise *f* I A, *g* K A, *h* L A, and through the points D, I, K, L, A, draw a curve. In the same manner may the curve for the opposite ordinate be drawn.

When the extremities of the diameter are on different sides of the ordinate, the curve is an ellipsis; but when the extremities of the diameter are on the same side of the ordinate, the curve is an hyperbola. When the diameter A B, is of infinite length, the ordinates, F I, G K, H L, will be parallel, then the curve is a parabola. Therefore, in *Figure* 4, the lines drawn from the points F, G, H, parallel to the transverse axis, or abscissa, A D, instead of being drawn to the point B, as in *Figures* 1, 2, 3, make the only difference.

It is hardly possible to conceive more convenient or easier modes of description than these; their correctness may be proved by showing that their common properties are similar to those demonstrated of conic sections.

Figures 7, 8, 9.—Let A B be the diameter, C D the ordinate, and A C the abscissa, as before. In C D take any point, G, and divide D E by *g*, in the same ratio as D C is by the point, G; draw *g* K A, B G K, *Figure* 7, and B K G, *Figure* 8; then, because of the similar triangles, B N K and B C G, B N : B C : : N K : C G; and also, because of the similar triangles A N K and A M G, A N : A M or *g* E : : N K : M G or C D. By construction we have *g* E : D E or E A : : C G : C D; and therefore by multiplication we have B N + N A : B C + B A : : NK^2 : CD^2, which property is known to be that of the ellipsis and hyperbola.

Corollary.—Since, in the parabola, B N and B C are of infinite length, and may therefore be said to be equal, B N and B C may therefore be expunged from the first two terms of the analogy in the above general property; then we shall have N A : C A : : NK^2 : CD^2.

Or the truth of the operation may be shown by a particular demonstration for the parabola thus: *See Figure* 9.

Because of the similar triangles A N K and A M *g*, A N : A E : : N K : M *g* or C D; by construction we have A M : A C : : C G or N K : C D; and consequently, by multiplication, A N : A C : : NK^2 : CD^2, which is the property of the parabola.

Figures 7, 8, 9.—*In a conic section, are given the abscissa,* A C, *an ordinate,* C D, *and a point,* K, *in the curve: to determine the species, and thence to describe the curve.*

Draw E *g* D parallel to A C, and A E parallel to C D; through the points A and K draw A K *g*, cutting E D at *g*; make D G : G C : : D*g* : *g* E, and through the points K and G draw K G B or G K B, which, if not parallel to A C, produce it until it meet A C or C A in B; then A B will be a diameter. In this case the curve is an ellipsis or hyperbola. It is an ellipsis when the extremities of the diameter are on different sides of the ordinate, as in *Figure* 5; but when the extremities of the diameter are on the same side of the ordinate, the curve is an hyperbola. If K G be parallel to A C, the curve is a parabola. A diameter, A B, and an ordinate, C D, being thus ascertained, the curve will be described as in *Figures* 1, 2, 3. Other particulars relating to these curves will be found under the articles ELLIPSIS, HYPERBOLA, and PARABOLA.

CONICAL ROOF, a roof whose exterior surface is shaped like a cone.

CONICS. *See* CONIC SECTION.

CONISTRA, the pit of a theatre.

CONJUGATE DIAMETERS, of an ellipsis or hyperbola, any two diameters that are parallel to tangents at the extremities of each other.

CONOID, (from the Greek, *κωνοειδης*, *partaking of the figure of a cone*), a figure generated by the revolution of a conic section round one of its axes. There are three kinds of conoids, viz., the elliptical, the hyperbolical, and the parabolical; which are sometimes otherwise denominated, *ellipsoid*, or *spheroid*, *hyperboloid*, and *paraboloid.*

Now because the solid is generated by the revolution of the section of a cone upon its axis, the axis will then also be that of the solid. In this case, since, in the generation of the solid, every point of the curve will describe a circle, every section of the solid parallel to the base will be a circle.

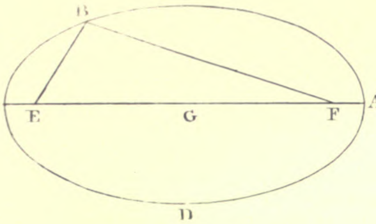
If a conoid be cut by a plane meeting the base, or the plane of the base produced, the section will be either an ellipsis, or an hyperbola, or a parabola.

Every section of an ellipsoid oblique to its axis, is an ellipsis; and if a paraboloid or hyperboloid be cut by a plane meeting the plane of the base, produced on the outside of the figure, the section will also be an ellipsis. In the paraboloid, if the cutting plane be parallel to the axis, the section will be an equal parabola. In the hyperboloid, if the solid be cut by a plane parallel to a section of the cone, made by a plane passing through the point where the asymptote of the generating section meets the axis of the solid produced, the section will be an hyperbola; but if the cutting plane be parallel to the plane in which is the asymptote, and at right angles with the generating section, the section will be a parabola.

Thus the ellipsoid has only two sections, viz. the circle and the ellipsis: the paraboloid, three sections, viz. the circle, the ellipsis, and the parabola: the hyperboloid, four sections, viz. the circle, the ellipsis, the hyperbola, and the parabola: and the cone itself has five sections, viz. the triangle, the circle, the ellipsis, the hyperbola, and the parabola. The triangle is a section peculiar to the cone alone; the hyperbola, to the cone and hyperboloid; the parabola, to the cone and parabolical and hyperbolical conoids; and the circle and ellipsis are common not only to the cone, but also to each of the three conoids.

All parallel sections of conoids are of similar figures; though it may seem singular that this should be a general property, when it is considered that, in a cone, a section through the apex, or point, is a triangle, and a section parallel thereto is an hyperbola; so that if the property existed generally, the triangular and hyperbolic sections of the cone so posited ought also to be similar. To reconcile this paradox, let us consider, that in all hyperbolical parallel sections of a cone, the asymptotes make equal angles, and the sections which are nearer to that passing through the apex of the cone, have a greater degree of curvature at the vertex of these curves, than those which are more remote, though both figures be similar. Farther, if the legs of the hyperbola be infinitely extended, they will be infinitely near a straight line, as they will fall in with the asymptotes nearly, and the curved portion will bear no sensible magnitude, compared with the part which is comparatively straight, as the legs of the hyperbola

Fig. 1.



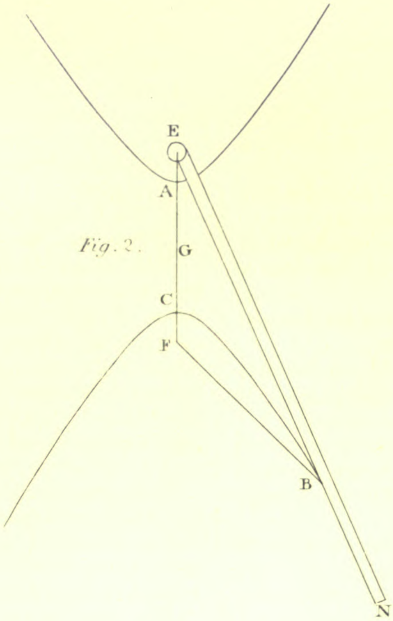
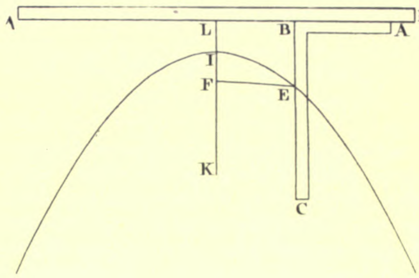


Fig. 2.

Fig. 3.



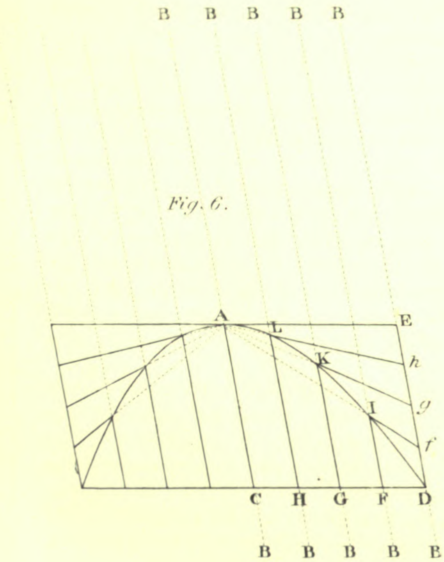


Fig. 6.

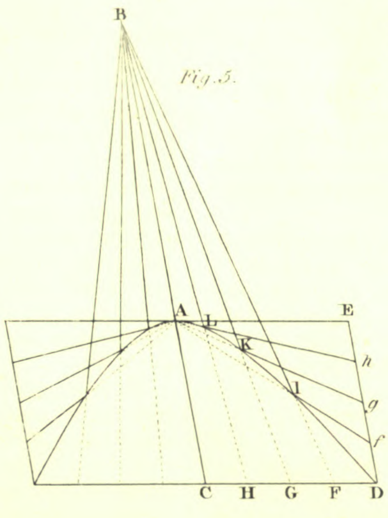
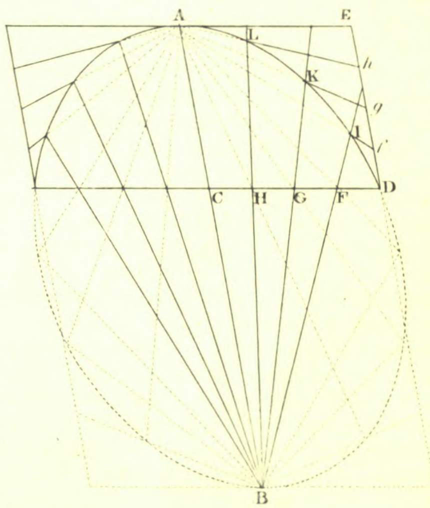


Fig. 5.

Fig. 4.



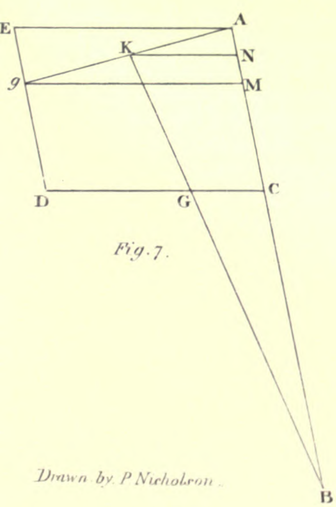


Fig. 7.

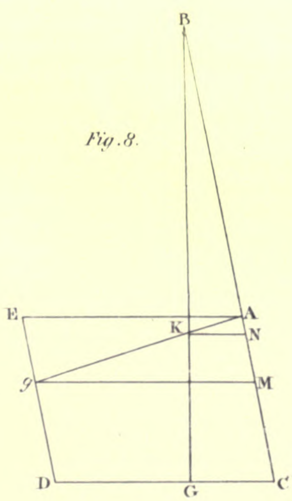
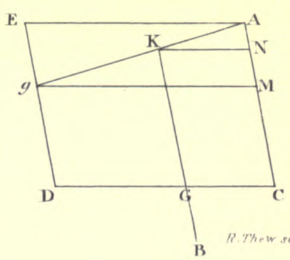


Fig. 8.

Fig. 9.



Drawn by P. Nicholson.

R. Thew sc.

become straighter and straighter as they are more and more produced. Thus the curved portion may be considered as a mere point to the whole figure, in a section through the vertex, the ideas of the general property seeming to vanish, or not apply; but if we allow a parallel section, though ever so little distant, it can very easily be compared with any remote parallel section, and their difference will be this, that, in like portions of the two curves, the similar figures inscribed in the section nearer to the apex will be incomparably small to those of the sections more remote, and in a parallel section passing through the vertex, the similar figures of comparison will be lost, as being of infinitely small magnitude.

The section through the axis, which is the generating plane, is, in the spheroid, the greatest of all the parallel sections; but in the hyperboloid, it is the least; and in the paraboloid, it is equal to any other parallel section.

If an hyperbola be supposed to revolve with its asymptote upon its axis, the curve will generate a conoid, and the asymptote a cone; and if these two solids be imagined to be cut by a plane in any position, then the two sections will be similar and concentric figures, of the same species in each solid.

To find the solidity of a conoid.—To the area of the base, add four times the area of the middle section, multiply one-sixth of the sum by the height, and the product will give the solidity. In the spheroid, one-sixth of four times the middle section only, multiplied by the height, gives the solidity; that is, two-thirds of the circumscribing cylinder.

Other particular rules and properties will be found under Ellipsoid, Paraboloid, and Hyperboloid.

CONOPEUM, in antiquity, a sort of canopy of net-work, hung about beds, to keep away gnats and flies.

CONSERVATORY (from the Latin, *conservo*, to keep) may be defined generally as a place for preserving anything in a state desired, as from loss, decay or injury; in this sense, granaries for keeping corn, ice-houses, &c., may be called conservatories.

In gardening, the word conservatory is so frequently confounded with Green-House, and the terms are applied with so little precision to buildings used for preserving plants in an artificial climate, that it is difficult to define what is properly a conservatory. "The term," says a writer in the *Penny Cyclopædia*, "which, as its meaning shows, was originally intended for buildings in which plants were preserved during winter, has come to be used, firstly, for glass houses in which plants are cultivated by growing them in the open border, and subsequently for all such glazed buildings whatsoever. A conservatory, properly so called, is a brick building heated by artificial means, having its whole southern part closed by large glazed sashes, which may be opened or shut at pleasure. Its floor is generally of stone, and a part of it is occupied by a stage on which plants in pots can be placed. Such a conservatory was intended to preserve during the winter, orange-trees, myrtles, American aloes, and similar plants, which during the summer will flourish in the open air, but which require during the winter to be protected."

The modern or popular meaning of the word, is now almost the opposite of the original one, and a conservatory is said to differ from a green-house principally in this, that in the latter the plants and trees stand in pots, placed upon stages; and in the former are regularly planted in beds of the finest composts, on being removed from the green-house, and taken out of the tubs or pots. By introducing stages, instead of beds, however, one may serve for the other.

The construction of a conservatory is similar to that of a green-house; but it should be more spacious, elevated, and finished in a superior style. The sides, ends, and roofs should be of glass, in order to admit light freely, and to protect the plants. It should likewise be so situated as to be quite dry, receiving as much of the heat of the sun as possible during the day, and provided with flues to communicate heat when found necessary, and valves and other conveniences for the introduction of fresh air, when required, for the purpose of ventilation. In summer-time, the glass roofs are sometimes taken off, and the plants exposed to the open air, but on the approach of the autumnal frosts, they must be restored.

There is much diversity of opinion amongst practical men as to the comparative merits of wood and iron in the construction of conservatories. Mr. J. Thompson, a man of great experience, in his "Practical Treatise," gives the preference to wood, although acknowledging the advantages of iron in lightness of appearance. "Any persons," he observes, "having a knowledge of the expansion and contraction of metals, may form some idea of the expansion of a large iron roof on a hot day during the months of July and August, and of the contraction on a severe frosty night; so great have I witnessed the action of the sun's rays in expanding the iron rafters and lights upon a hot day, that it has required two or three men to draw down the sliding-lights; and in an equal proportion have I seen the contraction during the intensity of winter, so much so, that large apertures have appeared between the rafters and lights, which admitted the external air to such an extent, that it required the strength of two fires, and the flues heated to the greatest excess, before the house could be raised three degrees of heat, and this in a house of not very large dimensions." This gentleman also objects to the iron-roofed houses, that they require double the quantity of fuel that is necessary in houses otherwise constructed. Notwithstanding some admitted disadvantages, the great convenience of iron, the readiness with which it is manufactured, and the extreme lightness and elegance of its appearance, will always give it a great advantage. Some of the most magnificent conservatories in this country, have been constructed of iron, amongst which we may especially notice that in the Botanic Garden, Regent's Park.

This building was erected under the direction of Mr. Decimus Burton, and forms the half of the centre part of the proposed "Winter Garden," in which, when completed, the subscribers to these beautiful gardens will be able to enjoy the luxury of the parterre at all seasons of the year.

It is constructed of iron, principally wrought, the pillars and guttering only being cast. The water from the roof is conducted by the internal pillars, to large tanks under ground, from whence it is pumped up for the supply of the house. The building is heated by warm water conveyed through pipes arranged beneath the surface, in brick channels, having large outlets for the hot air, with air-ducts at intervals to create a current, and give increased action to the hot air in the drains. The boiler-house is beneath the ground, at some distance from the building.

The structure is ventilated by sliding-lights in the roof, acted on by a simple contrivance, which opens and shuts the whole simultaneously, and is glazed with sheet-glass in long lengths.

The whole building contains above eleven thousand superficial feet. It was erected by Mr. Turner, of the Hammersmith Ironworks, Dublin, at a cost of about £6,000.

The conservatories at Sion House, the Duke of Northumberland's, Alton Towers, the Earl of Shrewsbury's, and the Duke of Devonshire's at Chatsworth, are on the most magnificent scale, and are especially worthy the study of the young architect who may be called on for designs for a building of this description. He will also find much valuable practical information in Mr. J. W. Thompson's work on the "*Construction of Stoves, and other Horticultural Buildings.*"

The conveniences which may be attached to conservatories, consist of retiring-rooms, seed-rooms, aviaries, &c. If there be no sheds behind, the walls should not be less than three bricks thick.

CONSISTORY (from the Latin, *consistorium*) a large hall, at Rome, in which the college of cardinals meet to plead judiciary causes.

CONSOLE (from the French) a bracket, or projecting body, formed like a curve of contrary flexure, scrolled at the ends, used for supporting a cornice, bust, or vase.

Consoles have been used for supporting an entire order of columns, as in the barbarous architecture of the palace of Diocletian, at Spalatro.

Consoles are otherwise denominated *ancones*, or *trusses.*

CONSPIRING POWERS, in mechanics, such powers as act in directions not opposite to each other.

CONSTRUCTION (Latin, *construo*, to heap up into one) the erection or disposition of several separate parts in such a manner, as to form a perfect and compact whole.

A good knowledge of the principles of construction, forms an essential item in the qualification of an architect. The principles of construction arise out of and are entirely dependent upon those of gravitation. "Gravity," says an excellent authority on this subject, "is the source of all the principles, inventions, and ingenuity, called into action in the structure of architectural works. The weight or downward tendency of their materials, is the cause of buildings holding together, or falling, or being thrust apart. Gravity, in its various dynamic modifications, is the sole acting power which operates in a building. All the mechanical perfections of scientific building result from a clear knowledge of the operation of gravity, and from the ability to direct their course: all the mechanical defects of buildings, result from an ignorance of the laws of gravity, and from inattention or inability to counterbalance their effect. A judicious architect enslaves to his purpose the active force of gravity, and compels it to exert all its force in holding together more firmly his structure; an ignorant or careless architect or workman, allows that force to exert itself in wracking, straining, distorting, breaking, and destroying his work."

The methods in which gravity acts upon materials, are by compression, by tension, and by cross-strain. The first of these modes of operation is the simplest and least destructive, unless exerted to too great an extent, and is that which forms the basis of the most sound construction; its tendency is to bring the particles of matter more closely together; instances of its application occur in all simple constructions, such as upright piers, arches, &c. The second method, that of tension, has a directly opposite tendency to the last, and exerts its influence in disengaging the atoms from each other, it is of course not naturally favourable to construction, but the contrary, nevertheless it is made a very efficient and useful agent; its influence is never exerted but upon materials which have a strong counteracting tendency, and it is made available to produce the first effect of gravity, or compression. Examples of its operation are to be met with in suspension-bridges, and in the tie-beams and king or queen-posts of trusses. The third method by which materials are affected by gravity, is cross-strain, which is a combination of the two last, as it is tension effected by pressure, and its result is to tear or wrench the particles of matter asunder; it is in principle totally inimical to construction, and must be avoided or counteracted. Cross-strain occurs in unscientifically formed roofs, where struts rest upon a tie-beam, also when any vertical weight presses upon any horizontal beam, as in the case of brest-summers; it happens likewise, when heavy untrussed horizontal beams have too great a bearing, the effect in this case is termed sagging, and is counteracted by cambering or trussing the beam.

Analogous, and arising out of these operations of gravity, are the three great principles in construction—repose, equipoise, and tie. The first of these is the simplest, and is the principle most usually adopted in very ancient buildings; it is used where the materials are merely piled up perpendicularly, so as to form piers or columns with cross-beams, architraves, or lintels, laid horizontally upon the piers or columns, pressing downwards merely with the gravity of these materials, without any thrust or other inclination to destroy the position of any part of the arrangement. "Buildings constructed on this principle, need only tenacity of material and unflinching foundations to be altogether perfect in construction; but buildings of this kind, owing nothing to geometrical science, lead to an enormous consumption of materials; all the materials of the horizontal spanning masses, of even a small building, must be huge, and are thence immensely expensive to procure, and to raise to their destined places; if these spanning masses be either so long or so brittle as to yield by their own weight, or by that which may be put upon them, the principle of simple repose becomes destroyed; the horizontal masses sink, and the piers or sustaining masses are thrust outwardly."

The disadvantages attending this mode of construction, led to the invention of others, yet at the same time they all aimed at attaining the same end, namely, simple repose throughout the materials and different members of a building. The principle of equipoise in construction is this, that all tendencies to disturb or produce motion amongst the parts of a structure, should be counterbalanced by an equal and opposite tendency, and the most perfect exhibition of its powers is to be seen in the arch. This principle of building allows of the employment of the smallest materials, and ensures stability with the least possible quantity of matter; it is therefore far preferable to the first method or principle. The third principle, of tying, is of modern invention, and by it the quiescent state of a structure is maintained, not by resisting the power as in the last case, by external opposition or abutments, but by confining the power by internal restraint. The principle is embodied in the structure termed a truss.

The most perfect specimens of constructive science are to be found in the wonderful erections of the Gothic architects: "The mediæval Christian builders arrived to such a delicate and intimate acquaintance with architectural dynamics, that by the discovery of the way in which all the particles of their materials were affected by gravity, they were enabled, by merely subjecting them to the frangibility caused by compression, so to economize them, and reduce their quantity, that many members of Gothic edifices, after five hundred years' devastation by time, are more sound than corresponding members of our modern builders, which have not subsisted fifty years, and which contain five times their proportion of materials. So admirable in general is the skill displayed in the dynamic disposition of the material of a Gothic cathedral, so shrewdly are the forces of its gravitation reduced to simple compression, that the whole is like a wonderful piece of shoring, sublimely and permanently imitated in stone."

Construction, the art of describing a diagram or scheme from given data.

In geometrical constructions, the accuracy of the diagram depends upon that of the points by which the lines constituting the figure are found. It is, therefore, of the utmost consequence to ascertain the situation of points correctly by lines crossing at right angles, or as nearly so as possible.

The choice of this is not at all times in the power of the geometer, but when it is, he ought to avail himself of it. The situation of a point must be ascertained by the intersection of two lines, and since a line cannot be without breadth, it will be an oblong, and the intersection of two lines will be a parallelogram; when the lines cross at right angles, the parallelogram will form a square; and when at oblique angles it will be a rhombus. In all those cases, the point required is in the intersection of the diagonals of the parallelogram. Now the least of all the parallelograms formed by the intersection of two lines of equal breadth, is a square; but the greater the obliquity of the lines of intersection, the longer will be the rhombus; and as the drawing of the figure depends upon vision, the more indistinct will the angles of the figure so formed become, and consequently the situation of the point must be almost guessed at. In some cases, the obliquity of the intersection is of little consequence; as, in finding a curve by points, where the lines, which form the intersection, fall very nearly in with the curve itself, or make very acute angles with the tangent, unless it be required to find the points in the curve in a given ratio; but if, in finding a point, through which a line is to pass from another given point, to meet a line, of which some parts are either given or found, or to be found, it will be of the utmost consequence to determine with accuracy the situation of the intermediate point; for the point asertained in the other line will vary from its true place, more or less, according to the distance of the intermediate point found by the intersection.

Another source of error arising from the intersection of oblique lines, which will also be more or less accurate, as the obliquity is less or greater, is, when one or both the lines are not exactly drawn through their extremities; even the deviation of a line being drawn its own breadth, will make the intersection fall its own length (which is the diagonal of the rhombus) to the end of the true intersection. Let it also be considered, that the longer diagonal of the rhombus may be of any length whatever, depending upon the obliquity of angles formed by the two intersecting lines. In the description of a diagram, when different points are ascertained in a line, in pointing out the line to the reader, it would be better to name all the letters in the order as they stand, instead of pointing out the line by two of the letters, particularly in a complicated diagram, where many other lines are concerned. This is still more necessary when several lines meet at the same point, as the use of all the letters not only gives a more immediate clue to identify the lines from others, but also shortens the description, as the same letters must be used again, in pointing out the other lines which cross the former line, and will thus supersede the necessity of the frequent repetition, after a line has been drawn in the required position to cut a former, of saying, "cutting such a line in the point" A or B, or whatever it may be; as the same letter cannot be in two lines, except at their intersection.

In tracing the boundaries of angular figures, it will only be necessary to name the letters progressively, as they stand at the extremities of the sides, that is, at the angles; but to trace out the whole enclosure or perimeter, it would be necessary to name the first letter again, at the end of the series of letters. It is true, that a triangle, a quadrilateral, &c., will easily be understood, without naming the first letter again, by naming the figure at the same time, or the number of its sides, as in polygons the last side will always be wanting.

Though these enumerations and repetitions of letters may appear clumsy, they lead sooner to an understanding of the construction, shorten the language, and give accuracy to the description.

CONSTRUCTIVE CARPENTRY shows the method of reducing wood into forms, and joining the parts, as directed by the rules of DESCRIPTIVE CARPENTRY, or by the laws of strength, and thereby forming a complete design.

It is much to be regretted that the first principles of this department of the art are frequently so little understood by those who are called upon to put them into practice. The young carpenter too often follows blindly in the track of those who have gone before him, without inquiry, and without even attempting to understand the mechanical construction of the work he has just put together. We do not mean that the practical builder must necessarily make himself master of the higher branches of science, but that it would obviously be of advantage to him that he should acquire that general knowledge of the elementary principles of the art, which would enable him to select the best materials, and employ them in the best manner.

Every species of construction should be characterized by stability, and a careful regard to economy of materials. These objects can only be obtained by judicious combinations of the substances used, so that the greatest amount of strength be secured with the smallest expenditure of material. Unless the builder possess a considerable knowledge of the principles of mechanics, unless he be acquainted with the effect of pressure, and the resisting powers of different materials, he cannot comprehend, much less design, such combination; but becomes a mere labourer putting together the several parts of a work, without knowing their relative dependence on each other, or the strength, or want of strength, of the whole. He is, indeed, from the want of such knowledge as we have described, incapable of judging what are the best forms of construction, or which of several modes of uniting timbers it is most advisable to make use of. It is the province of constructive carpentry to show this, and the carpenter who is desirous to make himself thoroughly acquainted with his business, should study to acquire not only a practical knowledge of its details, but also some insight into the principles on which it is founded.

Constructive carpentry, it has been observed, is the method of reducing wood into forms, and the combining of several parts into a complete, firm whole. In most works, especially those of magnitude, it will frequently be necessary to join one or more pieces of timber, in order to obtain beams, &c., of sufficient size, and in order to economize material. The processes by which these objects are effected is a subject of the greatest importance, as on their being properly and substantially performed depends the stability of the structure in which they are used. Under this article then we propose to describe some of the most approved methods of uniting timber, and to treat of the following operations, viz., the lengthening of beams, either by scarfing or joining them in pieces; the strengthening of beams by trussing; the methods of joining two timbers at angles, in any given direction; and lastly, the mode of connecting several timbers, in order to perform certain functions required by the design.

To lengthen a piece of timber, is to join or fasten two separate pieces, so that a portion of the end of the one piece shall lap upon a portion of the end of the other, the sides of both making but one continued surface, and forming a close joint, called a *scarf.*

It is evident, that in the formation of a continued straight timber, if the joint consist of a plane, or planes, at right angles to two opposite sides of the compound piece, but not at right angles to the plane of the other two opposite sides, the plane, or several planes, forming the scarf, will make the oblique angles, constituted by the surface of each piece on the same side, supplements to each other: or whatever oblique angle or angles the one piece makes with a side, the corresponding angle or angles formed by the joint or joints with the same continued surface of the other, will, together, form two right angles, and thus the solid part of the one will be equal and similar to the void of the other.

There are several methods of lengthening timber, either by joining whole pieces of the same transverse sections, and forming their ends, which are to come in contact in one or several planes, or by forming the connection by means of a third piece, or by building the piece to be lengthened in several thicknesses, making the joints abutting upon each other on the solid of the piece with which they come in contact on the parallel joint. It is evident, that two bodies united, and intended to act as one in a state of tension, can never be so strong as either piece taken separately.

Tabling is a mode of indenting the ends of the pieces which form the scarf, so as to resist a longitudinal strain; the pieces, therefore, require to be held together, or otherwise the notches and the tables which fit into them would require to be dovetailed. In this construction, the tables between the notches would be a very feeble support, as they are apt to split away. It must also be observed, that one single table, or one abutting part of resistance, is stronger, and much more easy to execute, than two or four; and that the resisting part should have as little projection as possible, because such projection diminishes the cohesive force, by a quantity of the timber equal in section to the abutting parts. Two pieces of timber may be very firmly fixed, by making the ends of the tables, instead of abutting, to form a tapering mortise, so that when the two pieces are brought close at the connecting surfaces, a wedge driven into the cavity will bring all the parts of the joint into contact.

Every two pieces of timber require to be held together by some force compressing them equally on each side, particularly when the pieces are light; for which purpose iron bolts are very convenient, they acting as a tie, and having the same effect as two equal and opposite forces would have in compressing the beam on each side of the scarf; and as iron is of great strength, the bore made to receive the bolt will not be so large as to diminish the section, and consequently the firmness of the timber at the scarf, in any considerable degree; whereas, when wooden pins are used, they require a large bore, which weakens the timber, and the two pieces thus connected are not so firmly compressed, or, indeed, compressed at all, but are held together almost solely by friction.

No limited distance can be specified for the length of the scarf; though it may be observed, generally, that a long scarf has no effect in diminishing the cohesive strength of a compound piece of timber. On the contrary, a long scarf gives an opportunity of increasing the number of bolts, which are the only ties when no tablings are used, as is the case where the abutting parts unite only by compression. It must here be understood, that all such abutting parts diminish the cohesive force in the proportion of their abutting surface to that of the whole section at any one of the abutments; so that should a scarf consist of a series of steps, formed by planes parallel and perpendicular to two of the opposite sides, the transverse sides of these steps to those of the piece should be all equal; and the greater the number of steps, the less will the strength be impaired; but if they be unequal, the timber will be weakest at the greatest section or compressed abutment, and if few, the section will be large, and the piece consequently deprived of a proportional degree of strength. We may also add, if the two pieces be strapped longitudinally across their abutting parts, the cohesive force will be considerably assisted thereby.

There is no part of carpentry which requires greater correctness in workmanship than scarfing; as all the indents should bear equally, otherwise the greater part of the strength will be lost Hence we see how very unfit some of the complicated forms shown in the old works on carpentry were for the purpose. It is certainly the height of absurdity to render the parts difficult to be fitted, when the whole of the strength depends on their fitting well. "But many," says Professor Robison, "seem to aim at making the beam stronger than if it were of one piece; and this inconsiderate project has given rise to many whimsical modes of tabling and scarfing."

Having already shown many varieties of scarfings under the general head of CARPENTRY, we shall here only point out the most approved forms for practical purposes, by way of illustrating the preceding observations.

Figure 1. Two pieces of timber connected by a single step on each piece. Here more than half the power is lost; neither is the scarf so capable of resisting the force of tension as a single piece of timber would be, were it sawed half through its thickness from the opposite side, at a distance equal to the length of the scarf: however, if assisted by straps, it may perhaps be capable of resisting a much greater force, particularly if each opposite surface be bolted on the sides of the transverse joints through the straps.

Figure 2. An oblique scarf, bolted in three places. Allowing the utmost cohesion of the part of the joint A B, to be the same as whole timber, and that the transverse parts, A D or B C, are one-fourth of the breadth, D E, the compound timber will possess three-fourths of the strength of a solid piece.

Figure 3. A scarf with parallel joints and a single table upon each piece. Here the cohesive strength is diminished in an additional degree to that of Figure 1, by the projection of the table; but this gives an opportunity of driving a wedge through the joint, between the ends of the tables and thereby forcing the abutting parts to a joint. This mode requires the scarf to be longer than those which have no tables; and the transverse parts of the scarf must also be strapped and bolted.

Figure 4. Allows of the same opportunity of wedging as before: if we would suppose the parts A B and C D to be compressed by bolts as firmly together as if they were but one piece they would be, by the continuity of the fibres, and if the projection of the tables be equal to the transverse parts of the joints at A and D; the loss of strength, compared with that of a solid piece, will be no more than what it would be at A and D.

Let it be here observed, once for all, that the strapping across the transverse part of the joint is the most effectual mode of preventing the pieces from being drawn from each other, by the sliding of the longitudinal parts of the scarf, and thereby giving the bolts an oblique position.

Figure 5. A scarf formed by several steps. In this, if all the transverse parts of the steps be equal, and the longitudinal parts as strongly compressed by bolts as the fibres of whole timber would adhere laterally, the loss of strength would only be a fourth, compared to that of a solid piece; there being four transverse parts, that is, the part which the end of a step is of the whole.

Figure 6. The end of each piece is formed by three steps, and the abutting parts of the middle step being greater than that at either extremity, the loss of strength in the compound timber is the part which the middle abutting surfaces are of the whole section.

PLATE I.

Fig 1

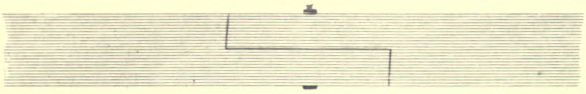


Fig. 2

Fig. 3

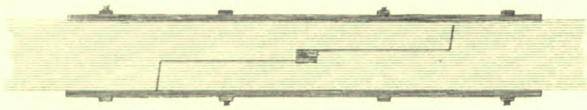


Fig. 4.

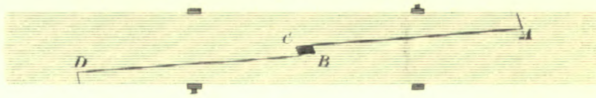


Fig. 5.

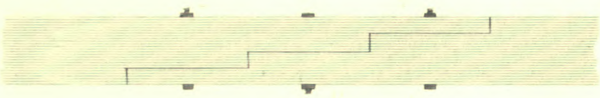


Fig. 6.

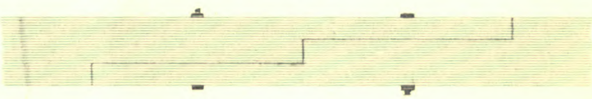


Fig. 7.

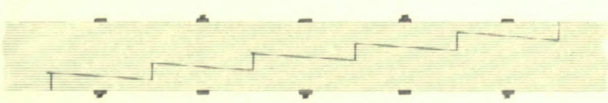


Fig. 8.

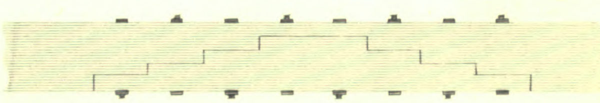


Fig. 9.

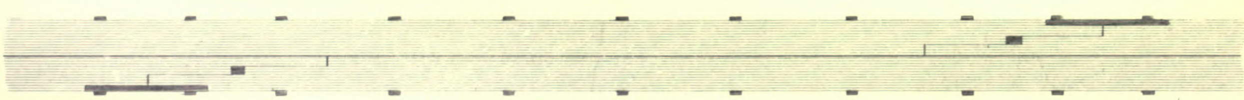
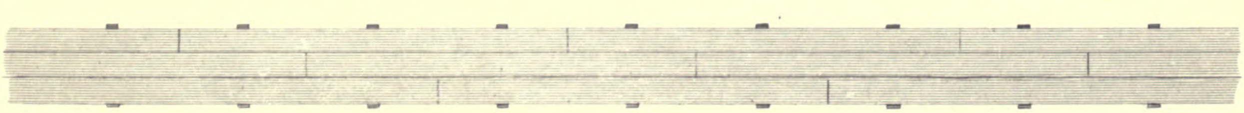


Fig 10.



Drawn by M. A. Nicholson. *Eng^d by R. Thew.*

Fig. 11.

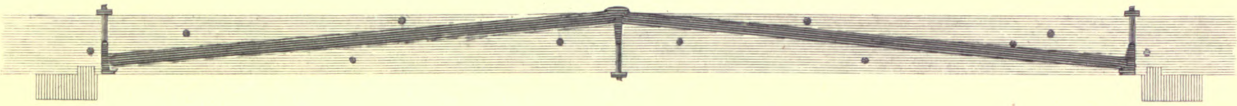


Fig. 12. No. 1.

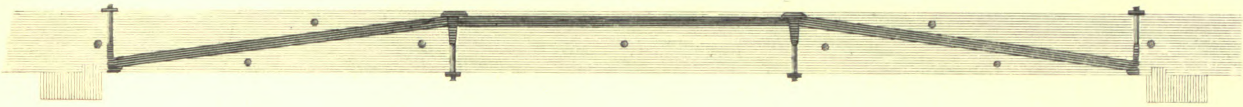


Fig. 12. No. 2.

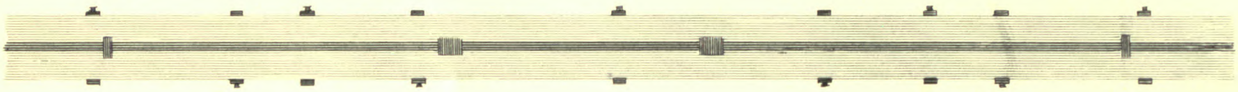


Fig 11. No. 3.

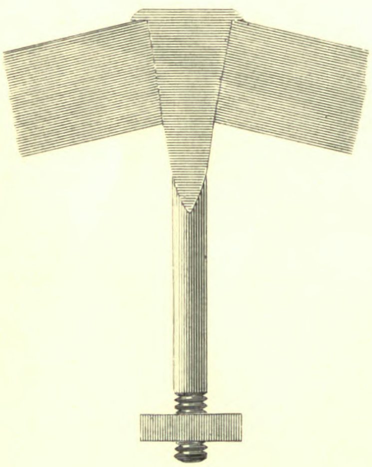


Fig 12. No. 4.

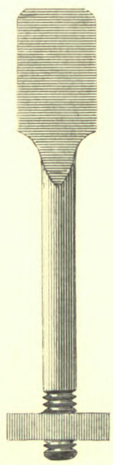


Fig 11. & 12. No. 5.

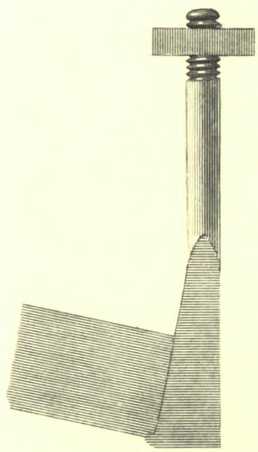


Fig 11. & 12. No. 6.

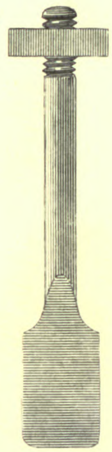


Fig 12. No. 7

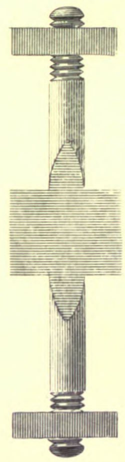


Fig 13. No. 1.

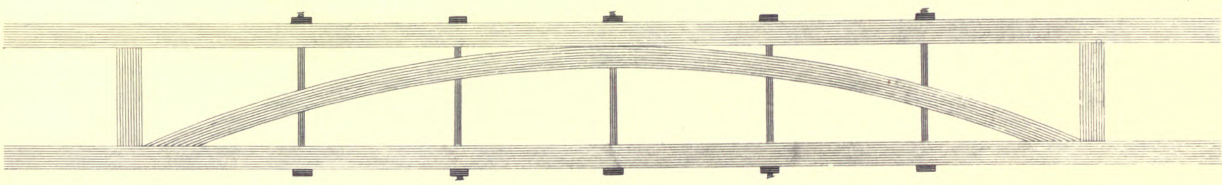
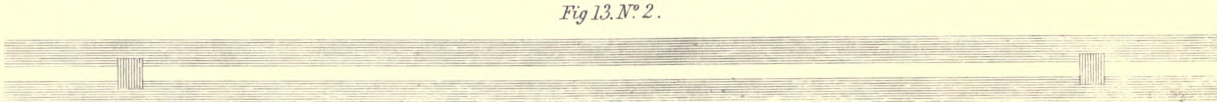


Fig 13. No. 2.



Drawn by M A Nicholson *Eng.d by R. Thew*

Figure 7. A scarf consisting of six steps, the abutting parts being equal, and the longitudinal parts inclined in a small degree to the sides; so that when the two parts come to be bolted together, the pieces will dovetail each other, and thereby prevent their being drawn; but as all timber is liable to shrink in proportion to the dimensions of its section, no dependence can be put in dovetailing, for the shrinking may be so great, that the thickest parts of the solids at the abutment of the joint may pass through the narrower cavities, and render the dovetails useless. We may also observe, in the case of bolting, that when the longitudinal parts shrink from each other, the bolts will be drawn obliquely, unless the transverse parts on the sides be stripped and bolted, both opposite to the scarf and through the solid at each end of it. The strength of the compound beam may likewise be assisted by the iron; the dovetailing therefore can only give greater adhesion at first; at the same time, it occasions a small loss of strength, equal to the difference of the extreme end of the outer step and the nearer end of the whole section.

Figure 8. The method of forming a compound timber, when the two pieces are not of sufficient length to allow them to lap, by means of a third piece, connected with both by a double scarf, formed of several degrees, or steps; the pieces abutting upon each other, with the middle of the connecting piece over their abutment.

When girders are extended beyond a certain length, they bend under their own weight in the middle, and the degree of curvature will increase in a much greater degree than their lengths. An excellent method to prevent this sagging, without the assistance of uprights or posts from the ground or floor below, is, to make the beam in two equal lengths, and insert a truss, so that when the two pieces are bolted, the truss may be included between them, they forming its tie. To prevent any bad effects from shrinking, the truss-posts are generally constructed of iron, screwed and nutted at the ends; and to give a firmer abutment, the braces are let in with grooves into the side of each flitch. The abutments at the ends are also made of iron, and either screwed and nutted at each of the ends, and bolted through the thickness of both pieces, with a broad part in the middle, that the braces may abut upon the whole dimension of their section; or, the abutments are made in the form of an inverted wedge at the bottom, and rise cylindrically to the top, where they are screwed and nutted. These modes may be either constructed with one king-bolt in the middle, or with a truss-bolt at one-third of the length from each end. When there are two bolts, they include a straining place in the middle. The two braces may either be constructed of oak, or cast or wrought iron; the latter material is, however, very seldom employed. As wood contracts less in length than most metals, oak is better for the purpose than cast iron, but then the parts of the core must be so much stronger. As to the bolts, wrought iron is indispensable. It is obvious, that the higher the girder, the less will the parts be affected by the stress, and consequently there will be less risk of their giving way under heavy weights, or through long bearings.

Figure 9. A beam of two thicknesses bolted together, the scarfing of each length of timber alternating in the two thicknesses, so as to have the junction of two lengths in the one thickness opposite the centre of a length in the other thickness: the scarfing is similar to that of Figure 3.

Figure 10. A beam of three thicknesses bolted together, each thickness consisting of a number of short timbers so disposed, that the joints in no thickness come opposite the joints in either of the other thicknesses; a bolt occurs between every two joints.

Figure 11. A section of a girder with two braces and a king-bolt.

Figure 12. The section of a girder with a straining piece, two braces, and two truss-bolts, of the best principle. No. 1 represents the girder laid open, in order to show the core. No. 2, the two parts bolted together. No. 3, the edge of a washer. No. 4, the face of the same. No. 5, the side of the cut metal bolts, in the transverse direction of the girder. No. 6, the side of the same, in the longitudinal direction. No. 7, the transverse direction of the truss-bolt, or king-bolt.

Figure 13. The section of a girder, calculated from its rise to sustain very heavy weights. If the tie-beam be very strong, the abutments may be wedged; but then the wedges ought to be very long, the tapper very small, that there may be no inclination to rise. The excess of length may be cut off afterwards. The bolts represented at No. 5, and No. 6, Figure 12, are nevertheless to be preferred.

Two timbers may be joined, either by making both planes of contact parallel with or at right angles to the fibres, or by making the joint parallel with the fibres of the one piece, and at right or oblique angles to those of the other, or at oblique angles to the fibres of both pieces. When two pieces of timber are joined so that the common seam runs parallel with the fibres of both, the joint is called *a longitudinal joint;* but when the plane of the joint is at right angles to the fibres, it is *an abutting*, or *butt-joint;* this position brings the fibres of both pieces in the same straight line. If the joint be at right angles to the fibres of one piece, and parallel with those of the other, it is called *a square joint;* if the joint be parallel with the fibres of one piece and oblique to those of the other, it is *a bevel joint;* and lastly, if the joint be at oblique angles with the fibres of both pieces, the fibres forming an angle with each other double to that formed by the fibres of one piece and the joint, it is *a mitre joint.*

These are the general positions of simple joints in respect to the fibres of one or both pieces; those which may be compounded by the position of different planes, are of infinite variety, but as they seem to have little or no practical application, we shall not detain the reader longer on the subject. In fixing two pieces of timber together with longitudinal joints, the pieces are generally bolted, and sometimes pinned.

As to butting and mitre joints, they are seldom or never used in carpentry.

When two pieces of timber are joined together at one or more angles, the one piece will either meet the other and form one angle, or by crossing it form two angles; or the two timbers will cross each other, and form four angles.

In all the following cases of connecting two timbers, it is supposed that the sides of the pieces are parallel with the fibres, or, if the fibres be crooked, as nearly so as possible; and that each piece has at least one of its surfaces in the same plane with those of one of the other; the four sides being at right angles to each other.

The angle or angles so formed will either be right or obtuse. Notching is the most common and simple form, in permanent works, and in some cases the strongest, for joining two timbers at one or more angles, particularly when bolted at the joint. The form of the joint may be varied according to the position of the sides of the pieces, the number of angles, the quantity and direction of the stress on the one or both pieces, or any combination of these circumstances.

In the notching of timbers upon each other, the notch is generally supposed to be formed by planes, at right angles to, and parallel with the side in which the excavation is made; therefore the part of the corresponding piece must have its planes in a similar situation, the solid being contained between these planes, instead of the empty space, or notch, as in the other. It may also here be remarked, that the notch is generally supposed to consist of three planes, unless it be otherwise specified.

Notching admits of the two pieces being joined at from one to four angles; but joining by mortise and tenon admits only from one to two angles.

In mortise and tenon joining, four sides of the mortise are always supposed to be at right angles to each other and to the surface whence it is recessed, and two of these sides to be parallel with each of the sides, which form a right angle with the side from which the mortise is made; the fifth plane, which is the bottom of the mortise, is parallel with the other. With respect to the tenon, four of its sides are parallel with the four sides of the piece.

In the application of timbers to buildings, it is here supposed that all pieces cut for use have a rectangular section, and when laid horizontally have their sides perpendicular to, and parallel with, the horizon.

If two pieces of timber are to be joined at four angles, cut a notch in one piece equal to the breadth of the other, so as to leave the remaining part of the thickness sufficiently strong, a very small excavation being sufficient; then insert the other piece in the notch: or if the work be required to be very firm, notch each piece reciprocally to each other's breadth, and fasten them together by pins, spikes, or bolts, as the case may require: this form is applicable where the pieces are equally exposed to a strain.

When one piece has to sustain another over it, transversely, and if only the upper be required to support a weight, cut a notch from its lower side, equal in breadth to about three-fourths of that of the lower piece, and as deep as the vertical distance that it is to be let down; then the lower piece must have a notch cut in its vertical side, leaving the middle of the upper face entire to three-quarters of its breadth, and the lower parts of the vertical side entire, so that the vertical depth of each notch may be the same as that of the upper notch: by this means the strength of the supporting or lower pieces is diminished in a much less degree than if the notch were cut out the whole breadth. This method is applicable to roofing and naked flooring.

The framing of timber by dovetail notching is chiefly applicable to horizontal framing, where the lower timber is sufficiently supported; but where the lower timber is unsupported, it is common to use mortise and tenon, which does not weaken the timber in any considerable degree; where the timber is notched from the upper side, the operation reduces its thickness, and consequently impairs its strength; though it may be said, if the solid of one piece fill the excavation of the other, and both be tightly driven or forced together (if we can place implicit confidence in the experiments of Du Hamel) and if the pieces be not cut more than one-third through, there will be rather an accession than a loss of strength. It may be observed, however, that in large works, where heavy timbers are employed, it is difficult, or almost impossible, to fit them with due accuracy; and even where the joints closely fitted at first, the shrinking would occasion cavities on the sides, that would render the tenons of no avail, because the axis of fracture would be nearer to the breaking, or under side of the supporting piece.

What has been observed with regard to horizontal pieces of timber, applies to framing in every position, where the force is to fall on the plane of the sides; and if a number of pieces thus liable to lateral pressure on either side, are to be framed into two other stiff pieces, the mortise and tenon will prove best for the purpose.

When joists are framed into trimmers, the usual method is to make the mortise on the tenon with a plain shoulder, in the middle of the sides of its respective timber: this mode is particularly used in letting down bridging joists upon binding joists, and small rafters upon purlins.

If it be required to join two pieces of timber, to form two right angles, so as to be immovable when the transverse is held or fixed fast, and the standing piece pulled in a direction of its length; cut a dovetail notch across the breadth of the transverse piece, and notch out the vertical sides of the standing piece at the end, so as to form a corresponding similar and equal solid. In some pieces of work, besides the dovetail, an additional notch is cut, to receive the shoulder of the lower piece. If the position of these pieces be horizontal, and the upper of sufficient weight, or pressed down by any considerable force, when the pieces are put together in their place, the dovetail will be sufficiently strong without the assistance of pins, spikes, or bolts. This construction requires the timbers to be well seasoned, for otherwise the shrinking will permit the standing piece to be drawn out of the transverse, and thus defeat the purpose which the construction was intended to answer. The following method of remedying this defect will be found effectual:—Cut the transverse piece in two excavations from the upper side, so that if the breadth be supposed to be divided into five equal parts, and a notch equal in breadth to three parts be cut next to the outer vertical side, and the other notch be made equal to the breadth of one part, and each notch depressed from the upper face about one-third the thickness of the piece, so as to leave the second part on the upper surface next to the inner vertical side, and the two-thirds of the depth of each vertical side next to the lower side entire: then the corresponding single notch being made on the standing piece to the solid left on the upper surface of the transverse piece, the two pieces will reciprocally receive each other.

When binding joints are framed into girders, as they have to support the bridging joists and boarding of the floor, there will be a considerable strain at their extremities; in order to make the tenons sufficiently strong to resist the weight, they should be framed with a shorter bearing tenon attached to the principal tenon and a sloping shoulder above, called *a tusk;* tenons thus formed are called *tusk tenons.*

When two parallel pieces, quite immovable, are to have another piece framed between them, proceed thus:—Insert the one end of the tenon of the connecting piece into a shallow mortise, and make a long mortise in the opposite side of the other timber, so that when the cross piece is moved round the shoulder of the other extremity, as a centre, it may slide home to its situation: thus if the tenon at the movable end fit the mortise closely, the bottom of the mortise would be the arc of a circle, of which the shoulder of the tenon first formed would be the centre: but the bottom of the long mortise may be straight instead of circular, provided it be sufficiently recessed to clear the end of the piece. This mode of framing a transverse piece between two others is employed in trimming in ceiling joists: the binding joists are always previously mortised before they are disposed in a situation to receive them, and the ceiling joists are seldom or never cut to their lengths and fitted in before the building is covered over.

When a transverse piece of timber is to be framed between two parallel joists, of which the vertical surfaces are not parallel, turn the upper edge of the transverse piece downwards upon the upper horizontal surface of the joists; mark the interval or distance between them upon the surface of the transverse piece now under; then turn the transverse piece in the way it is intended to be framed, placing the edge over the places where it is to be let down; then apply a straight-edge to the oblique surface of the joist, and slide the transverse piece so as to bring the mark upon the upper side of it in a line with the straight-edge. This being done, proceed in the same manner with the other end, and the two lines drawn on the vertical sides of the intermediate piece will mark the shoulders of the tenons. This process is called by workmen *tumbling-in joists*, and is particularly useful when the timber is warped or twisted.

Having shown the principles of lengthening timber and strengthening of beams, also the methods of joining timbers at angles, we shall now proceed to construction in general.

In groin centering, the boarding which forms the exterior surface for building upon is supported by transverse ribs of timber, which are either constructed simply, or with trusses, according to the magnitude of the work; and as a groin consists generally of two vaults crossing each other, one of them is always boarded over, the same as a plain vault, without having any respect to the other, which is afterwards ribbed and boarded, so as to make out the regular surface.

Timbers disposed in walls and at returns or angles, are joined together where the magnitude of the building, or exposure to strain, may require. These are of three denominations, as bond-timber, lintels, and wall-plates.

Flooring is supported by one or more rows of parallel beams, called *naked* or *carcase-flooring*, and is denominated either *single* or *double*, accordingly. The manner of joining the timbers we have already spoken of.

During the construction of the building, the flooring of carpentry, if not supported by brick or stone partitions, is either supported by the partitioning of timber or by shores. The construction of the flooring, whether single or double, depends upon the magnitude of the building, the horizontal dimensions of the apartments, or the weight which the boarding may be required to support. When the flooring is required to be very stiff, it becomes necessary to use truss girders.

Naked flooring for dancing upon should be made very strong, and so contrived that the upper part of it may spring, so as to bend to the impression of the force, while the lower part, sustaining the ceiling, remains immovable.

Partitions are constructed of a row of timbers, or if the length of the bearing require very great stiffness, they are made of framed truss-work, and afterwards filled in with parallel timbers. The trussing of partitions may be made to assist in giving support to the floors, where they are unsupported below. The framing ought to be so managed as to discharge the office of hanging up the floor, in whatever situation the doors are placed. Truss partitions are also of the utmost use in supporting the superior floor.

The covering of the roof is sustained by one or several rows of parallel timbers, each row being in a plane parallel to the covering. The force of the timbers, which would act laterally upon the walls, is generally restrained by tie-beams placed upon wall-plates on the top of the walls, and fixed to the lower ends of the rafters. In roofing, many ingenious contrivances may be resorted to, their application depending upon the pitch of the roof, the number of compartments into which it may be divided, or whether there are to be tie-beams or not. If an apartment is required to be coved into the roof, a longitudinal truss, supported at the ends, may be placed in a vertical plane under the ridge, by which the rafters may be hung; for it is evident, that if the upper ends of the rafters were held in their situation, their lower ends would descend by their gravity, and would describe arcs of circles in vertical planes, and in their descent would approach nearer together, and, consequently, instead of pushing out the walls, would have a tendency to draw them towards each other, And if beams were placed transversely immediately under the longitudinal truss, and fixed to the opposite rafters, they would act as straining pieces, and prevent the exterior sides of the roof from getting hollow. If the whole space within, under the rafters, were required, that is, to have no intermediate work of trussing, the sides of the roof may be prevented from descending by arching them with cast iron, or trussing them with wood in the inclined planes of their sides; and to restrain the pressure of the rafters, which would be discharged at the extremities of the building, a strong wall-plate, well connected in all its parts, must be introduced, which, acting as a tie, would prevent the lateral pressure forcing out the walls.

In this construction, as well as in the former, the rafters would have a tendency, from their gravity, to become hollow; in this case straining beams should be introduced at a convenient height, which would have a good effect in counteracting that tendency. If it be required to occupy very little space by the wood-work, cast-iron arches, abutting upon each other, and screwed with their planes upon the upper sides of the rafters, will answer the purpose best.

The idea of trussing roofs upon these principles was discovered, many years ago, by Mr. P. Nicholson, in consequence of a dispute concerning a roof which had been constructed upon a chapel, and which had pushed out the walls to such an alarming degree as to threaten the demolition of the whole fabric: Mr. Nicholson was chosen as arbiter, but the principle which the architect adopted was so incompatible with the nature of the design, that, though chosen by the architect himself, he was under the disagreeable necessity of giving judgment in favour of the constructor. This roof was truncated, or flat, and the ceiling within cylindrical, extending horizontally the whole clear of the walls, and in height to the under sides of the camber-beams, so that there were no ties between opposite rafters. The principle consisted, therefore, of two sloping sides and a camber-beam, which were only tied together by angle-braces, and as the ceiling came in contact with the under side of the rafters and the under sides of the camber-beams, the braces were also disposed so that the middle of their under sides came in contact with the ceiling, and thus, to maintain the roof in its position, depended entirely upon the resistance of the walls, or upon the inflexibility of the timbers, or both; all of which were of unusual strength.

The lesson which every architect ought to learn from this, is, always to construct his roof in such a manner as to make it entirely dependent on itself.

In the year 1802, two years subsequent to the above dispute, a model of a roof was exhibited before a numerous meeting of the Philosophical Society at Glasgow, wherein the timbers consisted simply of rafters abutting at the top upon a ridge-piece, leaving the whole space under the rafters clear, and, of course, forming a triangular hollow prism, with the two upper sides parallel to the inclined planes of the exterior. The wall-plates were unsupported, except at the four corners, which were sustained by uprights or posts; the pieces let in upon the upper sides of the rafters consisted of small arcs, almost straight, forming on each inclined plane a parabolic curve, and extending from post to post. From the ridge-piece equal and very considerable weights were suspended, one from the meeting of every pair of rafters, without producing any visible effect upon the wall-plates.

The form of a parabolic curve is best adapted to that of equal weights suspended at equal distances. Instead of arcs, simple trusses may be used, and the rafters may bridge over them.

In many cases, where space is required, we cannot help thinking, that the disposition and fixing of the boarding in the form of a truss, is vastly superior to placing them with their joints parallel to the horizon, and would be a very proper substitute for arching or trussing the sides in all roofs of moderate dimensions. It must, however, be observed, that the meeting of every two boards ought to be as nearly as possible upon the middle of a rafter, and not over the hollow. To which we may add, that as all the joists are abutting in such disposition, the boards forming trussed work may be made thicker, and let into the rafters, which will give greater security to the abutments; but for this purpose they ought to be firmly fixed at their meeting, to prevent them from starting.

The principle of arching the inclined sides of a roof, and making the wall-plates act as ties, is exhibited in the architectural plates of Rees' *Cyclopedia*, published in 1805.

Circular roofs may be executed without ties, or without any precaution of trussing, as in rectangular buildings, but the wall-plate ought to be one continued mass. There are two methods of covering circular roofs with boards: one is, to bend the boards with their joints in horizontal planes; and the other is, to bend them in planes passing through the axis. As that species of circular roofs called *domes* lays considerable claim to our attention, it will here be proper to say something on their construction.

If the dome be spherical, and have no lantern to support, the ribs may be constructed of boards in two or three thicknesses, with the longitudinal joints of the boards tending to the axis of the dome, and intersecting the spherical edges, and the butting joints intersecting the sides of the ribs, which tend to the said axis.

Let us now suppose the thickness of a rib to consist of three boards, and suppose the circular pieces which are to compose the ribs, to be all prepared of equal lengths and breadths. Take one of the lengths, suppose for the left-hand piece at the bottom, and lap the next higher length, which is the middle piece, two-thirds upon the lower piece; take another length for the right-hand piece, next higher, and lap this two-thirds on the middle piece; so that the right-hand piece will lap one-third upon the left-hand piece; between the ends of this third, bolt or pin the three pieces together; the middle board will want a third, the right-hand board two-thirds, to make it complete at the bottom; these parts being supplied and fixed, lay another board at the higher end of the right-hand board, the end of another to abut upon the higher end of the middle board, and the end of a third board to abut upon the upper end of the left-hand board, then there will be three piles of boards, which must be fastened together between each pair of heading joints, which are three in number. Proceed in like manner with every succeeding three boards, as with the last three, until you arrive at the top, and the deficiency must be supplied as at the bottom. In this manner, every rib in succession must be constructed, until they are all finished. Each rib ought to be fitted to the curvature of the axal section of the dome, drawn on a floor, and the three thicknesses fixed together throughout the whole length, before it is removed. If, in addition to the fixing, the joints be strapped, it will add considerably to the strength, and will not be much inferior to that of a solid piece. In large domes of this construction, it becomes necessary to discontinue the ribs, otherwise an unnecessary quantity of timber would be employed; and it must be observed, that the greatest intervals must be so regulated in their dimensions, as not to be greater than what would make the horizontal ribs for the boarding, when fixed, sufficiently strong.

As all domes are best boarded with their joints in vertical planes tending to the axis, horizontal pieces must, in this case, be strutted between the ribs, and their outer sides formed with the spherical surface. A dome constructed in this manner, might also be made to support a heavy lantern, provided the strutting-pieces were strapped together. In the above manner was the timber dome of the Halle du Bled, at Paris, constructed by Moulineau, supposed to be the first of the kind.

If the boarding of the dome is required to be bent, with the joints in horizontal planes, and the dome have no lantern, a very good method is, to construct it with several vertical ribs, their planes being disposed at equal angles round the axis as their common vertex, and constructed according to the above method; between every pair of such ribs, place other ribs, the curvature of which will be portions of less circles of the sphere, unless one stand in each interval, and its plane bisect the inclination of the vertical planes of the two adjacent principal ribs: dispose of these ribs in equidistant parallel planes, and fit their upper ends upon the sides of the principal ribs. This disposition of the ribs will be a considerable saving of timber, besides what it would have been, had the planes of all the ribs tended to the axis.

In the construction of plaster groins, two methods are employed in the disposition and fixing of the ribs. By both methods, ribs are made to answer the intersections at the angles: by one method, ribs are formed to the transverse sections of the vault, and disposed in vertical planes accordingly; but by the other, the ribs are prepared straight, and fixed parallel to the axis of each vault.

The lathing for plaster is sustained upon walls, by a number of parallel posts of very small scantlings, called *battening*, and ranged according to the figure they are intended to form.

CONTABULATE, to floor with boards.

CONTACT (from the Latin, *contactus*, touch) the mutual touching, or meeting, of two things.

Contact, in geometry, is when a line or plane meets a figure or solid, without cutting it, though the line or plane be produced. Thus, a line and a circle are in contact when the line is a tangent to the circle; and two circles are in mutual contact, when they touch each other without cutting: the like is to be understood of a plane and a convex body, as a cylinder, cone, conoid, &c.

CONTENT (from the Latin, *contentus*) that which is contained, the thing held, included, or comprehended within a limit or line. In geometry, the area or quantity of matter or space included in certain lines. *Linear content*, length simply; *superficial* content, area or surface; *solid* content, the number of cubic inches, feet, yards, &c. contained in a given space.

CONTEXTURE (from the Latin, *contexo*, woven) the disposition or union of the constituent parts of a body in respect of each other.

CONTIGNATION (from the Latin, *contignatio*, *con* and *tignum*, a beam), a frame of beams, in ancient Roman carpentry, the same as we now understand by *naked flooring*.

CONTIGUITY (from the Latin, *contiguus*, to meet) the relation of surfaces or solids whereby their sides join each other.

CONTIGUOUS ANGLES, in geometry. *See* Angles.

CONTINUED, a term applied to whatever is not interrupted, but proceeds in the same course.

Continued Attic, an attic not broken into pilasters.

Continued Pedestal, a pedestal with its mouldings and dado, or die, continued both through the column and intercolumn, without being broken.

Continued Proportion, is when there is a series of lines or quantities, such that the first is to the second as the second is to the third, and the second to the third as the third to the fourth, and so on.

Continued Socle, the same as *a continued plinth. See* Plinth.

CONTINUOUS BEARINGS, balks of timber laid under the rails of a railway for their support, in place of stone sleepers, or blocks fixed at certain intervals. These balks, or longitudinal sleepers, as they are generally termed, are secured to cross transoms fixed to piles.

Continuous Impost, in mediæval architecture, the mouldings of an arch carried down to the ground without interruption, or anything to mark the impost-point.

CONTORTED, wreathed. *See* Wreathed.

CONTOUR (from the French; synonymous with *contorno*, Italian) the outline of a body; to have which correct, is one of the greatest requisites in drawing and painting.

CONTRAMURE. *See* Countermure.

Contramure (from the French, *contre*, against, and *mur*, a wall) in fortification, an external wall built about the walls of a city.

CONTRARY FLEXURE, *Point of*, or Point of Retrogression, the point in which two curves meet that have the convexity of the one and the concavity of the other on the same side of the line.

CONTRAST (from the French, *contraste*) to avoid the repetition of the same thing, by introducing variety; as is done in antique edifices, where rectangular and cylindrical niches with spherical heads are alternately introduced; also, in the dressings of niches, as in the Pantheon, tabernacles are introduced with circular and triangular pediments alternately.

CONTRAVALLATION, (in fortification), a trench guarded with a parapet, thrown round a besieged place by the besiegers, to protect themselves, and check sallies of the garrison.

CONVENIENCE (from the Latin, *convenientia*) an easy or accessible distribution of apartments in respect to the intention of the design.

CONVENT (from the Latin, *conventus*, an assembly). *See* Monastery.

Convent, a religious edifice, in which lived assemblies of persons devoted to a religious life, under the authority of a superior. Convents for males are termed monasteries, those for females, nunneries; when under the jurisdiction of an abbot, or abbess, they are named abbeys, and under that of a prior, or prioress, priories.

CONVENTUAL CHURCH, a church belonging to a convent, and consisting of regular clerks, professing some order of religion, or of a dean and chapter, or other societies of spiritual men.

CONVERGENT CURVE. *See* Curve.

Convergent lines, such lines as if produced would meet.

CONVEX LINE, that side of a curve which has no contrary flexure, and on which a tangent may by drawn.

Convex Rectilinear Surface, a curved surface, such, that if any point be taken, a straight line passing through the point can only be drawn in one direction, and if another point be taken out of the straight line so drawn, another straight line passing through this and the former point, will pass within the solid. Bodies having this property are cones, cylinders, and many others.

Convex Surface of a Solid, a curved surface, in which, if any two points be taken, the straight line joining them will pass through the body: all the solids generated by the revolutions of conic sections, except the triangle, have this property.

CONVEXITY (from the Latin, *convexus*) the same as *convex surface.*

CONVOLUTION (from the Latin, *convolutio*) a winding or turning motion.

COOPER (from the Dutch, *kype*, a barrel) a person whose business it is to make vessels of wooden boards, hooped together around a circular or elliptic circumference.

COOPERY, the art of making vessels of boards, by joining them edge to edge, and binding them round the exterior sides with hoops, so as to form a hollow body of circular or elliptic sections, and so as to contain a liquid, with one or two ends.

The boards of which vessels are made, are called, in the rough state, *clap-boards;* but when wrought up in the vessels, they are called *staves.*

The art of coopery is a curious branch of mechanism; it requires a knowledge of geometry, as well as of the covering of solids, to be able to construct a vessel or cask of a rotative figure, agreeably to a given section through the axis; the edges of the staves require to be of a particular curvature, so that, when joined together, they may form the required contour of the vessel. This, though not a branch of architecture, is founded upon the same common principles.

CO-ORDINATE (from the Latin, *con*, with, and *ordinatus*, order) a term expressive of two objects holding the same rank.

Co-ordinate Pillars, such pillars as stand in equal order.

COPED TOMB, one which has its top or covering sloping down towards both sides.

COPESTONE, head or top-stone.

COPING (from the Dutch, *kop*, the head) in masonry, the stones laid on the top of a wall, to strengthen and defend it from the injuries of the weather.

Coping of equal thickness, is called *parallel coping*, and is only used upon inclined surfaces, as on a gable end, or in situations sheltered from the rain; as on the top of a level wall intended to be covered by the roof.

Coping thinner on one edge than on the other, for throwing off the water on one side of the wall, is called *feather-edged coping.*

Coping thick in the middle and thin at each edge, whether the back be formed of two planes meeting in an angle over the middle of the wall, or whether forming the arch of a circle in its transverse section, is called *saddle-backed coping.* This kind of coping throws the water on both sides, and may be used over the walls of sunk areas, or of a dwarf wall, which is to have an iron-railing, and in the best-constructed fence-walls.

Coping upon the gable end of a house, is called *factabling*, in Liverpool.

Coping, in the pointed styles of architecture, is either inclined upon the faces, or plumb. When inclined upon the faces, the sides of the vertical section are the sides of an equilateral triangle, whose base is horizontal. This sort of coping is sometimes in one inclined plane, terminated with an astragal at the top, while at the bottom it changes its direction into a narrow vertical plane, which projects with a level soffit before the parapet. Sometimes it is in two inclined planes, parallel to each other, the upper terminated with an astragal at the summit, and projecting before the lower, and the lower before the vertical face of the wall, in the same manner as that which has only one inclined plane. This coping is used in plain parapets, or in battlements. When used in battlements, it is either returned on the vertical sides of the embrasures or notches, or only crowns the top of the ascendants, and bottom of the notches.

The coping of battlements with vertical faces, has a small projection beyond the face of the wall, and the coping is returned on the sides of the notches.

Inclined coping is sometimes made without the astragal at the top, and the soffit before the vertical face of the parapet perpendicular to the inclined face of the coping.

Coping over, is said of the soffit of a projecture from the naked of a wall, when the soffit is inclined so as to make an acute angle with the vertical face of the wall below it; that is, when the edge of the soffit in the surface of the wall, or next to it, is higher than the outer edge.

CORBEILS (from the Latin, *corbis*, a basket) a piece of carved work, representing baskets filled with flowers or fruit, to finish some ornament.

CORBEL, a term used by some for a niche or hollow in a wall, to contain a statue, bust, &c.

Corbel, a block of stone or other material projecting from the face of a wall, and used to support a superincumbent weight, such as the beams of a roof, ribs of vaulting, columns, and such like. The term is confined chiefly to such supports employed in Gothic architecture, in the buildings of which styles corbels occur very frequently; they perform somewhat of a similar office to the modillions or consoles used in Classical buildings, but their more perfect prototype is to be seen in the projecting figures and heads supporting consoles, in the remains of the baths of Dioclesian, at Rome.

Corbels are usually carved in grotesque heads, animals, flowers, &c.; in the Romanesque style they are either simple square blocks with the face occasionally rounded, or carved in the shape of grotesque heads; in the Early-pointed, the corbels are sometimes moulded, and in the richer specimens carved into knops of foliage; when heads or masks are used, they are not of such grotesque appearance as during the preceding period; in the next style they are more frequently foliaged, and in the Perpendicular carved in the form of angels sometimes bearing shields and other devices; in the later styles, the corbel is usually terminated above by a moulding, or series of mouldings, forming a kind of capital. Corbels of large dimensions, such as those supporting a group of clustered columns, are generally very elaborately ornamented in combinations of masses, or groups of foliage springing from one or more points underneath, and clustered together under the cap; sometimes groups of figures are introduced, as in the beautiful specimens to be seen in Exeter Cathedral.

Corbels are not unfrequent in castellated architecture, and when so employed are of a very massive character. They have usually two of their sides vertical planes, perpendicular to the surface or face of the wall; and their other surfaces, which are their edges or fronts, quarters of cylindroids, with the greater axis of their section perpendicular.

The edge of each corbel generally consists of one, two, and sometimes three convex rectilinear surfaces: when the edge of each bracket consists of two or three convex rectilinear surfaces, these surfaces are generally separated by fillets, which have vertical sides parallel to the face of the building, and horizontal soffits.

Corbels are also a horizontal row of stones or timber, fixed in a wall, or in the side of a vault, for sustaining the timbers of a floor, or those of a roof. Many of the timber floors, or contignations, in old buildings, were thus supported; the timbers of the domic roof of St. Paul's are tied to the conic vault by means of corbels. The ends of the corbels are generally cut into a convex or ogee form.

Corbels, in the Caryatic order, are those parts upon the heads of the Caryatides, under the soffit of the architrave cornice, that represent baskets, or rather cushions, and have an abacus, as in the Grecian orders.

The term is also used for the vase of the Corinthian capital, it being in form of a basket.

Corbel-Bole, a moulding, in Norman architecture, employed frequently to support a blocking course. It consists of two rows of billets or cubical blocks of stone disposed at intervals, and so arranged, that the blocks alternate in the two rows, a block coming under a space, and *vice versa*. *See* Billet-Moulding.

Corbel-Steps, sometimes called *corbie*-steps, a term applied to steps up the sides of a gable; when the parapet is formed into a kind of battlement, broken into steps or ledges, which converge from the eaves to the apex. Specimens are to be seen in many old houses, especially in Scotland, Flanders, Holland, and Germany. They may have been used perhaps for extinguishing fire, or escaping from it, or merely for ornament.

Corbel-Table, a series of corbels disposed at regular intervals projecting from a wall, to support a parapet or other continuous projection, and frequently seen under the eaves of a roof. The corbels are occasionally plain, but often carved in the shape of grotesque heads, and other devices, as abovementioned. Sometimes the corbels are connected by small arches which intervene between them and the superstructure, and form its immediate support; these arches vary in shape, according to the style of architecture of the building in which they are employed, as do also the corbels; in the Romanesque structures they are circular, during the next period intersecting, and lastly, pointed and trefoiled. Corbel-tables were more frequent in the Romanesque styles than in any others, in which they form a bold and effective feature. They are found in a peculiar situation in many Lombardic structures, running up the raking sides of the wall beneath the gable; a singular instance of this position is to be seen in the west gable of Adel Church, Yorkshire.

CORBETT, a word used by Harris, in his *Lexicon*, for a corbel. Corbetts, niches for images.

CORBETTIS, a word used by Chaucer, for stones upon which images stand.

CORBS, a Spanish word for architectural ornaments.

CORD, in geometry. *See* Chord.

CORDON, the edge of a stone on the outside of a building.

CORE, the interior part of anything. Every masonic wall should have thorough-stones at regular intervals, in order to strengthen the core, which is generally made of rubble-stones: or, otherwise, when thorough-stones are only to be had with difficulty, two bond-stones lapped upon each other, one from each face of the wall, may be used: or, instead of each thorough-stone lay two stones level on the upper bed, and one large stone in the core, lapped upon both, observing that the tails of the two lower stones be right-angled; by this means the two sides of the wall will be completely tied together.

CORICEUM (from *κωρικειον*) in Grecian antiquity, the undressing-room belonging to the Gymnasium.

CORINTHIAN ORDER, the third of the orders of Classical architecture, and the first of the foliaged, under which title we include the Corinthian and Composite. These two orders might conveniently be classified together, and reasonably too, if we consider their general resemblance, and also that some examples of the former class differ as much from that which is considered their most perfect type or model, as do those which are included under the Composite or Roman order; if both styles were comprised under one division, it would form a very distinct and marked style, which might be entitled the Roman or Foliaged order.

How this particular class of examples obtained the appellation of Corinthian, is not very readily accounted for; one would naturally suppose this name was assigned on account of the origin of the style, or the prevalence of examples in Corinth or its neighbourhood, but such is by no means the case. In the first place, the origin has never been attributed to that locality by any author except Vitruvius, and even if we give credit to his account, the merit of the first idea ought in fairness to be given to the Athenians; but at best the story told by this author rests on a very insecure foundation, as we shall presently attempt to show. No other writer has alluded to any buildings of this order as existing at Corinth; and if the style ever did prevail in that city, we have now not a single example remaining to testify to the fact.

Vitruvius's account of the invention of the capital, is as follows:—Callimachus, an Athenian sculptor, passing the tomb of a young lady, observed an acanthus growing round the sides of a basket, covered with a tile, and placed upon the tomb, and seeing that the tops of the leaves were bent downwards, in the form of volutes, by the resistance of the tile, he took the hint, and executed some columns with foliated capitals, near Corinth, of a more slender proportion than those of the Ionic, imitative of the figure and delicacy of virgins.

This story, though bearing no marks of improbability in itself, when compared with facts, loses a considerable amount of its credibility, and stands upon the same level as the other fanciful tales related by the same author. As regards the one more immediately before us, it need only be remarked, that the earliest specimens of this order have but little in agreement with the idea which one would suppose to have presented itself to the mind of an artist under the circumstances related; the foilage of what seems to be the earliest specimen extant, does not consist of acanthus leaves at all, but of what have from their shape been termed water-leaves; it is in the Roman examples we see the best illustration of the basket and acanthus; in short, the earlier the example, the less the resemblance, a fact which throws discredit upon the whole story, and would lead us to believe that the latter was invented by Vitruvius, not the order by Callimachus. Moreover, there is reason to doubt of the antiquity of the order being so great as Vitruvius would have us believe; for Callimachus flourished about the 60th Olympiad, or 540 years before the Christian æra. We are informed by Pausanias, lib. viii., that the ancient temple of Minerva, at Tegæa, in Arcadia, having been destroyed, a second edifice was erected, under the direction of Scopas, far exceeding in splendour and magnificence every building of the kind in the Peloponnesus. In this structure, all the three Grecian orders were employed; the outside was embellished with colonnades of the Ionic order; and the hypæthral area of the interior was surrounded with porticos and galleries above, formed by the Doric and Corinthian orders. This æra of building may be placed in the fourth century before Christ, and is the first in which a distinct account of the Corinthian order being introduced in any regular building, is to be found. It was not in general request till the third age of Rome, under the emperors. The examples which are to be found in Greece, are but few, and some of them seem of a date posterior to the period of the Romans getting possession of that country; such as the temple of Jupiter Olympius at Athens.

Most modern writers are of opinion that the Corinthian capital was invented by the Egyptians, and with good reason; yet, although many bell-formed capitals are to be found among the ruins of Egypt, the taste, the delicacy of the foliage, the beautiful form and elegance of the leaves, caulicoli, and volutes, with the symmetrical and easy disposition of the whole, are superior to anything yet discovered among the Egyptian ruins; and even in the present day, this capital exhibits the utmost elegance, beauty, and richness, that have ever been attained in architectural composition, though many attempts have been made to exceed it.

Some writers suppose that the Corinthian arose naturally out of the Doric order, and cite in favour of their hypothesis, the absence of bases, the simple capital, and the square abacus, in the Tower of the Winds, the use of mutules in the shape of modillions, and such like; but we think those who maintain its Egyptian origin, have the better evidence on their side.

The Corinthian order, like the other two, after being introduced, continued to be the fashionable order in Greece, Italy, and Asia; and was the only order well understood, and happily executed, by the Romans. Among the superb ruins of Balbec and Palmyra, excepting the lower Ionic order in the circular temple, and a Doric column at the former place, it is, we believe, the only order to be found.

Vitruvius says, the shafts of Corinthian columns have the same symmetry as the Ionic, and that the difference between the entire columns arises only from that of the heights of their capitals; the Ionic being one-third, and the Corinthian the whole diameter of the shaft, which, therefore, makes the height of the Corinthian two-thirds of a diameter more than that of the Ionic: hence, as he has allowed the Ionic to be eight diameters, the Corinthian will be eight and two-thirds.

The average height of the column, inclusive of capital and base, taking a mean proportional between those of the Pantheon and of the temple of Jupiter Stator, is ten diameters, the shaft containing eight, and the remainder made up in the capital and base.

The shaft in the ancient examples was almost invariably fluted, and the flutes occasionally filled to about one-third of their height with cabling; the number of the flutes is generally twenty-four, the same number as in the Ionic order, and arranged in the same manner, having a fillet between every two channels. The only ancient examples in which the flutes were omitted, were cases in which the shafts were composed of polished granite or some variegated marble, in which there was sufficient richness and play of colour, without further decoration.

The capital is separated from the shaft by an astragal and cincture, or fillet, and is in the shape of an inverted bell, the ornamentation of which may be described as follows: Immediately above the astragal, are two rows of acanthus or olive leaves one above the other, each row consisting of eight leaves; the upper row is arranged in such a manner as to have one leaf immediately in the centre of each side of and beneath the abacus, and one other under each corner of the abacus, which altogether, one in the centre of each side, and one at each angle of the capital, will make up the eight leaves. The leaves of the lower range are disposed so as to alternate with those of the upper; that is to say, the spaces left between the lower leaves are occupied by the lower portions or stalks of the upper leaves, or, in other words, the upper leaves rise between the divisions of the lower ones. Between every two of the leaves of the upper or second series, rises a stalk, out of which springs a bunch of foliage, consisting of two leaves, one of which branches towards the centre of the abacus, and the other towards the angle. We have therefore eight of these stalks, termed *caulicoles*, each giving out two branches or leaves, of which therefore there are sixteen, and if we consider their direction as above described, we shall find that we have two of them tending to meet at each angle, one from each contiguous side of the capital, and two likewise tending towards the centre of each side above the central leaf of the second range. Out of each of the leaves at the angles, proceeds in a diagonal line, a spiral horn or volute, the two at each angle meeting under the abacus, which they support; two similar though smaller ones emerging from the central leaves, meet under the centre of the abacus, and are surmounted by a small flower, called the flower of the capital.

The abacus is square in its general plan, or rather is of such form as may be inscribed in a square; the sides are concave, curving out towards the angles, but the points which would be formed by the intersection of the curves, are most usually cut off; sometimes the corners are pointed, but rarely. This shape of the abacus arises out of the form of the capital, which recedes in the centre of each side, and projects at the angles; the abacus does not overhang the capital. The mouldings consist of a cavetto, fillet, and echinus, the first and last of which are sometimes enriched.

The proper Corinthian base differs from the Ionic or Attic, in having two smaller scotiæ separated by two astragals; both bases, however, are used indiscriminately, and perhaps the Attic is more generally employed—it was preferred both by Palladio and Scamozzi.

The above may be considered as a description of the standard form, for the details of the order vary to a very considerable extent in the different examples, to such an extent, indeed, that there are scarcely two ancient examples alike. The ornamentation of the capital differs very greatly in the Greek and Roman examples; in the former, the leaves have angular points, and are almost straight on the sides, while in the latter they are altogether of a more rounded form, in fact the Greek leaves were more harsh and stiff, and have the natural character of the acanthus, whereas the Roman are more artificial. In the Temple of the Winds, which is a very early, if not the earliest specimen remaining, the upper row of leaves, if it may be said to have more than one row, is merely carved upon the vase, and consists of broad flat leaves, which have been named from their appearance, water-leaves; there are no volutes, and in consequence the abacus is not curved, but is merely a square block; add to this the absence of a base, and you will perceive at once that this specimen disagrees almost entirely from the description above given. In the temple of Vesta at Rome, which is probably copied from that at Jackly near Mylasa, the lower range of leaves, instead of following the line of the shaft as usual, project beyond it. The monument of Lysicrates is a beautiful though small specimen, and differs materially from any of the above; in short, every example, whether Greek or Roman, has its peculiarity.

The height of the abacus is one-seventh, the lower and upper tier of leaves each two-sevenths; and the caulicoli and volutes, which spring from the stalks between every two leaves in the upper row, the remaining two-sevenths of the diameter: the breadth of the capital at the bottom is one, and each diagonal of the abacus two diameters of the column.

Vitruvius makes no mention of obtunding the corners of the abacus, as is generally practised by the ancients as well as the moderns: we are therefore led to suppose, that each pair of the four faces of the abacus were continued till they met in an acute angle at each corner, as in the temple of Vesta, at Rome, and in the Stoa, or Portico, at Athens. The division of the capital is the same as is frequently used by the moderns; but the entire height is generally made one-sixth more than the diameter of the column, while that of the column is ten diameters.

This order does not appear to have had any appropriate entablature in the time of Vitruvius; for, in book iii. chap. i. he informs us, that both Doric and Ionic entablatures were supported by Corinthian columns; whence it appears that the columns constituted the order, and not the entablature. "The Corinthian," says he, "has no cornice, or other ornaments peculiar to itself, but has either triglyphs, mutules in the cornice, and guttæ in the epistylium, as in the Doric order; or otherwise, the zophoras is ornamented, and dentils are disposed in the cornice, as in the Ionic."

This observation of Vitruvius regarding the use of the Doric entablature, is no less extraordinary in itself, than that it is unsupported by any ancient examples; but his remark, concerning the Ionic, is verified in many instances; as in the temple at Jackly near Mylasa, the temple of Vesta near Tivoli, and that of Antoninus and Faustina at Rome; the arch of Adrian at Athens, the Incantada at Salonica, and the portico of Septimius Severus at Rome. However, in the remains of antiquity, we more generally find Corinthian columns supporting an entablature of a peculiar species. This consists of architrave, frieze, and cornice, the first of which is divided into three faces, the lowest one much narrower than the upper two, with mouldings between each; the upper surmounted by an astragal, ogee, and fillet, the middle by a small ogee, and the lower by a bead; these mouldings were frequently plain, but sometimes enriched, more especially the two last mentioned. The frieze was sometimes plain, sometimes enriched with sculptured figures, foliage, or other ornamentation. The most striking peculiarities are to be observed in the cornice, which consists of the denticulated band of the Ionic, supported by an ogee and astragal enriched, and surmounted by an enriched astragal and echinus; over these are the mutules of the Doric, but their proportion is changed, and their figure converted into a console, which shows upon the ends and sides of each, the bottom being covered with a foliated leaf. The consoles in this application, are called *modillions*, and support the corona which consists of the same mouldings as the Ionic, with occasionally a greater amount of enrichment; the cymatium is often decorated with lions' heads, to serve as spouts or gurgoyles. This entablature does not appear to have been in use in the time of Vitruvius, since he takes no notice of it; though very particular in many other points less worthy of attention. The cornice here specified, is not only to be found in most of the ancient buildings of Italy, but is observed in all the celebrated works of Balbec and Palmyra.

Thus the Romans, and other contemporary nations, affected to give the Corinthian order an appropriate entablature, though the Ionic was sometimes employed. We find also another form of cornice introduced occasionally, with modillions consisting of two plain faces, instead of consoles, without any band below, either plain or denticulated. Examples of this are only to be found in the frontispiece of Nero, at Rome, and the Poicile, or Portico, at Athens. In some instances, an uncut dentil band is substituted in place of dentils, and in the temple of Antoninus and Faustina, both dentils and modillions are omitted.

The above disposition inverts the order of the original hut, as well as the description given by Vitruvius. The only example where dentils are placed above modillions, is in the second cornice of the Tower of the Winds, at Athens; although Vitruvius seems to assert that the contrary practice of placing the modillions uppermost, was never resorted to by the Greeks. It is certain that the Romans employed modillions in the latter position, as is evidenced in the temples of Jupiter Tonans and Jupiter Stator, as also in the Forum of Nerva.

If the entablature be enriched, the shaft should be fluted, unless it be composed of variegated marble; for a diversity of colours confuses even a smooth surface; and if decorated, the ornament increases the confusion in a much greater degree.

When the columns are within reach, the lower part of the flutes, to about one-third of their height, is sometimes filled with cables, as in the case of the interior order of the Pantheon, with a view to strengthen the edges. In rich work of some modern buildings, the cables are composed of reeds, husks, spirally-twisted ribbands, flowers, and various other ornaments: but these trifles, which are of French origin, would be much better withheld, as their cost would be employed to greater advantage in giving majesty or grandeur to the other parts of the fabric.

As the cornice, which has obtained the name of Corinthian, consists of so many members, it will be necessary to increase the whole height of the entableture more than two diameters, so as to make the members distinct, and, at the same time, to preserve a just proportion between the cornice, frieze, and architrave, making the height of the entablature two-ninths of that of the column: but where the Ionic cornice, which is very appropriate, is to be employed, or the dentils and their cymatium omitted, two diameters, or a fifth of the height of the column, will be sufficient.

It is by some considered ridiculous to give so many members to the cornice, since, say they, it is evident that these slight columns are incapable of bearing an entablature of the same part of their height, as columns of fewer diameters are. Notwithstanding this, however, we cannot but think that the richer and deeper cornice is more in keeping with the character of the order, on account of the increased height and enrichment of the capital. The apparent weight does not depend so much upon the real bulk, as upon the arrangement and proportions of the different dimensions, for were this the case, we might successfully employ the argument produced by those who object to the loftier entablature, to disparage the beauty of the entire order. We might reason thus:—the Corinthian shaft is of the same proportions as the Ionic, and therefore equally light in appearance, how contrary to sound taste, is it, therefore, to load it with a capital of so much greater bulk, how much heavier the column will appear! Our objectors will readily see that this reasoning is false, because it is evident to the senses, that the Corinthian column, although surmounted by a capital of much greater bulk than the Ionic, has a much lighter and more elegant appearance; and what is the cause of this? It is simply that the proportions are regulated in a different manner; in the Ionic the breadth is in excess, in the Corinthian the height. But there is another reason for the comparative lightness of the Corinthian capital; it is much more highly enriched than the Ionic, and this enrichment tends to make it a vast deal lighter in appearance; the difference between the unshapen block of stone and the finished capital, will be evident to any one who will picture the two in his mind's eye. Now, all these arguments apply with equal truth in the comparison of the two entablatures; for our own parts, we think the larger the more elegant and the more imposing, and certainly its cornice gives the more complete finish to the whole order.

"The symmetry of the capital," says Vitruvius, "is as follows:—the height of the capital, including the abacus, is equal to the thickness of the column at its lower end. The breadth of the abacus is so regulated, that its diagonal, from angle to angle, may be twice as great as the height of the capital; for this gives a proper dimension to each face; the fronts of the capital are bowed, or curved inwardly, from the extreme angles, a ninth part of its breadth. The bottom of the capital is as thick as the top of the column, without the apothesis and astragal. The thickness of the abacus is the seventh part of the height of the capital. The remainder, when the thickness of the abacus is deducted, is divided into three equal portions, of which one is given to the lower leaves; the second is for the height of the middle leaves; and to the caulicoles, or stalks, from which the leaves project to support the abacus, the same height is given. The flowers on the four sides are in size equal to the thickness of the abacus." From a comparison of ancient examples, the height of the capital varies in height from 60 minutes, or 1 diameter, the measurement of those belonging to the temple of Tivoli, to 87 minutes, the height of the Lysicrates example; the capital in the temple of Jupiter Stator measures 66 minutes. In the first case, the diagonal of the abacus is 81 minutes, in the last 97, and in the monument of Lysicrates, 94 minutes.

Thus much for proportions; how greatly they vary in different examples, will be readily seen in the subjoined table taken from Knight's Cyclopædia:—

	Height of Column.		Diameter of Base.		Upper Diameter of Shaft.		Height of Entablature.	
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
Incantada, at Salonica	23	8.6	2	5.9			5	7.75
Temple of the Winds (without base)	13	6.85	1	7.4				
Monument of Lysicrates, at Athens	11	7.67	1	2	0	11.65	2	8.218
Stoa, or Portico, at Athens	28	0.534	2	11.3				
Arch of Trajan, Ancona	23	2.7	2	4.25	2	0.25	5	6.3
Arch of Constantine	27	4.1	2	11.2	2	9	7	1.2
Portico of Pantheon, at Rome	46	5.2	4	10.4	4	3.5	10	11.6
Interior of Pantheon, at Rome	34	10.4	3	8.2	3	2.3	8	2.9
Temple of Antoninus and Faustina	46	7.7	4	10.3	4	2.8	10	9.1
Temple of Vesta, at Tivoli	23	6	2	5	2	1.8	4	3
							Architrave.	
Temple of Jupiter Tonans	46	6.2	4	8.3	3	11.4	10	0
Temple of Jupiter Stator	48	4.9	4	10.2	4	2.5	12	10.3
Temple of Vesta, at Rome	34	7.2	3	2.5	2	8.1		
Temple at Jackly, near Mylasa, in Asia Minor, the supposed site of Labranda	27	2.8	2	10.35	2	3.6	5	6.6
Temple of Mars Ultor, at Rome	57	11	nearly 6 ft.		5	1.6	3	10.5

The proportions of this order vary to a very great extent; the following may be taken as an average:—shaft, 16 modules 20 minutes, base 30 minutes, capital 70 minutes, which gives 10 diameters for the whole column; the diminution of the shaft, from the base to the neck, is 7 minutes. The entablature is about a fifth part, or a quarter the height of the column; if the latter, it would consist, in this case, of 5 modules, or $2\frac{1}{2}$ diameters, of which the architrave would occupy 45 minutes, the frieze 45 minutes, and the cornice 60 minutes, having altogether a projection of 58 minutes.

Although the Romans in all probability borrowed the idea of this order from the Greeks, and cannot therefore rightfully lay claim to its invention, they are fully entitled to the praise due to its perfection; the order, as far as we know it, is rather Roman than Greek. We cannot be said to know of more than three examples in Greece, and these are the Tower of the Winds, the Monument of Lysicrates, and the Temple of Jupiter at Olympia; there are others, it is true, as the temple of Jupiter Olympus, at Athens, but this was erected long after the order had been practised by the Romans. The principal Italian specimens are the temple of Jupiter Stator, three columns of which remain in the Campo, Rome, and have been imitated at the office of the Board of Trade, London; the Pantheon, copied in the portico of S. Martin's Church; the temple of Vesta, or the Sibyl, at Tivoli, copied at the Bank; the temples of Mars Ultor, Jupiter, Capitolinus, Vesta, at Rome, Antoninus and Faustina, and of Jupiter Tonans. Copies of the columns of Choragic monument are to be seen at S. Philip's Chapel, S. James's and at the entrance to Exeter Hall; original fragments may be seen in the Elgin collection at the British Museum, where there are also casts from the Pantheon, and the temples of Jupiter Stator and Mars Ultor. Amongst all the specimens which have come to our knowledge, there are not two alike, they all vary in detail, and some very much so; some fragments bear evidence of the introduction of figures of animals, &c.

The Corinthian order is appropriate for all buildings in which magnificence, elegance, and gaiety are requisite. Its splendour also recommends it in the decorations of palaces, galleries, theatres, banqueting-rooms, and other places consecrated to festive mirth, or convivial recreation.

The Romans, in borrowing their architecture from the Greeks, appear to have indiscriminately employed the Corinthian order, which they found possessed of an ornamental character, adapted to the splendour and magnificence of their taste, in the same manner that the early Greeks used the Doric, and the Ionians the order which bear their name. Thus the Romans erected temples to Jupiter, Neptune, and Mars; and the Greeks to the same deities, of the Doric order. Thus the temples of Minerva, at Athens and at Sunium, are Doric, and the temple of Minerva, at Priene, is Ionic. The temple of Jupiter Olympus, at Elis, was Doric; but that erected to the same idol, by Adrian, at Athens, is Corinthian.

The orders of architecture appear to be altogether national; thus the numerous temples of Greece, and its Sicilian colonies, are Doric, and bear one general character: the Ionian cities present the best, the most elegant, and chaste examples of the Ionic order: while Italy, Balbec, and Palmyra exhibit the Corinthian order, almost to the exclusion of any other.

Plate I. *Figure* 1.—Nos. 1 and 2 show the method of projecting the plan and elevation of the capital: thus, beginning with the plan, divide the semi-circumference of the top of the shaft into four equal parts, commencing and terminating with half a part, which will give the stems of the lower range of leaves, then complete the contour of the leaves, both in the elevation and plan, as shown under the article PROJECTION; divide each of the parts into halves on the said semi-circumference, and the points of bisection will mark the stems of the second or superior range of leaves. But if the true forms, as ascertained by the principles of projection, be impressed on the mind of the delineator, and if great nicety be not requisite, after dividing as above, and completing the outlines of the leaves on the plan by his eye, he may then draw lines from the bottom of each stem, and from the tips of each on the plan, to their respective places on the elevation, and there complete the two ranges of leaves entirely by the eye; here the jutting points, stems, and breadths of the leaves, are the only guides in the formation of the outline. This process being only a preliminary, though necessary step to the raffling of the leaves, the general contours, thus found, must be rubbed out, after inking the subdivisions, in order to make the foliage appear.

Figure 2, is the profile of the modillions; No. 1, being the plan, showing soffit inverted; and No. 2, the elevation of the same.

Figure 3, is a leaf completely raffled to a large scale; No. 1, is the front view; No. 2, the profile or side view.

Figure 4, shows the finished flower of the capital on a large scale.

Plate II. Some few of the more noted examples of Greece and Rome.

Plate III. A finished elevation of the Corinthian base, capital, and entablature. The example here chosen, is from the three famed columns in the Campo Vaccino, at Rome, supposed to be the remains of the temple of Jupiter Stator, and certainly one of the most perfect and elegant remains of this order, that antiquity can produce.

Plate IV. A general outline of the same, with the proportions of the members figured in minutes.

CORINTHIAN ŒCUS, an œcus decorated with the Corinthian order. *See* ŒCUS.

CORNICE (from the Latin, *corona*, a crowning) any moulded projection which crowns or finishes the part to which it is affixed; thus we have the cornice of an order, of a pedestal, of a house, of a pier, of a door, of a window, &c.

CORNICE OF AN ORDER, a secondary member of the order itself, or a primary member of the entablature. The entablature is divided into three principal parts, the upper one being the cornice. The forms of the particular cornices belonging to the orders, will be found under the heads DORIC, IONIC, CORINTHIAN, TUSCAN, and ROMAN.

According to Vitruvius, the application of cornices to stone buildings originated in the juttings of the eaves of the first wooden structures, the cornice representing the uppermost beams of the roof, which are described by this author as assers, templates, and canthers, of which the last is supposed to apply to the common rafters, the first to the timbers immediately beneath the tiles, and the templates to the cross pieces between the two. The mutules represent the ends of rafters, and dentils the ends of laths for supporting the tiles, or covering; but as the lath is more lofty in situation than the rafters, so ought the dentils to be more lofty than the mutules: this, however, is not the case in the joint application of these members in modern cornices.

Our present practice of architecture was borrowed from the Romans, who, in all their works, inverted the natural disposition of these members. Vitruvius remarks, "as the mutules represent the projectures of the canthers (rafters), the dentils of the Ionic order are in imitation of the projecture of the assers (laths). For this reason, in Grecian buildings, dentils are never placed under the mutules; for assers cannot be under canthers. As, therefore, they should be above the canthers and templates, if they are represented below them, the work is on false principles. The ancients, likewise, did not approve of placing mutules or dentils in the fastigium, but in the corona only; because neither canthers nor assers are laid towards the front of the fastigium, nor can they there project, for they are laid inclining towards the eaves. As, therefore, it could not be done in reality, they judged it not proper to be done in representation, for the propriety of all things, which they introduced in works of perfection, they derived from truth and nature, and approved only those which could bear the test of rational argument."

CORINTHIAN ORDER, PLATE I.

Fig 2
No 2

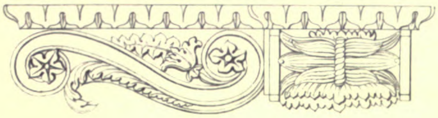


Fig 2

Fig 2.
No 1.

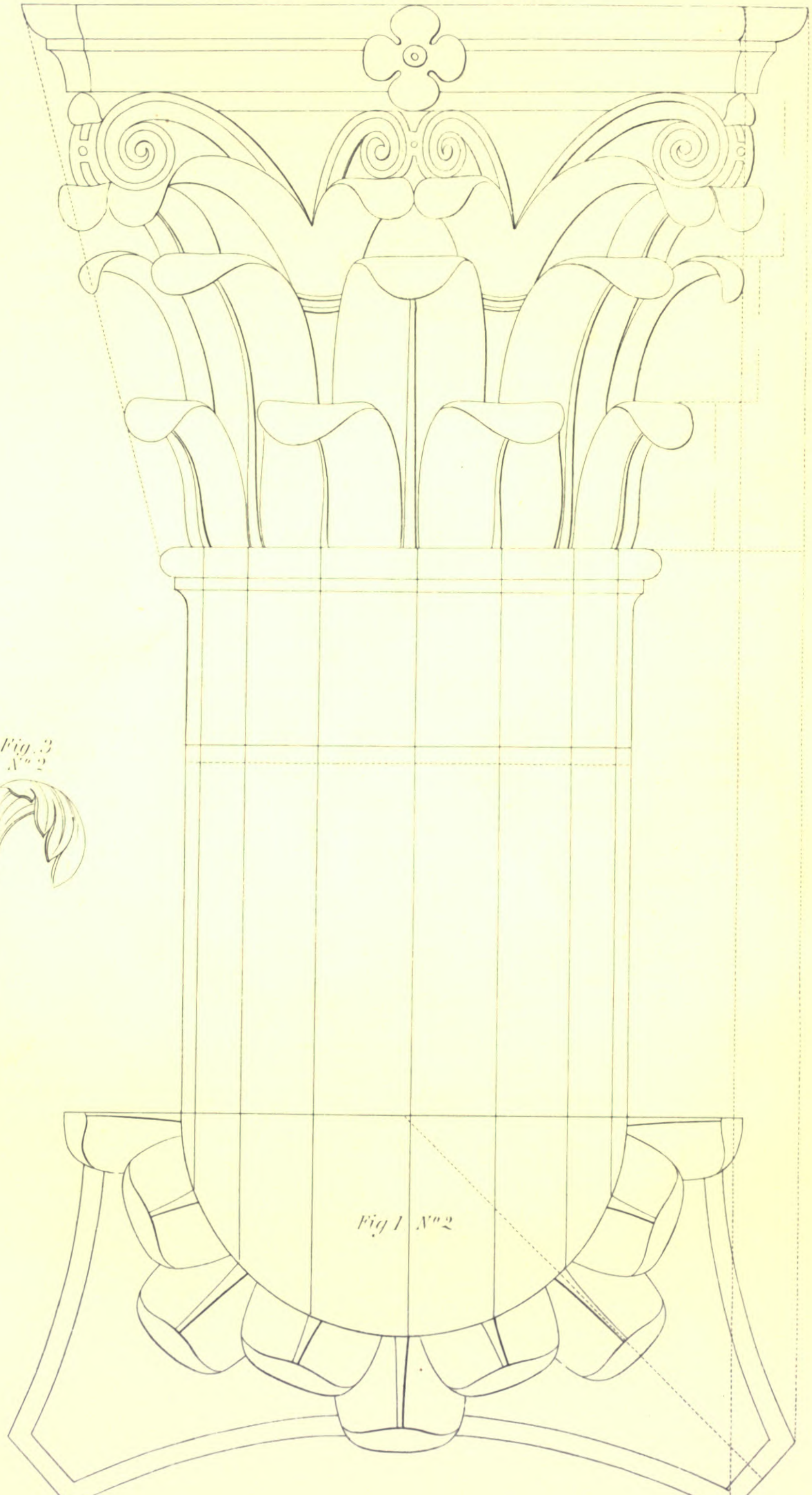


Fig 3
No 1

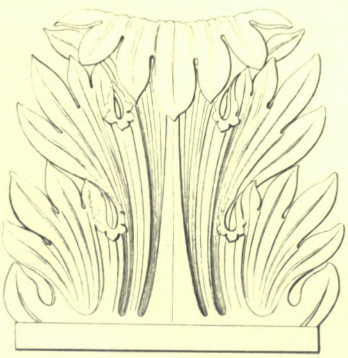
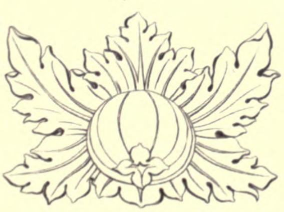


Fig 3
No 2

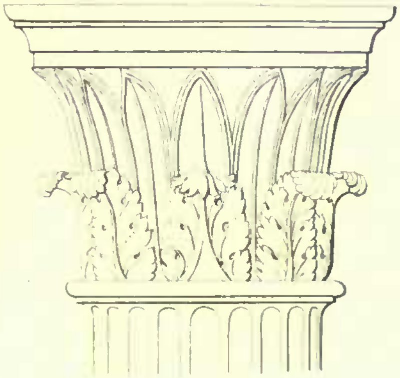
Fig 4



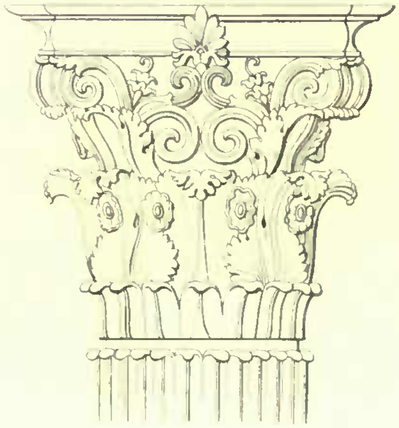
Drawn by P. Nicholson

Engd by R. Thew.

CORINTHIAN ORDER PLATE II.

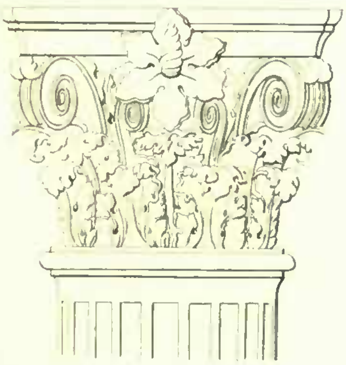


TEMPLE OF THE WINDS

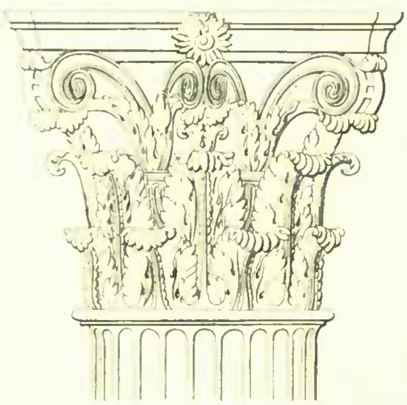


MONUMENT OF LYSICRATES

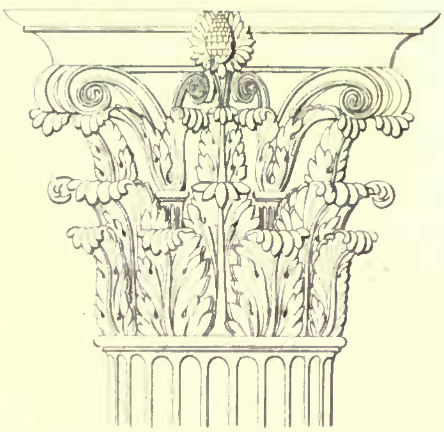
PANTHEON



TEMPLE OF VESTA AT TIVOLI

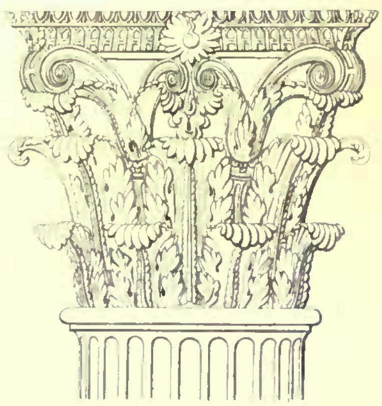


[illegible]



TEMPLE OF VESTA AT ROME

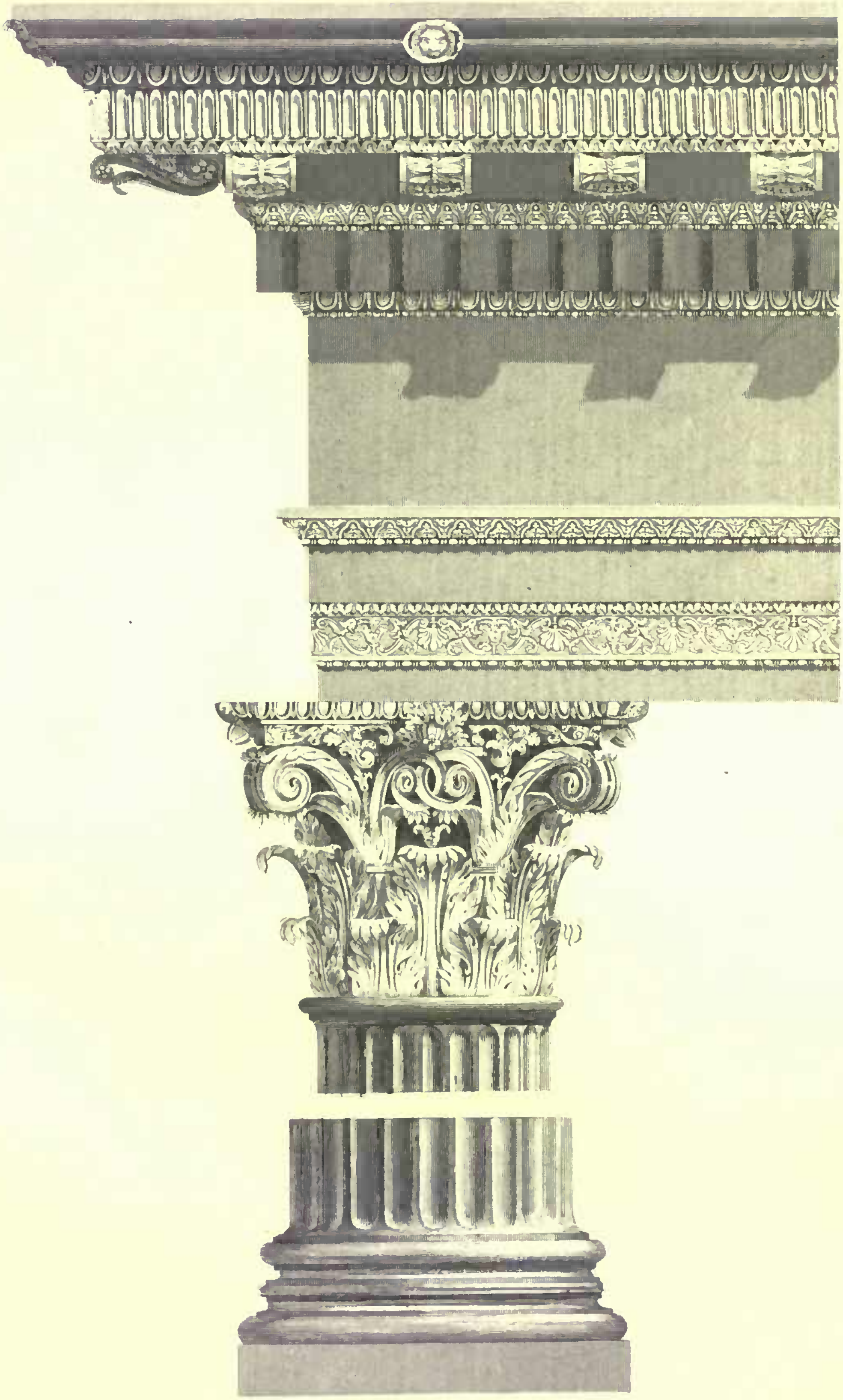
ANTONINUS & FAUSTINA



JUPITER TONANS

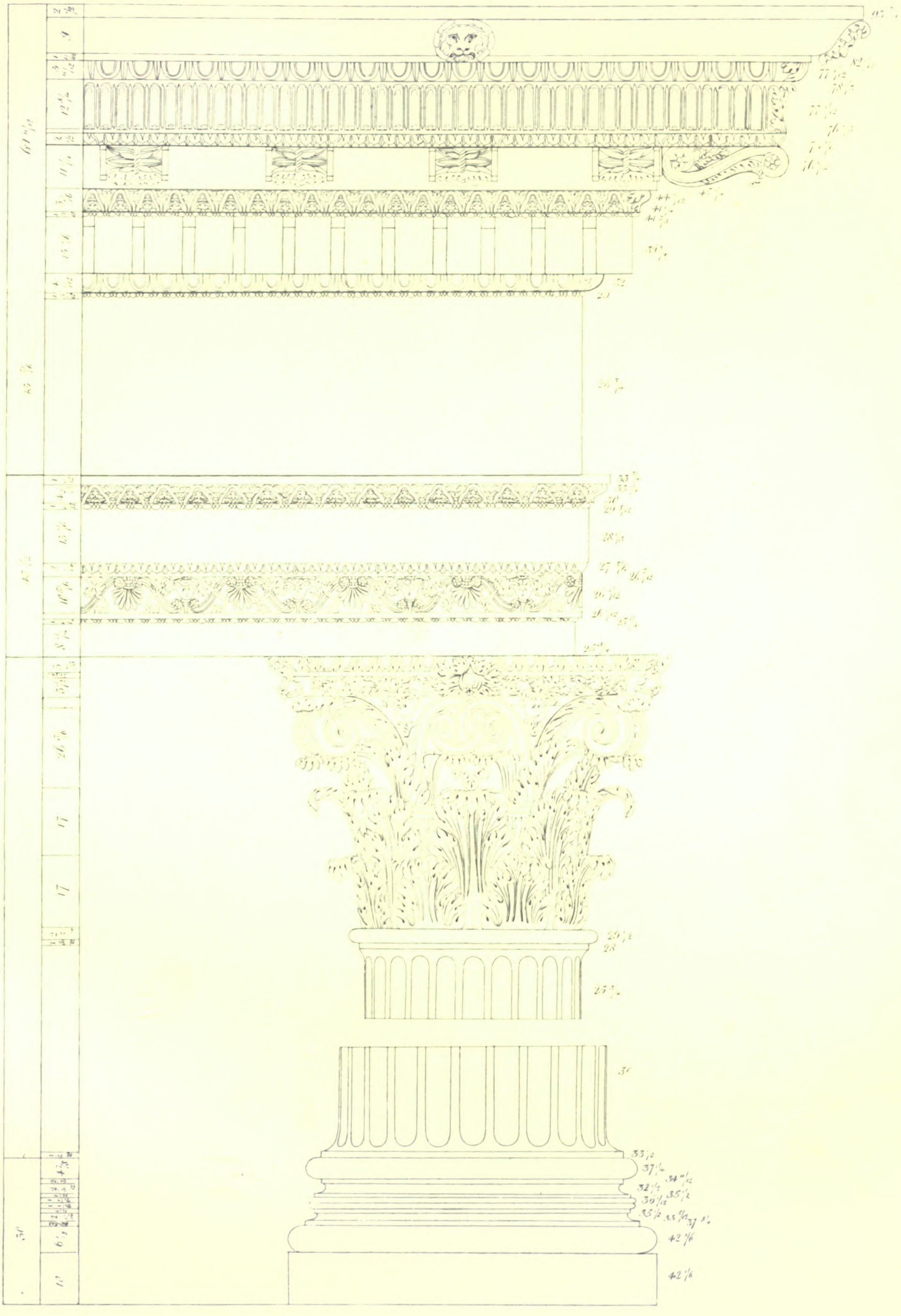
A. Gilbert

R. Thew sc.



CORINTHIAN ORDER

PLATE IV.



P. Nicholson. | H. Ilsley.

We have no example, in the remains of well-authenticated Grecian antiquity, of cornices, where both modillions and dentils are employed, except in the inner cornice of the Tower of the Winds, at Athens: in this instance, the assertion of Vitruvius is completely verified; for there the dentils are placed above the mutules: but in every Roman example, where both are employed in the same cornice, the very reverse takes place; yet, with respect to pediments, we have an example in the frontispiece of the doors of the said Tower of the Winds, where dentils are employed in the inclined cornices of the pediments, contrary to the observations of Vitruvius, and to the original principles whence, according to his theory, these members derived their existence.

In the cornices of all Grecian edifices, particularly those of the Doric order, we always find one very bold member, with a broad vertical face, called *the corona*, which is one of the most distinguished members of the whole cornice: but in some of the Roman buildings, the corona is reduced to a mere fillet. *See* Corona.

Cornices are divided into several kinds:

An *architrave cornice* rests upon the architrave, and the frieze is omitted. An instance of this may be seen in the famous Caryatic portico, at Athens. Cornices of this description are adapted to situations where a regular entablature would be out of proportion to the body which it crowns.

A *mutule cornice* is appropriate to the Doric order, the mutules having inclined soffits.

A *dentil cornice* has a denticulated band, and is usually employed in the Ionic order, though very appropriate also for the Corinthian.

A *modillion cornice* is one with modillions, which are a kind of mutules carved into consoles. It has been chiefly applied to the Corinthian order.

A *block cornice* is that where plain rectangular prisms with level soffits are employed to support the corona, instead of mutules.

A *cantaliver cornice* is constructed of a horizontal row of timbers, projecting at right angles from the naked part of a wall, for sustaining the superior parts of the cornice. Sometimes the cantalivers are placed on the soffits and vertical sides, and sometimes they are cased with joinery.

A *coved cornice* is one with a large cove, and generally lathed and plastered upon brackets. Cornices of this kind are hardly used at this time, but are frequently found upon old houses.

A *mutilated cornice* has some, or the whole of its members interrupted by another object, as the projection of a tablet, &c.

CORNUCOPIA, or Cornucopiæ, the horn of plenty. Ovid tells us in his "Fasti," that one of the goats of Amalthea, who nursed the infant Jupiter in Crete, broke off its horn against a tree, when the nymph having wreathed it with flowers, and filled it with fruit, presented it to the god. When Jupiter came into power, he called Amalthea to the skies, and made the horn the emblem of fertility. In the "Metamorphoses," the poet derives the origin of the Cornucopia from a different fable. He speaks of it as the horn of the river-god Achelous, broken off by Hercules, and consecrated by the Naiads. The real meaning of the fable is this, that in Libya there is a little territory, shaped something like a bullock's horn, exceedingly fertile, given by king Ammon to his daughter Amalthea, whom the poets feign to have been Jupiter's nurse.

In architecture and sculpture, the cornucopia, or horn of plenty, is represented under the figure of a large horn, out of which issue fruits, flowers, &c. On medals, F. Joubert observes, the cornucopia is given to all deities, genii, and heroes.

CORONA (from the Latin) a member of the cornice, with a broad vertical face, and a bold projection. The solid, out of which it is formed, is generally recessed upwards from its soffit; hence the Italians call it*dgocciolatios* and *lagrimatios*, the French, *larmier*, and the English workmen, *drip*, from the circumstance of its discharging the rain-water in drops from its edge, and by this means sheltering the subordinate parts below.

The corona is one of the principal members of the cornice, and that which marks its distinctive character, by the massive shadow which it produces on the plain surface of the frieze. This member, from being the principal feature of the cornice, ought never to be omitted.

Grecian antiquity affords no instances of an order without a corona; nor, indeed, are there many examples among the Romans.

There is nothing in architecture better supported by reason, and by the general example of antiquity, than the necessary use of the corona. It is, however, omitted in the temple of Peace at Rome, the third order of the Coliseum, and the arch of Lyons, at Verona. It is singular, that in the arch of Constantine, the cornice finishes with the corona, surmounted with a fillet only; and in several other examples the corona has almost dwindled into a mere fillet. The frontispiece of Nero presents one of the boldest coronas of all the Roman works, being very nearly 16 minutes in height; the three columns in the Campo Vaccino is another example of an elegant and bold corona. In the temples of Minerva and Theseus, at Athens, it is divided into two faces. The term *corona* is sometimes applied by Vitruvius to the whole cornice, the word originally signifying a *crown*.

Corona Lucis, a kind of chandelier anciently employed in churches, of beautiful and appropriate design, and admitting of delicate elaboration.

COROSTROTA, according to Pliny, a kind of inlaid work.

CORPS, (from the French) any part that projects or advances beyond the naked of the wall, to be used as a ground for some decoration.

CORPSE-GATE, the same as Lich-gate, which see.

CORRIDOR, (from the French) a long gallery or passage around a building, leading to the several apartments; sometimes open one side, and sometimes enclosed on both sides.

CORSA, the same as Platband, which see.

CORTILE, a small enclosed court.

COSSUTIUS, a Roman citizen, who was architect to the temple of Jupiter Olympus, at Athens.

COST, in building, the expense of any design, a knowledge of which is to be obtained by analyzing the whole, and making separate calculations of the quantity and expense of each part. In buildings of a similar description, the expense of the whole can be roughly ascertained, by taking the number of cubic feet at an average rate; but when the price of materials or labour, or of both, is subject to variation, this method will be liable to mislead.

COTTAGE, a name mostly applied to a small house, erected for the use and accommodation either of the farm labourer, or those engaged in some other occupation, but more generally of those employed in agriculture.

The word cottage is also used in modern parlance to designate a small elegant residence, more properly a villa, or, as sometimes called, a cottage ornè. Houses of this description, however, do not belong to our present subject, which must be understood as treating of the cottage in the acceptation of the term explained in the preceding paragraph.

Cottages were formerly constructed of rude and perishable materials; as, earthy substances mixed with straw; and cottages of this consistence were denominated *mud cottages* in some districts, and *cab and dab* in others; but these have now given way to a more durable kind, which, though perhaps as expensive in the erection, are much more comfortable, and cheaper in the end, as they require little or no repairs for many years.

In the construction of cottages, economy, convenience, cleanliness, comfort, and decency, must be the chief points in view, and these ought to be united with as much picturesque beauty as circumstances will admit.

"The accommodation required," observes Mr. Dean, in his very interesting work, "Essays on Agricultural Buildings," "is not such as would be looked for by persons moving in a higher sphere of life, and who are accustomed, comparatively, to luxuries; the labourer belongs to a totally distinct class of society. Let the dwellings of the poor be scientifically constructed, and much illness and misery will be prevented. In effecting this, the whole community is interested, as parochial expenses are increased or diminished according to the healthy state of the labouring population.

"Cottages should be warm and substantial; judgment will also be displayed when the architectural character of the building is in harmony with its use. Their exteriors may be made exceedingly ornate by the application of a correct taste, which does not necessarily create much expense; and although ornament is not a necessary appendage to stability or comfort, it frequently happens that ornamental buildings are preferred, and when judiciously disposed, will materially assist in heightening the landscape. It then becomes a question with the owner of an estate, whether he will, in the erection of cottages, incur a small additional outlay for this purpose.

"England has justly been designated a cultivated garden, and perhaps in no particular possesses a greater pre-eminence of appearance over other countries, than in the beauty of her rural scenery; which, it is submitted, may be greatly enhanced by the substitution of cottages erected in accordance with architectural principles, in lieu of the clumsy-looking and comfortless buildings existing in many districts."

We fully agree with Mr. Dean in these observations, and we trust that noblemen and gentlemen in the management of their estates, will not only provide for the comfort of the poor in the erection of warm, well-constructed cottages, but that they will add some little in the way of ornament also. How much may the picturesque appearance of the cottage be increased by entrance-porches, overhanging roofs, and stacks of chimney-shafts, having ornamental summits. The porch, independent of its architectural effect, affords both warmth and shelter, as does also the overhanging roof. The lofty chimney clustered shafts, besides assisting to prevent a smoky room, have a very pleasing appearance.

In the erection of cottages, it is preferable to build them in pairs if possible, as the cost is considerably less than when singly placed, and they are much warmer. The *site* also is a most important consideration, as houses placed on low marshy soils, are liable to be damp. Independently of the miasma arising from the surface of the ground in such situations, there is a continual humidity in the atmosphere, which communicates itself to all objects surrounded by it. This vapour is a deadly poison, acting on the human system through the medium of the lungs, and producing fevers and other epidemics.

Good drainage is the next important consideration, and this may generally be obtained at small cost. The common earthenware pipes, of an oval or egg-shaped form, about 5 inches by 2½ inches at bottom, are sufficiently capacious to carry off the drainage from a cottage; they are not so costly as brick-drains, and are more efficient.

All drains should be trapped with a syphon trap, so as to prevent the escape of foul air, and the admission of vermin to the dwelling. The drains should communicate with a cesspool sunk in the garden, domed over with brick, having a stone man-hole or flap to eanable the cottager to repair or cleanse it; or to avail himself of its contents for manuring his garden. A drain should also lead from the sink in the scullery to the cesspool (trapped as before described), and this should be so arranged as to carry off the water used for washing the floors, when they are of stone, brick, or composition. The cheapest and best form for the cesspool is that of a parallelogram about 5 feet long, 2 feet 6 inches wide, and 3 feet 6 inches deep.

Cottages may be divided into several classes, or sizes: one of the smallest size for the common labourer; the second size for the labourer, who, by his frugality and industry, in earning more than ordinary wages, deserves a more comfortable dwelling than that of the most common labourer; the third size, for the village shopkeeper, shoemaker, tailor, butcher, baker, &c.; the fourth size, for the small farmer, maltster, alehouse, or other trades, requiring room; the fifth size, for the large opulent farmer. Every cottage should have at least two apartments, and in many cases three, or even four. If the apartments be two in number, and in two floors, one roof will cover both; but then there must be the expense of an additional floor, and a stair to get up to it, besides a loss of room in both floors, for the space occupied by the stairs; however, with respect to a sleeping apartment, a room in an upper story is more healthy than in a lower. In cottages which are built singly, the families are less liable to contention than in those which are joined: but in those which are built together, a considerable expense of walling will be saved, as the flues may be carried up in one common stalk, and in case of sudden trouble, one family may assist another.

Where a cottage consists of two stories, with a sleeping-room in the upper one, it would tend much to the comfort of the cottager, if the upper story were warmed by means of a flue from the fire below; for this purpose, the vent ought to be carried up the middle, with its sides as thin as possible. Another mode, suggested by Mr. Beatson, is to permit the heated air, which always ascends from the ceiling of the lower story, to ascend through an aperture in the floor of the upper story; this may be done by means of gratings, or turning-plates, in the least frequented part of the floor.

With respect to economy, Mr. Loudon, in his treatises on country-residences, has suggested a plan, by which he thinks much more heat may be thrown out from a given quantity of fuel, than by any other method yet proposed, and even by more simple means. The grate which contains the fuel being placed on a level with the surface of the floor, makes the smoke ascend slowly, and thus in its passage allows it time to give out its heat. In small cottages, the staircase ought to be so constructed, as to take up as little room as possible.

The chief conveniences of a single square cottage, are an eating-room of about 12 feet square; over this a sleeping-apartment, which may be partitioned in such a way, as will best accommodate the decency to be preserved in the family; an idea of this construction may easily be formed without a plan. If the dimensions of the buildings be two or even three feet more, it will give much more advantage in point of convenience. For cottages built in rows, the accommodations may be as follow: a room below, of 16 feet square, with the entrance-door and one window in front; the fire-place with an oven opening into it by means of a flue; a door opening into a lean-to, at the back, for covering fuel, the tools of the labourer, and sheltering for a pig, &c.; a pantry, fitted up with shelves, may be made under the stairs, in the lower room.

To accommodate a large family, with children of different sexes, the necessary separation may be effected, by placing one bed over the other, and the entrance to each of the beds on alternate or different sides.

There are two kinds of cottages, English and Scottish, used in Great Britain, of very distinct characters.

The old English cottages were constructed of clay, turf, and other similar materials, supported and strengthened by posts and wooden braces, with a roof of very steep pitch, in order to lessen its pressure upon the walls, and to discharge the rain. The eaves of the roof were continued downwards, so that the projection might throw the water from the surface of the walls, and by this means prevent not only the waste of materials, but the dampness which the interior would otherwise be liable to; the rain-water is also thus kept from the windows and door. The chimneys were generally carried up singly, in one or both ends of the building, most commonly on the outside of the wall. The covering of the roof consisted principally of straw, reeds, or slate-stone. Garrets were sometimes formed in the roof, with a window, either in the sloping sides, or in one of the gables. In consequence of the lowness of the side-wall, and to give sufficient light, the horizontal dimension of the window was much greater than the height. The long bearing of the lintel, or head of the window, was supported in the middle by an upright piece of timber, called a *munnion*. The glass-frames were made to revolve upon hinges with a vertical axis, glazed with small squares of glass, inserted in lead, and stiffened by cross pieces of wood, or frequently iron, called *saddle-bars;* the form of the squares sometimes rectangular, but frequently rhomboidal, and the lead into which they were inserted fixed to an iron frame. To this construction the cottager frequently added a small shed, for keeping a cow, and sometimes one or more hovels to the end of the side, which might be used as a pantry, or as a place wherein to deposit his tools, or other articles of convenience. It is probable that cottages were at first built of a single story only; but, in course of time, they were constructed two stories in height, and as the lower story could not then be protected by the roof, a projection of wood or slate-stone was introduced over the lower apertures, to prevent the rain-water from falling upon the wall. To make these projections ornamental, they were formed into labels of hewn-stone, after the manner of those in Gothic edifices.

The width of the English cottage does not admit of more than one room: the chimneys are variously ornamented, sometimes several flues are united in one shaft, which is built in a variety of fanciful forms, and sometimes several shafts are carried up separately, and united under one cope.

The best English cottages, of late, have been generally constructed of brick, and covered with slate: and the use of these materials has changed the external features very considerably, though the general disposition of the parts remains much the same.

The roofs of many English cottages are partly gabled and partly hipped; and in general the roof is extended at both ends, so as to oversail the gables: the projection thus affording protection to the walls in the same manner as the eaves over the front and rear walls; by this means the gable-tops, being under cover, are less liable to want repair. The walls of English cottages are generally adorned, either by white-washing or colouring the walls; or with creepers of various kinds.

The Scottish cottages differ considerably in form and features from the English, not only in being generally constructed of stone, which is the material most easily procured in the country, but from their being so wide as to admit of two apartments; and being commonly one story only in height. One of these circumstances is sufficient to occasion a great dissimilarity when compared with the proportion of the English cottage, in making the roof top-heavy, and the general appearance of the building squat; and when both are united, this effect will be still more apparent.

In the Scottish cottage, the roof has only a very small projection over the walls; the windows and doors are generally plain; the gables most frequently surmount the roof; the apertures of doors and windows are therefore not so well protected from rain as in the English cottage; but this want of projection is counterbalanced by the great thickness of the walls, and by the narrowness of the windows, which are made to slide in a vertical position, in grooves on the sides of a surrounding frame.

An inducement to make the windows narrow, was the length of the stones, which would not have been easily obtained otherwise. In order to procure the greatest quantity of light, the sashes were glazed with planes of glass comparatively much larger than those used in English cottages, and the sides of the windows were splayed from the glass-frame, so as to form very obtuse angles with the interior surface of the wall. The windows of the Scottish cottage are thus not only very different from those of the English, in being without dressings, and of a different proportion, but also in their manner of glazing and shutting them. The chimneys are either carried up in one or both gables, or in a partition-wall, which separates the two apartments in the length: when carried up in the ends, as the walls are always made sufficiently thick to receive the flues, the walls are not recessed upon the flanks of the stalk of chimneys, in order to save materials. These, consisting of crude stone cemented with mortar, being of little value. The chimney shafts, or the turrets surmounting the roof, are generally plain, finished on the top with a coping of hewn-stone.

In many old constructions of Scottish cottages, the chimney is placed in the front-wall, with a large recess all round the fire, which gave great advantage, in admitting more than double the number which the modern construction admits of, and was therefore useful in times when the master and his servants sat in common with each other. In the old constructions, the roof was covered with thatch, turf, or heath, as being the most ready materials; but these, as in England, have generally given place to the more durable coverings of slate and tile, for similar reasons.

Few appendages are used in Scottish cottages; and in days of old, so little attention was paid to cleanliness, that the cottager who was blessed with a cow, admitted the beast to lodge at night in the same house with himself, without any other partition than the back of a bed or press, to separate his apartment from that of the animal. We are, however, happy to find, that among many other improvements in the north, comfort and cleanliness are now as much objects of the wishes of the inhabitants, as in other parts of the United Kingdom; but even in the present time, from the impression of ancient forms, though the cow-house be separated from the cottage, they are still in one continued formal line, and want that picturesque beauty which an appendage would give, as in the English cottage.

The common kind of the present cottages in the north, are made very wide, either to receive a framed bedstead and press, or to form recesses, by means of a partition, for the reception of the bed and cupboard, on the side of the apartment opposed to the window.

The gables on some old cottages in North Britain, are surmounted with steps, following the sides of the roof, instead of the plain coping, which formed the thatch-way.

Scottish cottages are frequently decorated by training honeysuckles or ivy upon the walls, and a row of house-leek is disposed along the ridge, and not unfrequently upon the sloping sides, in case of a thatched roof.

The materials to be used in the erection of cottages will necessarily depend in a great measure on the locality in which they are to be built. Cottages are built of clay, or turf, bricks with wood, crude stone, flint, large pebbles, *cab*, &c.; those used for the covering are turf, straw, tiles, slate, tarred paper, tessera, &c. When fir abounds, as in the north of Scotland, this timber may be used both for boarding and scantling; in places yielding stone—that material with flag-stones—for roofing.

In some parts of Lancashire, houses are built with a framework of wood, filled up with wattled shed-work, and afterwards covered with a composition of clay and wet straw, locally termed "clot and clay;" this, when plastered and limewhited, has a neat appearance. In Devonshire, walls of a similar character are called "cob-walls;" in France, *pisé*. Houses in the departement of the Isère, Rhone, and Din, the walls of which are formed with this material, have existed for upwards of a century, and effectually resist the inclemency of the weather.

Clay may be used with advantage in a similar manner in this country if properly prepared, and applied with judgment. It should by well tempered, and mixed with a portion of fine gravel, or sand; this facilitates the drying, and prevents the composition from cracking. In forming the walls, fix temporarily in the ground two parallel rows of poles, planked on the inner sides—a space of 20 inches between being left for the thickness of the wall: ram the prepared clay well into this space, raising the planks as the work proceeds, care being taken that the walls are carried up perpendicular. Iron-hooping should be laid diagonally in the substance of the wall, as bond. Over all the openings, stout lintel should be laid; and the door and window-frames fixed as the work progresses. When the walls have *set*, remove the planks and poles, which may serve as timber for joists and rafters. After the walls are completed and thoroughly dry, the exterior may be rough-cast, and a coating of plaster laid on the interior.

A good method of keeping such walls dry, is to build in, at intervals, small perforated drain-pipes. These should be laid in the substance of the walls, the bottom resting upon a framed opening defended by a cast-iron air-brick; the top having a small orifice under the eaves leading outward. The current of air passing through these pipes will carry off all moisture exuding from the walls. The improvement of the dwellings of the industrial classes is now occupying, in a considerable degree, the attention of philanthropists. Several societies have been formed expressly to carry out so benevolent an object, and their attention has been especially directed to the erection of a better description of cottage for the agricultural labourer. The young architect, in the outset of his professional career, may possibly be called upon to furnish designs for such buildings, and with a view to assist him, we have subjoined the following specification principally taken from a work we have before quoted, Mr. Dean's "Essay on Farm Buildings." Mr. Dean is a practical architect, and is thoroughly master of the subject on which he has written; and his "Essays" may be consulted with advantage by those who are about to erect agricultural buildings.

The specification is for a pair of labourer's cottages, semi-detached, but may be altered as to materials, &c., according to locality and circumstances.

The general conditions are as usual, and it is unnec[illegible]ary to occupy space by transcribing them.

"Specification.

"*Excavator.* Dig out the earth for the foundations to the several walls, drains, and cesspools, as shown in the drawings, or herein described. The cesspools to privies to be sunk outside the building. Fill up the trenches to the depth and width shown in drawings with concrete composed of one part of ground-stone lime to six of gravel, broken stone, or clean ballast. Fill in and well ram the ground-work to the trenches and walls, so as to prevent the rain soaking down to, or standing against, the walls and foundations."

"*Bricklayer.* The footings to the walls to be formed with sound, hard, well-burnt stock-bricks or burs from the brick-field, filled in solid, and well flushed with mortar. On the footings spread a layer of gas-tar and sand, and over this a course of slate is to be laid, should there be the slightest chance of dampness arising from the foundation. The cesspools to be built in 4½ inch brickwork, steened and domed over, having stone man-holes let in. The drains from the sinks to be 3 inches diameter, of glazed earthenware, with syphon traps. The cesspools and drains to be completed previous to the walls being erected. Carry up the walls and chimneys in old English bond, leaving a space of about 2 inches in the centre of the thickness of the walls, and insert air-bricks where required. Carry up from the ceiling of each room, on corbel-stones, a ventilating flue 6 by 9 inches. All the flues to be well pargetted and cored out at the completion of the works. The chimney flues not to be gathered over sharply, and twisted as much as possible.

"The external walls are to be faced with best red stock-bricks, white Suffolk bricks being used for plinths, quoins, and dressings to windows and chimney-shafts; all of which are to be carried up in the manner shown in drawings. No wall to be, at any time during the progress of the works, more than 4 feet higher than any other wall. No indents or toothings will be allowed, and no four course of bricks to exceed 11½ inches in height.

"All the brickwork must be worked in sound regular bond, with a close joint neatly struck; every course well flushed in with mortar, and the whole made perfectly level, straight, and perpendicular. The chimney openings to have chimney bars to turn up at each end. The quarter partitions to be brick-nogged with bricks, laid flat, and well bonded.

"All openings to have arches turned over them, with proper skew backs, and left neatly pointed. The chimney and jambs are to be chamfered, to have plinths, and two projecting bricks, cut, as shown in drawing, to support mantel shelf. The fire-places are to be lined with fire-bricks, and an oven built at back. The bottom, sides, and top of oven to be of fire tiles, with flues for carrying the fire under and up the sides of the oven. The smoke-flue to be provided with dampers, and a door provided with damper leading to the oven, which is to be fixed in chimney jamb. Fire-grates are to be formed by letting round iron bars into the brickwork of fire-places.

"The privies to be provided with Boulton and Watt's closet-pans, and glazed earthenware pipes leading to cesspools. The boilers to be set with rounded bricks, and the inside work, where exposed to the fire, lined with fire-brick. The mortar to be composed of one part of good lime to three of sharp sand, or fine-sifted gravel; the whole to be well tempered. Properly bed all lintels, plates, frames, and sills; point round all frames and sills; stop all putlock holes, and leave the works in a complete state."

"*Mason and Paviour.* Provide and fix 4 inch tooled York stone steps to porches and entrance-doors. Provide and fix 3 inch York stones over cesspools; 4 inch stones for corbels, to carry brickwork to air-flues; a circular space about 4 inches diameter, to be cut in these stones, and a ventilating valve inserted in each. Inch hare-hill hearths, and back-hearths to all chimney openings, with stone-kirbs round to act as fenders. The kitchens to have ash-pits with iron movable gratings over. Sink-stones to wash-houses 2 feet 6 inches by 1 foot 9 inches, out of 7 inch stone, properly dished (or wood lined with zinc may be used), each sink to be provided with a bell-trap. Pave the porches and pantries with 10 inch tiles, well bedded, the ground being previously well rammed. The rest of the ground-floors to be made with concrete. Two-inch York stone treads, and risers to stairs, properly cramped, and supported by dwarf brick walls. The floors of privies to be paved with $1\frac{1}{2}$ inch York stone."

"*Carpenter.* The fir timber to be free from sap, large knots, and shakes. The oak to be English, die-square. The framing to be executed in the most approved manner, and to be of the following scantlings:—Wall-plates $4\frac{1}{2}$ by $2\frac{1}{2}$; lintels over all openings, 4 by 4; chamber-joists 7 by $1\frac{1}{2}$, 12 inches apart, with bays of herring-bone struts 2 feet apart, thin iron hooping being nailed to the under side of the joists, and the space between the joists to be filled up solid with broken stone or clay and mortar. Trimming-joists 7 by 3; struts 4 by 2; partitions to have heads and sills 4 by 3; uprights and braces 4 by 2. Door-frames chamfered on the edges 4 by 3; rafters $4\frac{1}{2}$ by $2\frac{1}{2}$; purlins 4 by 3; collars to every sixth pair of rafters, 6 by 2; ridge, 7 by $1\frac{1}{2}$; $\frac{3}{4}$ yellow deal battens to carry slates. Provide and fix 2 inch cut and splayed barge-boards, with pinnacles, &c., as shown on drawings."

"*Joiner.* External doors to be square-framed and battened, hung with 4 inch butts, with 7 inch drawback locks, 6 inch round bolts, (3 to each door,) and Norfolk thumb-latches; $\frac{3}{4}$ ledged internal doors, and $\frac{3}{4}$ ledged privy, pantry, and coal-closet doors, with bolts and latches. The doors to have inch jamb-linings and stops."

"*Windows.* Solid deal frames, $4\frac{1}{2}$ by 3, with oak-sunk sills; $1\frac{1}{2}$ ovolo sashes, suspended by pivots; those in the pantries to be filled with perforated zinc."

"*Fittings.* Inch deal seats and risers to privies, on fir carriages. The seats to have flaps hung with $2\frac{1}{2}$ inch butt hinges; 1 shelf to be fixed round each cupboard closet in bed-rooms, and 3 in those in kitchens: $1\frac{1}{2}$ inch dresser-tops, and 3 shelves to pantries. Angle staves to be provided and fixed to all angles; $\frac{3}{4}$ clamped shutters to dwelling-rooms, hung as flaps, with deal framed brackets, to be turned on pivots, the flaps forming tables. Fir mantel-shelves, 6 by 2 inches, over each opening."

"*Plasterer.* The walls of the dwelling-rooms and bed-rooms to be rendered and set. The ceilings and rafters lathed with iron hooping; the space between the joists and rafters filled up solid with broken stone, or earth and lime. The ceilings to be plastered, set, and whited. The chamber floors to be laid with floor plaster, and trowelled to a smooth surface. The walls of the sculleries, pantries, coal-closets, and privies, to be twice lime-whited; cement skirting, 6 inches high, to be run round all the kitchens and bed-rooms."

"*Slater.* Cover the roofs with countess slates, laid hollow to a proper guage. The ridges to be of slate, bedded in cement."

"*Ironmonger.* Fix No. 8 $1\frac{1}{4}$ round iron bars to all the fire-places, to form stove. Fix iron pans in sculleries. Fix where directed an iron pump, with double handle; fix No. 4, stacks of 4 inch descending pipes, with cistern heads and shoes, the bottom length to be of cast iron. Provide and fix No. 12 cast iron air bricks, to be fixed where directed; fix No. 8 Arnott's valves where directed. Fix perforated zinc-plates to doors of rooms not having chimney openings in them. Provide No. 10 chimney bars, to turn up at each end."

"*Plumber.* Inch lead waste pipes from sinks to drains curved round so as to form stink-traps, and provided with bell-traps. Lead flashings to chimneys, 5 pound to the foot super. Provide and fix 15 feet of $1\frac{1}{2}$ suction-pipe from well to pump."

"*Glazier and Painter.* Glaze the several sashes with 3d Newcastle crown glass. Stain the whole of the wood-work of the exterior with a composition of gas-tar and Roman ochre, laid on when boiling hot. The interior to be stained with 'Stephen's stain,' and afterwards varnished."

The above Specification is so carefully drawn, that we have thought it expedient to extract it entire, as a useful guide to the young architect. It may, of course, be altered according to circumstances, and it may not always be desirable to incur so large an outlay. The estimate for a pair of cottages similar to those specified, would range from £200 to £300, according to the amount of ornament bestowed on them.

COUCH, in general, the lay of any mucilaginous substance on any material, as wood or plaster, in order to protect the surface of that material from the weather, and thereby render it more durable, or less vulnerable to the corroding influence of the atmosphere.

Couch, in painting, denotes a lay or impression of colour, whether in oil or water, with which the painter covers his canvass, wall, wainscot, or other material to be painted.

Paintings are first covered with a couch of varnish. A canvass, to be painted, must first have two couches of size before the colours are laid: two or three couches of whitelead are laid on wood before the couch of gold is applied.

COULISSE, French; the pieces of wood which hold the floodgates in a sluice; also any timbers having grooves in them.

COUNTER, COMPTER, (from the Latin, *computare*) the name of two prisons in London, for the use of the city, to confine debtors, breakers of the peace, &c.

Counter, a term formerly used among engineers to denote the superintendent of a canal, or other great work, under the resident-engineer. His business was to keep an account of the time of the men employed, not only in different departments of the work, but in different soils also, as a check on the charge of the men; and thereby to enable the resident-engineer, who received his accounts, to ascertain the rate of any quantity of common measure in similar operations. The counter seems to have been the same as what we now call clerk of the works.

Counter Drain, a ditch or channel parallel to a canal or embanked water-course, for collecting the soakage-water by the side of the canal or embankment, to a culvert or arched drain under the canal, by which it is conveyed away to lower ground.

Counter Drawing, the copying of a design by means of a fine linen cloth, oiled paper, &c., laid on the drawing; the strokes of the drawing appearing through the transparent cover, being traced and marked with the pencil.

Sometimes drawings are copied on glass, or with frames or nets divided into squares. The pentagraph is not only useful in making fac-similes, but for reducing or enlarging drawings in any proportion; but of all instruments employed in copying rectilinear or regular curved-lined drawings, or mixed of the two, the proportional compass is the most accurate, the most expeditious and convenient instrument ever yet invented; and if the parts of the drawing stand at different oblique angles, a pair of triangular compasses will be necessary to assist in taking the angles. Although the pentagraph will of itself enlarge or reduce, or make equal, and find the quantity of the angle, it requires much room, and for drawing straight lines and curves, the tracer to be drawn along a straight-edge. In retrograding or retracing a line in the same path, towards the contrary extremity to which it was drawn, the representative line is liable to be doubled. The pentagraph is therefore a cumbersome and inaccurate instrument for such purposes, and should only be used in reducing for rough or sketch-maps, &c., where great accuracy may not be absolutely necessary.

Counterforts, projections of masonry or brickwork from a wall, built at regular intervals, in order to strengthen the wall, or to resist a pressure of earth behind it, the counterforts increasing the breadth of its base, and thereby aiding the resistance against the power which tends to overturn it.

Counter Guage, in carpentry, a method used to measure the joints by transferring, *e. g.* the breadth of a mortise to the place of the other timber where the tenon is to be made, in order to adapt them to each other.

Counter Lath, in tiling, a lath placed between every two guaged ones, so as to divide every interval, as near as can be judged by the eye, into two equal intervals.

Counter Light, a window opposite to anything which makes it appear to a disadvantage: a single counter light is sufficient to take away all the beauty of a fine painting.

Counter Parts, of a building, are the similar and equal parts of the design on each side of the middle of the edifice; they are absolutely necessary to the character of a Grecian or Roman edifice, but in Gothic buildings a duplicature of parts is not requisite.

COUNTRY-HOUSE, as its name implies, one erected in the country. In the erection of these, under a liberal employer, the architect has the greatest scope for his fancy, ingenuity, and skill in contrivance. He is not confined to space, as in town-houses, and therefore has it in his power to extend in any direction consistent with the nature of his design. For farther information, *see* Villa, and House.

COUPLE-CLOSE, a pair of spars of a roof.

COUPLED COLUMNS, those which are disposed in pairs, making a narrow and wide interval succeed each other alternately. Of this disposition of columns, ancient architecture affords no instance; for, although in the temple of Bacchus at Rome, the columns are coupled, or stand in pairs, still the intervals between are all equal. The only use of coupled columns is in low colonnades, or porticos of edifices which have large piers, where the employment of single columns would have a meagre appearance. The ancient disposition of columns in the same range was always beautiful, on account of the proportion of the intercolumn being always narrow. In the application of columns to modern architecture, the intercolumniations must be regulated by the apertures of our domestic edifices, but the ancients were under no such restrictions. The perspective succession or gradation of coupled columns, is not so harmonious as when columns stand single. If a design be well suggested, there will be little occasion for their employment. *See* Column, Colonnade.

COUPLES, rafters framed together in pairs, with a tie, which is generally fixed above the feet of the rafters. This mode of framing is used in the ordinary houses of Scotland, without either principals or purlins. The rafters called *spars*, are most commonly notched, and the tie which couples them is also notceed with a dovetail. In a building about 25 feet wide, the spars may be 7 inches at bottom, 6 inches at top, 2½ inches thick, and about 2 feet 2 inches apart, for boarding covered with slate.

Couples, *Main*, or Main Couples, the same as trusses for roofs, which support the roof in different bays: this term is also used in the north.

COURSE, a continued level range of stones or bricks in a wall, as far as the solid part runs. It sometimes happens, that a course of masonry is only laid to a certain length, and the other part or complement divided into two courses, in the same height as the single course; but this ought not to be admissible, and should be specified against, in countries where the contractors are ready to take every advantage in order to save the expense of larger stones, or to accommodate themselves with those already at hand.

Course of the Face of an Arch, the arch-stones, whose joints radiate to the centre. In stone work, the arch-stones are called *voussoirs* or *ring-stones*, in the face of the arch, and each radiating part consists of one stone only. In brickwork, each part, of one thickness of brick, sometimes consists of several bricks in length: but whether one or several bricks be contained between two adjacent radiating joints, the quantity thus disposed is called *a course*.

Course, in slating and tiling, a row of slates or tiles, disposed with their lower ends in the same level, which line may either be a straight line or a circle.

Course of Plinths, the continuity of a plinth in the face of a wall, to mark the separation of the stones. The course of plinths is otherwise called *string course*, which is most frequently executed with stone, but sometimes also with plaster, to save expense.

Course, *Barge*. *See* Barge-Course.

Course, *Blocking*. *See* Blocking-Course.

Course, *Bonding*, that which is farther inserted into the wall than either of the adjacent courses, for the purpose of binding the wall together. Two bonding-courses lapping upon each other, one from the face, and the other from the back, make excellent work: these courses should be placed so as to leave regular intervals for stretching courses between them, on each side of the wall.

Course, *Heading*, the same as Bonding-Course. *See* the last article.

Course, *Springing*. *See* Springing-Course.

Course, *Stretching*. *See* Stretching-Course.

Coursed Masonry, that in which the stones run in courses.

Coursing Joint, the joint between two courses.

COURT, an hypæthral, or uncovered area, either in front of a house, or surrounded entirely by the walls. As it is impossible on the same floor to light apartments surrounded with other apartments on all sides, and these again completely covered with other apartments, it will be impossible to execute an extensive building, which may have more than three rooms in length and breadth, and more than one story in height, without the intermediate rooms being entirely dark, or receiving their light by secondary windows from the exterior rooms; hence the necessity of introducing as many intermediate courts as the extension of the building, with regard to the number of rooms, both in length and breadth, may require, will be obvious. Mr. Barry has made advantageous use of a court of this description in the Travellers' Club-house. *See* Club-House. It is true, that a building can be executed without courts, and that it may contain any number of rooms; but it must have only two rooms in breadth, or otherwise the plan cannot be a simple rectangular figure. Courts may be ornamented in the most elegant manner, and being more confined than the external parts of the edifice, the ornaments may be of a more delicate nature; and if any parts of the building can admit of arcades, or of two or more orders, one above the other, a court is certainly the most susceptible of such decoration. We are informed by Vitruvius (book vi. chap. iii.) that the ancients had five kinds of courts, called *cavœdii*, distinguished by the denominations of *Tuscan*, *Corinthian*, *tetrastyle*, *displuvinated*, and *testudinated.* For the description of each, see Cavædium.

COUSINET, Coussinet, a Cushion, a stone placed upon the impost of a pier or pedroit, for receiving the first stone of an arch. If the arch be the segment of a circle, the cousinet may be an isosceles triangle, with the base upon the impost, and the two sloping sides radiating to the centre; or if the arch be a semicircle, the cousinet will be the first arch-stone itself, or otherwise the arch must spring above the impost.

Cousinet is also employed to denote that part in the front of the Ionic capital, contained between the abacus and the echinus, or quarter-round. It is this which forms the horizontal fillet, or band, in common volutes, or the band and festoons in the Grecian Ionic, from which the volutes on each side of the column depend.

COVE, any kind of concave moulding, or the concavity of a vault.

Cove Bracketing, is the bracketing of any cove, but more generally understood to be that of the quadrantal cove, which is sometimes employed between the flat ceiling and the wall. *See* Bracketing.

COVED AND FLAT CEILING, one whose section is a portion or quadrant of a circle, springing from the walls of the room, and rising to a flat surface in the middle.

Coved and flat ceilings seem to be altogether of modern invention, and admit of some beauty in the decoration. It is a sort of compromise between the flat or horizontal ceiling, and the various forms of arched ones practised by the ancients. It does not require so much height as the latter mode, and has therefore been of considerable use in the finishing of modern apartments; but as its form is a compound, it wants both elegance of figure, and grandeur of design; nor does it admit of that beauty in decoration, that entire arched ceilings are susceptible of. The ancient forms were of three kinds, the cylindric arch, the dome, and the groin. We find no arches of any description in Grecian antiquity; but in the Roman edifices all the three varieties are to be found; and among other ceilings in the ruins of Balbec, the quadrantal coved ceiling, with the flat in the middle, may be distinctly traced, at least in length, if not in breadth. *See* Ceiling.

COVER, in slating, the part of the slate that is hid or covered; the other part exposed to view, is termed *the margin* of the slate.

Cover Way, in roofing, the recess or internal angle left in brickwork or masonry to receive the covering.

Covered Way, a passage covered over. The term Covered Way, or Covert Way, is also used in fortification to denote the piece of ground level with the field on the edge of the ditch, three or four fathoms broad, extending quite round the works towards the country. It has a parapet raised on a level, together with its banquettes and glacis. It is sometimes called the counterscarp.

Covering. *See* Roofing.

COVING, the exterior projecture over the ground-plan of buildings, made in an arched form with lath and plaster: it is not now in use. In former times, when the streets were very narrow, the upper rooms were made in part to jut over the wall, in order to give room.

Covings of a Fireplace, the inclined vertical parts on the sides, for contracting the opening, and throwing out the heat.

COW-HOUSE, a building where cows or other cattle are kept, in order to protect them from the severities of the weather. *See* Cattle Shed.

Cow-Yard, the enclosure in which cows are kept, to shelter them from the weather.

CRAB, an instrument used in masonry for raising large stones.

CRACKING OF BUILDINGS, those fissures occasioned by improper management in the foundation, or in carrying up the work. Cracks, so frequent in modern buildings, will for the most part be found to arise from unequal settlement, caused by insufficient foundations, from inadequate coverings to apertures, such as what are called French arches, or from the employment of improper or inferior materials, soft bricks, unseasoned timber and such like.

Cracking, in plastering, the fissures occasioned by an undue tempering or mixing of the materials, or by an unseasonable application.

CRADLE, or Coffer, in engineering, a large wooden trunk, open at top, with movable ends, large enough to receive a barge or vessel when floating on a canal, for the purpose of raising or lowering it to a higher or lower pond of the canal, by cranes or other means, without the use of a pond lock.

The term is also applied to the segment of a hollow cylinder formed of ribs and lattice, similar to centering, used by bricklayers and masons, for turning culverts and arches; the inside is smooth, and the exterior rough, for supporting and retaining the shape of the inverted arch of the lower half of the culvert in soft ground, particularly in quicksands and peaty places. A very slight cradle of this kind, will sometimes prevent the distortion or ultimate fall of a barrel culvert. This precaution should never be omitted in laying culverts under canals or roads, in soft grounds, as the falling of the culvert may prove of the greatest inconvenience.

Cradle-Vault, a word improperly applied to cylindric vaults.

CRADLING, the mass of timber-work disposed in arched or vaulted ceilings, for sustaining the lath and plaster. For the application of the various species of cradling, *see* the words Cylindric-Vault, Cove-Bracketing, Dome, Groin, and Niche. The compound term, *dishing-out*, is sometimes used by workmen, instead of cradling.

Cradling is also used for the rough timber-work for sustaining an entablature for a shop-front.

CRAMP, an iron instrument, about 4 feet long, with a screw at one end, and a movable shoulder or arm at the other, by which mortise and tenon work is forced together.

CRAMPERN, or Cramp-Iron, an iron bent at each extremity, towards the same side of the middle part, used to fasten stones together in a building.

When stones are required to be bound together with greater strength than that of mortar, a chain, or bar of iron, with different projecting nobs, is inserted in a cavity cut in the upper side of the course of stones across the joints, instead of single cramps across the joints of each two stones. Cramps are generally employed in works which require great solidity, as in the piers and abutments of bridges, and the voussoirs of large arches. They are also employed in uniting the stones of copings, and cornices, and generally any external work upon the upper surface, or between the beds of the stone. External work liable to the injuries of the weather, ought to be cramped. The most secure manner of fixing cramps is to let them into the stones their whole thickness, and run them with lead; but in slight works, it is sufficient to bed them in plaster, as is the practice in chimney-pieces. Iron is used in modern buildings, but the Romans, who were accustomed to employ cramps in the greatest profusion, used bronze, a material much more durable than iron, as it is not so liable to rust.

Bronze or copper is preferable to iron, not only on account of its own durability, but likewise because it is not so liable to destroy the masonry which it connects: the rust which accumulates round iron cramps, tends to rupture the masonry to a much greater extent, than the cramps to keep it together; besides this, if placed near the surface, iron is sure to discolour it. In general work, if the masonry be well put together, there will be but little need of cramps, especially if the separate masses be of moderate size; nor even if they be of small dimensions, is there any absolute necessity for their employment, as we may gather from the works of the ancients. Mr. Murphy instances the spires of Salisbury cathedral, and of the church of Batalha, Portugal, which though not more than seven inches in thickness, are for the most part connected without the aid of iron cramps. These observations apply with greater emphasis to wrought than to cast iron.

Sir Christopher Wren used a large cramp or chain below the springing of the dome of St. Paul's, in order to distribute the pressure equally. This architect, however, seems to have been fully aware of the caution requisite in the use of iron in stone buildings, for he observes in his *Parentalia*, "It has been observed in removing cramps from masonry at least four hundred years old, which were so bedded in mortar that all air was perfectly excluded, that the iron appeared as fresh as when it came from the forge. In cramping stones therefore, no iron should lie within nine inches of air if possible; for air is the menstruum that consumes all materials. When for want of large stones the use of iron is requisite, care should be taken to exclude the air from it."

Copper, bronze, or gun-metal, form excellent and incorrosive substitutes for iron in cramping masonry; they are more expensive at the first outlay, but will be found in reality more economical; the first material may be mixed with a small portion of tin, which imparts to it greater durability.

The above objections to iron, do not hold good as regards brickwork; the only inconvenience in this case arises from the stain with which the rust is apt to disfigure the work, if the iron be placed too near the facing.

CRAMPOONS, pieces of iron hooked at the ends, for drawing or pulling up timber, stones, &c.

CRANE-HOUSE, a house to shelter a crane; it should be constructed of brick.

CREALS, a sort of jetties, or weir hedges, sometimes erected on the shores of rivers or the sea, for checking the force of the tide in particular places, and occasioning a deposit of filth or mud in place of the constant wear and encroachment of the water upon the land. Smeaton's *Reports*, i. p. 4.

CREASING, *Tile*. *See* TILE-CREASING.

CREDENCE, a shelf or small table by the side of a Christian altar, on which the sacred elements are placed previous to consecration. Sometimes the credence is simply a shelf in the niche above the piscina, but at other times a separate table. At the church of S. Cross is a beautiful specimen, rectangular in plan, having its front decorated with panels, and the stone slab supported above a cornice enriched with flowers, it is fixed in a corner so that only two sides are exposed; at Fyfield, Berks, is another specimen, semi-octagonal in plan, supported on a stem of similar plan, but of smaller dimensions; the sides are panelled all the way up.

CRENELLE, the embrasure of a battlement, sometimes applied to the whole battlement, as also to the loopholes and other small apertures in the wall of a fortress, through which missiles were discharged.

CRESCENT, an ornament used by the Mahometans in their mosques.

CRESCENT, a series of buildings, disposed in the arc of a circle, which is either the half circumference, or the arc of a segment less than the half.

CRESILLA, a Grecian sculptrix, who chiselled seven statues of the Amazons, for the temple of Diana at Ephesus, and was accounted the third in merit among the numerous competitors who vied in decorating that famed edifice—being only inferior to Polycletus and Phidias.

CRESSET, an open metal frame or cage, used to contain a light or beacon-fire.

CREST, the ornamental finishing at the summit of a structure, consisting of battlements, open tracery, finials and crockets, or even plain coping.

CREST-TILES, tiles placed along the ridge of a roof overlapping on both sides like a saddle; they are sometimes plain, and at others ornamented, moulded in the form of battlements, Tudor-flowers, crockets, leaves, &c.

CREUX (from the French) a term in sculpture, implying a hollow, out of which anything has been scooped; and hence it has been used to denote that kind of sculpture and graving, where the lines and figures are cut and formed within the surface carved or engraved upon.

There is no word in the English language that answers to this idea, and hence the necessity of adopting the term. It is opposed to the word *relievo*, where the lines and figures are prominent, and project without the surface.

CRIB, the rack or manger of a stable, or the stall or cabin of an ox. It is also used for any small habitation, as a cottage.

CROCKET (from the French, *croc*, a hook, or fork) an ornament used to decorate or finish the raking arrises of parts of Gothic buildings, such as spires, pinnacles, gables, canopies, &c.; consisting of projecting leaves, flowers, or knops of foliage, and terminating usually in a larger ornament or bunch of flowers or leaves at the summit, called a finial. Sometimes they are used in vertical lines, as at the cathedral, Lincoln, where they run up the mullions of the tower window. Crockets of the Early English style are often simple trefoil leaves, and sometimes bunches of such leaves, placed at considerable intervals, and curled backwards, in a similar manner to the head of a bishop's pastoral staff: early specimens are to be seen at Salisbury and Wells cathedrals, but the simplest example exists at Lincoln, which exhibits a simple curve, curling round downwards. In the Decorated period, the leaves were usually continued for some distance attached to the moulding, and curled upwards towards the extremity, sometimes the extreme point was turned up; a similar form prevailed in the Perpendicular style, but they are sometimes merely flat square leaves united to the moulding by the stalk and one edge. In some cases we meet with animals in the place of crockets, as on the flying buttresses of Henry VII.'s chapel, Westminster, and the gables of the hall at Hampton Court; on the tomb of Archbishop Kempe, Canterbury, we find swans, and on that of Bishop Bingham, Salisbury, angels are used for the same purpose.

CROISSANTE CROIX, having a crescent or halfmoon, fixed to each end thereof.

CROKET. *See* Crocket.

CRONACA, SIMONE, a Florentine architect, born in the year 1454. This artist travelled to Rome, and other cities of Italy, in order to take accurate admeasurements of the ancient edifices. When he returned to Florence, he acquired considerable reputation, and was employed to finish the Palazzo Strozzi, which was begun by Benedetto da Maiano. Among his other works in this city, are the sacristy of the church of Santo Spirito, and the church of S. Francesco del Offervanza, at S. Miniato, in the suburbs of the city. He died in the year 1509, and was buried in the church of S. Ambrozio Vasari.

CROOKED LINE, one that cannot have a tangent on any point to the two adjacent parts of the line on each side of the point of contact.

CROSETTES, in the decorations of apertures, the trusses or consoles on the flanks of the architrave, under the cornice; they are otherwise named *ears*, *elbows*, *ancones*, or *prothyrides*.

CROSIER, a bishop's staff; it was originally a plain rod with a cross-head at its summit, and subsequently with a curved top similar to a shepherd's crook. Crosiers were sometimes of a very costly description, being formed of gold or silver, engraved, enamelled, and inlaid with jewels and precious stones. A good specimen is that of William of Wykeham, preserved at New College, Oxford. The crosier of an archbishop is surmounted by a cross, and that of a primate or patriarch by a double cross.

CROSS, a figure consisting of four branches, at right angles to each other; or a geometrical figure, consisting of five rectangles, each side of one angle being common with one side of each the other four.

The cross, as the most prevalent symbol of the Christian religion, was often introduced into their architecture. Their churches, more especially the larger ones, were frequently built on a cross plan, and were decorated internally and externally with this symbol; crosses of a highly decorative character and beautiful design were often affixed to the apex of gables, and in the interior were depicted on the walls; a large ornamental cross, usually of wood, called the rood, was set above the screen, which separates nave and chancel, and a small one of metal, enriched with jewels, &c., on the altar.

There are two kinds of cruciform plans used in ecclesiastical buildings; one, in which all the five rectangles are equal; or, in which each of the four wings is equal to the middle part formed by the intersection, is called a *Greek cross.* The other, in which only two opposite wings are equal, and in which the other two are unequal, and the three rectangles in the direction of the unequal parts of greater length than the three parts in the direction of the equal parts, is called a *Latin cross*, the middle part in each direction being common.

Stone crosses were erected in front of the entrance to the church, and these consisted of a tall shaft raised on one or more steps, and surmounted by an ornamental cross; the shaft was usually of a simple character, but sometimes enriched with sculpture. Besides these, there were boundary, memorial, sepulchral, preaching, and market crosses.

Boundary-crosses were of a very simple character, being usually merely upright stones ornamented with some simple sculpture; memorial crosses were of a like plain description, there is a specimen at Blore-heath, Staffordshire. The crosses erected by king Edward I. at the places where the corpse of his queen Eleanor was rested during its progress from Lincolnshire to Westminster for interment, would probably come under this head, but if so, they are of a very different description to the majority. Out of fifteen of these originally existing, only three now remain, at Geddington, Northampton, and Waltham: of those now destroyed, five are known to have been erected at the following places, Lincoln, Stamford, Dunstable, St. Alban's, and Charing. They were very elaborate structures, consisting of several stories of multangular plans, each story being somewhat smaller than the one below it, so as to give the erection a pyramidal form, having the apex surmounted by a cross, and the whole enriched with sculpture, statuary, &c; that at Waltham consists of three stories, and is hexagonal in plan, the lower story is richly panelled, the second canopied, containing statues of the queen, the third panelled, similarly to the lowest, and the whole finished at the top with a decorative cross.

The preaching-cross was a covered pulpit usually erected in the vicinity of a church, the most noted is that of St. Paul, London, which was an erection of wood raised on steps, and covered with a canopy; it was octagonal in plan, closed in on all sides, with the exception of the entrance and the aperture, through which the preacher addressed the people. Specimens of this class exist at Hereford, Iron Acton, Gloucestershire, and Holbeach, Lincolnshire.

Market-crosses seem to have been originally of a similar form to those of Queen Eleanor, but having open arches at the sides in the lowest story. In the later and more general form, the plan of the basement was considerably extended, so as to present a space of considerable size covered with a vaulted roof, and having a central pillar or pier to support the superstructure, which at the same time was much reduced in height; the shape of the original plan was preserved, the only difference being in its size; thus the market-cross at Leighton Buzzard, Bedfordshire, is pentagonal, that at Salisbury, hexagonal, and that at Malmsbury, which is a beautiful specimen, hexagonal. Other market-crosses exist at Winchester, Cheddar, and Chichester, and there were two excellent ones at Coventry and Glastonbury. They served to shelter the people attending market from heat and rain.

The cross at Chichester is the most beautiful specimen of the kind. It is supported on eight buttresses and a central column, from which issue a number of ribs dividing the vaulted roof: between the buttresses are eight arches moulded, and surmounted by an ogee canopy, which is crocketed, the finial supporting a pinnacle; the spandrels of the canopy are richly panelled, as are also the walls above, the whole being finished by a panelled parapet. The buttresses terminate in crocketed pinnacles. The structure is covered externally by an ogee cupola, crocketed ribs springing from each of the buttresses at the angles, and the whole is surmounted by a small octangular turret pierced with eight arches, and otherwise elaborately ornamented.

Crosses of a simple character were originally erected at the entrance of towns and villages, at the intersection of crossroads and sides of highways, to arrest the attention of travellers, and excite their devotion.

Cross-banded, in hand-railing, is when a veneer is laid upon the upper side of the rail, with the grain of the wood crossing that of the rail, and the extension of the veneer in the direction of its fibres less than the breadth of the rail.

Cross Garnets, hinges, with a long strap, which is fixed to the closure of the aperture, and with a cross part on the other side of the knuckle, which is fastened to the joint.

Cross-grained Stuff, wood with its fibres in contrary directions to the surface, and which therefore cannot be made perfectly smooth by the operation of the plane, without either turning the plane or the stuff. This most frequently arises from a twisted disposition of the fibres in the act of growing.

Cross Multiplication, a term used by artificers for the peculiar arithmetical process employed in the mensuration of their work. Cross multiplication and duodecimals are generally confounded together as being synonymous expressions; but the order of performing their operations is materially different. In cross multiplication, the parts are actually multiplied *crosswise*, as well as in direct order, and the terms of each factor are confined to feet and inches; whereas, in duodecimals, the terms of each of the factors are not confined to number, and the parts are multiplied in the order of common multiplication.

The rule in cross multiplication is as follows: Write the given numbers, as in addition. The sum of the products of the alternate parts, and the product of each pair of parts in each denomination, will be the product of the whole. It must be remembered, that

Feet multiplied by feet give feet.
Feet multiplied by inches give inches.
Feet multiplied by seconds give seconds.
Inches multiplied by inches give seconds.

The method of performing the operation will be seen in the following examples.—What is the area of a board, the length of which is 25 feet 11 inches, and the breadth 23 feet 7 inches?

ft.	in.		
25	11		
23	7		
0	6	5	= 7 × 11
14	7		= 7 × 25
21	1		= 23 × 11
575			= 23 × 25
611	2	5	

Required the product of 58 feet 9 inches, by 36 feet 6 inches.

ft.	in.		
58	9		
36	6		
0	4	6	= 6 × 9
29			= 58 × 6
27			= 36 × 9
2088			= 58 × 36
2144	4	6	

The following method is another form of cross multiplication, discovered by Mr. P. Nicholson, in which side operations are unnecessary, and consequently, as a part of the work, must either be wrought on the margin, as above, or in the mind: the work, by the method proposed, will be shorter than the above, or less liable to mistake, if the side operations be not used. The rule is thus:

Multiply the inches together, and the product is seconds; divide the product by 12, if so divisible, the quotient is inches, and the remainder seconds; then, placing the feet and the inches in their respective order, one after the other, set the products of the two cross parts in inches, under the inches of the former quotient; add the three numbers together, and divide their sum by 12, the quotient will be feet, and the remainder inches; multiply the feet of the multiplier by the feet of the multiplicand, and place the products under the feet of the last division, then the sum of these products will be the number of feet in the whole contents, and the remainders of inches and seconds, if any, the parts which are required to complete the whole product. We shall take the two former examples, and the one method will be the best proof of the truth of the other.

First Example.			Second Example.		
ft.	in.		ft.	in.	
25	11		58	9	
23	7		36	6	
	6	5		4	6
175			348		
253			324		
12)434			12)676		
	36	2		56	4
75			348		
50			174		
611	2	5	2144	4	6

By this means, the whole is performed in one operation, without laying any stress on the memory, and will therefore be particularly useful to those who have not sufficient practice to fix the products and quotients of small numbers on their memory: and it is the shortest method of the two, if the number of marginal figures be counted into the work of the former method of operation.

In duodecimals the process is as follows: beginning with the last term, or the farthest from the left-hand in the multiplier, multiply by it each term of the multiplicand from the right-hand to the left, carrying one for every twelve to each successive product, but the denominations must not be carried farther than the place of feet; again, multiply all the terms of the multiplicand, by each successive term towards the left of the multiplier; then place the products one under the other, with the first term of every product on the left, under the second term of the product of the horizontal row immediately above; then add the similar denominations of each product: the sum will be the whole product. Observe, in the first place, to put the highest denomination, viz., the feet, under the first term on the left of the multiplicand, and the terms of the product under each respective term of the multiplicand will be of the same denomination with each other.

Example.—Suppose, again, it were required to multiply 25 feet 11 inches by 23 feet 7 inches, by duodecimals.

25	11	
	23	7
15	1	5
596	1	
611	2	5

$$11 \times 7 = 77$$
$$6 \quad 5$$
$$25 \times 7 = 175$$
$$181$$
$$15 \quad 1 = \tfrac{181}{12}$$
$$11 \times 23 = 253$$
$$21 \quad 1 = \tfrac{253}{12}$$
$$25 \times 3 = 75$$
$$25 \times 20 = 500$$
$$596$$

Cross multiplication is much better adapted to finding the superficial contents of a piece of work, where there are only two terms in each factor, and where the feet of the multiplier run to a high number, as well as the feet of the multiplicand, and more particularly the second mode of cross multiplication; as in duodecimals, the calculator must either have a very good memory to require no marginal work, or otherwise the quantity of marginal operations will exceed that of the principal work. Artificers and measurers never take any account of denominations less than inches, except in glazier's work, and hence cross multiplication is almost the only useful method of finding the contents; but where more denominations are concerned, recourse must be had to duodecimals or decimals, as when the terms of each factor are more than two, cross multiplication cannot be applied.

When the terms of the multiplier are under 10, the operation will be exceedingly easy, as the following example will show.

Example.—Multiply 8 feet, 3 inches, 5 seconds, and 7 thirds, by 5 feet, 4 inches, 9 seconds, and 6 thirds.

ft.	in.	ii	iii			
8	3	5	7			
			5	4	9	6
		4	1	8	9	6
	6	2	7	2	3	
2	9	1	10	4		
41	5	3	11			
44	9	0	6	3	0	6

It will be perceived that there is a great difference between cross multiplication and duodecimals, and the purposes to which each may be most advantageously applied; but the reader who wishes for farther information on this subject, may have recourse to the articles DECIMALS, DUODECIMALS, and PRACTICE.

CROSS SPRINGERS, in groins of the pointed style, are the ribs that spring from one diagonal pier to the other.

CROSS VAULTING, a vault formed by the intersection of two or more simple vaults. When each of the simple vaults rises from the same level to the same height, the cross vaulting is denominated *a groin;* but when one of two simple vaults, in cross vaulting, is below the other, the intersection is simply demominated an *arch* of that particular species which expresses both the simple arches; thus if one cylinder pierce another of greater altitude, the arch so formed is called *a cylindro-cylindric arch;* and if the portion of a cylinder pierce a sphere of greater altitude than the cylinder, the arch is denominated *a sphero-cylindric arch:* and thus, for any other species of arch whatever, the part of the qualifying word which ends in *o*, denominates the simple vault which has the greater altitude, and the succeeding part the other of less altitude.

CROUDE, a subterraneous vault or crypt.

CROW, a bar of iron, used in bricklaying and quarrying.

CROWN, in architecture, the uppermost member of a cornice, comprehending the corona and its superior members.

CROWN OF AN ARCH, the most elevated line or point that can be taken on its surface.

CROWN, in geometry, a plane ring, the surface being contained between the circumferences of two concentric circles.

The area will be found by multiplying half the sum of the two circumferences by its breadth; for it is easy to conceive, that if radiating lines be equidistantly drawn indefinitely near each other, the whole will be divided into truncated isosceles triangles, or trapezoids, whose opposite angles are equal to two right angles; then the broad and narrow ends being placed alternately in a straight line, and the sides in contiguity with each other, the whole will form a rectangle, whose length is equal to the half sum of the two circumferences, and the breadth that of the ring; for all the middle breadths are in one straight line, equal to the length of the rectangle.

Example.—Suppose the greater circumference of a crown to be 24 feet 8 inches, and the lesser 21 feet 6 inches, and the breadth 2 feet 9 inches, required the superficial content?

By cross multiplication.	By decimals.
ft. in.	
24 8	24.666 = $24\frac{2}{3}$
21 6	21.5 = $21\frac{1}{2}$
2)46 2	2)46.166
23 1	23.083
2 9	2.75 = $2\frac{3}{4}$
0 9	115415
207	161581
2	46166
12)209	63.47825 content in ft. & dec.
	12
17 5	
46	5.73900 inches
	12
63 5 9	
	8.868 seconds.

CROWN GLASS, the finest sort of window-glass. *See* GLASS.

CROWN-POST, in truss-roofing, the truss-post, which is placed between a pair of principal rafters, or depending from the summit of the principals, in order to support braces or struts for sustaining the intermediate bearing of the principals, or keeping them from being bent by the weight of the covering. It is otherwise called *king-post* and *joggle-post. See* POST and TRUSS-POST.

CROWNING, in general, the part that terminates any piece of architecture. Thus the cornice, a pediment, acroteria, &c., are called *crownings.*

CRUCIFIX, a cross with a figure or representation of S. Saviour crucified, affixed to it.

CRYPT, according to Vitruvius, the under part of a building, answering nearly to our cellar.

The term is more particularly applied to a vaulted apartment beneath a church, either entirely, or partly under ground. Crypts owe their origin to the circumstance of the early Christians being compelled, for the sake of secresy and concealment, to perform their sacred services in caves and subterraneous places, some of which are still pointed out at Rome. Crypts are not unfrequent, especially under large churches, they seldom, however, extend the whole length of the church, being usually confined to the choir or chancel, and sometimes not extending so far as this: they are usually low and massive, of an earlier and plainer style than the superstructure. Many crypts are claimed as belonging to the Saxon style, as those of Lastingham Church, Yorkshire; S. Peter's, Oxford; Repton Church, Derbyshire; and portions of those of many of our cathedrals.

Crypts were formerly used for service, and accordingly are provided with altars and other furniture requisite for the purpose. The most extensive building of this kind is that under Canterbury Cathedral, which is thus described by Mr. Britton·

"Like those at Winchester, the crypts of Canterbury Cathedral appear to have been built at different times. Their eastern termination is semicircular; which form has been also observed in the small lateral chapels. The interior length of the Canterbury crypts is 286 feet 6 inches. The age of the oldest part has long been the subject of controversy; but from its similarity to the crypt at Oxford, it may be regarded as contemporaneous with that; it was most probably the work of Lafranc, about A.D. 1080. The larger, or western crypt, is divided into a nave and four aisles, by two rows of massive piers, and by a double range of small columns; whilst the piers and walls of the aisles have semi-columns to support the vaulting. Branching laterally from each aisle is a vault or chapel; that on the south side, the vaulting of which is adorned with many ribs, bears evident marks of innovation, and is supposed to have been converted into a chantry chapel by Edward the Black Prince, whose arms are seen among its ornaments. Towards the eastern end of this crypt was a chapel, inclosed with screen-work, and dedicated to the Holy Virgin. The crypt under the Trinity Chapel, or east end of the cathedral, is singular in form and character. Its plan assumes the figure of an horse shoe; and is divided into a nave and aisles by a series of eight piers, each formed of two columns, engaged about one-quarter of their diameter, supporting four semicircular and five pointed arches, their respective forms being influenced by the width of the inter-columniations. In its central division, or nave, are two small insulated shafts, with large capitals and bases to support the ribbed groining, which is distinguished from that of the western crypt by cross-springers and bold mouldings. At the eastern extremity is a small vaulted chamber, forming the termination of these interesting apartments."

Amongst the smaller examples, may be noticed that of Hythe, Kent, and those of Repton, and St. Peter's in the East, Oxford, before-mentioned.

Crypto-Porticus, a subterraneous passage, as the original word implies. If we may judge (says Winckelman) from the remains of antique edifices, particularly those of the Villa Adriani, at Tivoli, we might be led to believe that the ancients preferred darkness to light: for, in fact, we find scarcely any chamber or vault among these ruined edifices, which has any appearance of windows. It seems probable, that in some, the light was only admitted through an opening in the middle of the vault, but as the vaults are generally fallen, this point cannot be ascertained. The inhabitants of Italy are naturally attached to the shade and coolness of half-lighted apartments. The long galleries of the Villa Adriani, which are undoubtedly crypto-porticos, receive a feeble light at each end, from embracing near the ceiling.

The term crypto-porticus was, however, applied, in course of time, to apartments similar to our galleries.

We find, in Pliny's description of his house at Laurentium, that the crypto-porticus had windows on each side, looking towards the sea, and upon his garden; also other windows over these. When the weather was cold, they were shut on the side that sheltered them from the wind, but in warm and serene weather they were all set wide open.

CUBATURE, or Cubation, of a solid, the solid contents according to any common measure, as a solid inch, foot, yard, &c., which is called the measuring unit. The cubature is the same in respect to the contents of a solid, as the quadrature is in respect of a superficies.

There is one general rule that will apply to finding the cubation of nearly all the regular solids as entire bodies, or to their frustums or segments, viz. "to four times the area of the middle section add the area of each end; multiply one-sixth of this sum (which is the mean area) by the distance between the ends, and the product will give the content of the solid."

This rule has been applied to three particular cases, viz., in the prismoid, cask measuring, and the frustum of the hyperboloid; it has also been demonstrated rather as a theoretical curiosity, than as a practical rule, at the end of Dr. Hutton's Mensuration, applied to solids generated from conic sections.

This rule, however, applies to solids in general, and comprehends the whole of mensuration in its principle; though such an extension has never been noticed by any writer on the subject, yet it cannot fail to be of the utmost use in assisting the memory; for when particular rules are forgotten, this general one may be easily remembered. It will apply with accuracy to prisms, pyramids, prismoids, cones, conoids, cuneoids, spheres, spheroids, and to all their segments and frustums, cut by planes parallel to their axes.

Some may object, however, by saying it is not easy to come at the dimensions of the middle section; but in straight solids these will be very readily ascertained, by taking half the sum of the two ends; in complete spheres and spheroids, the middle dimension is absolutely given. In the hyperboloid and its frustums, the dimensions of the middle section is much easier obtained than either the transverse or conjugate diameters, one of which, or both, it would otherwise be necessary to have. In the paraboloid and its frustums, the middle area is half the sum of the areas of the two ends. The reader who is desirous of seeing the application of this general rule, may consult the article Solid.

CUBE (from *κυβος*, *tessera*, die) a solid, bounded by six squares; it is otherwise called a *hexahedron*, from its six sides. Its simple properties are, that its sides are all equal and at right angles with each other: it has also its opposite sides parallel to each other. The cube may be conceived to be generated by a square figure along a right line, of equal length to the side of the square, and perpendicular to the plane. From its construction, it is evident that all sections of the solid, parallel to any side, are equal.

The envelope, rete, or net, may be thus constructed: Draw two lines, A D and A B, at a right angle with each other; make A B equal to the side of one of the squares, and A D equal to four times A B, marking the points of division, E G I; draw B C parallel to A D, and D C parallel to A B, parallel to which also draw E F, G H, I K, cutting B C at F, H, K: produce E F and G H on both sides, to L and M on the one side, and N and O on the other, making E L, G M, F N, H O, each equal to E F, and join L M and N O; this will complete the envelope required.

Hence the superficies of a cube is found by multiplying the area of one of its sides by 6.

The solidity of a cube is found by multiplying the area of one of its squares by one of the lineal sides of a square. Hence if one lineal side be 10, the solidity will be 1,000; and if 12, it will be 1728; wherefore a cubic perch contains 1,000 cubic feet, and a cubic foot of 1728 cubic inches.

Cubes are to one another in the triplicate ratio of their lineal sides.

CUBIC NUMBER, one which arises by multiplying two equal numbers, and the product again by another equal number: thus, $12 \times 12 = 144$, and $144 \times 12 = 1728$.

CUBICLE, a bed-chamber. *See* Chamber, and the next word.

CUBICULUM, among the Romans, a bed-chamber. This name was also given to the balcony or logia, in which the emperors were placed at the public games.

CUBIT, a lineal measure used by the ancients, particularly by the Hebrews, taken from that part of a man's arm between the elbow and tip of the hand. The English cubit may be calculated at 18 inches, the Roman at 17.406, and the Hebrew at 21.888 inches.

CUL-DE-FOUR, or CU-DE-FOUR, a sort of low spherical vault, ovenlike. This is the definition generally given; but this term, as also the following, are altogether void of specific meaning. As they define nothing, we have only retained them as being found in all large encyclopædias and builder's dictionaries, in order that our architectural nomenclature should not be thought deficient. What is meant by a low spherical roof? Is it a segment less than a hemisphere? Where is the similarity between an oven and a spherical surface? Is not the latter definite, but the former indefinite?

CUL-DE-FOUR OF A NICHE, denotes the arched roofs of a niche on a circular plan. These two definitions are of French origin.

There may be many forms of arched roofs or heads, on a circular plan; however, the probability is, that it is either spherical or spheroidal, terms perfectly specific, unless it be in the quantity or portion of the surface employed.

CULMEN, in ancient Roman carpentry, answers to what we denominate the ridge-piece of a roof.

CULVERT, an arched drain for conveying rills and brooks of water under canals or roads, from the higher level on one side, to the lower level on the other side of the canal or road.

They are also employed for discharging the rain-water out of hollows on the upper side of a canal. When such a drain or water-passage has a descent, so as to make it lower in the middle, it is said to be *broken-backed*.

CUNEUS, one of the mechanical powers. *See* WEDGE.

CUNEUS, in Roman antiquity, that part of the theatre where the spectators sat, which was so named on account of its resemblance to a wedge. This form became necessary on account of the elliptic figure of the edifice, and of the staircases and doors, which were fixed in radial directions, and divided the seats into wedge-form compartments.

CUPBOARD, a recess in a wall, fitted up with shelves, to contain articles when not in use.

CUPOLA, a roof or vault, rising in a circular or elliptic curve, from a circular, elliptic, or polygonal plan, to its summit, with its concavity towards the plan, the interior or exterior surfaces being such, that every horizontal section, whether the one or the other, are similar figures. A cupola is otherwise termed *tholus*, or *dome*. *See* the latter word for its history and properties.

CURB, in a general sense, signifies a check or restraint.

CURB FOR BRICK STEPS, a timber nosing generally of oak, employed not only to prevent the steps from wearing, but also from being dislocated or put out of their places. When the steps are made to return, the curb also returns, but when they profile against a wall, the ends of the curb or nosing-pieces, house at each end into the wall.

CURB PLATE, a circular continued plate, either scarfed together, or made in two or more thicknesses. The wall-plate of a circular or elliptically ribbed dome, is termed *a curb plate*, as also the horizontal rib at the top, on which the vertical ribs terminate; likewise the plate of a skylight or a circular frame for a well.

CURB PLATE, also the horizontal piece of timber supported by the upper ends of the lower rafters, for receiving the feet of the upper rafters, in a curb roof.

CURB RAFTERS, the upper rafters on both sides of a curb roof.

CURB ROOF, a roof formed of four contiguous planes, of which each two have an external inclination, the ridge being the line of concourse of the two middle planes, and the highest of the three lines of concourse. This construction is frequently denominated *a Mansard roof*, Mansard being the name of its inventor. It is very well adapted to a house surmounted by a parapet, so high as to cover the lower plane of the roof, as it gives a free or uninterrupted space from the level of its base to that of the summit of each lower plane, or to the base of the two upper planes. In curb roofing, there is no danger of springing the walls by lateral pressure, for the distance between the base of the lower sides and the base of the upper sides, being sufficiently high for head-room, ties can always be fixed in these two situations, which will prevent all danger. Indeed, if the four sides of the roof be properly balanced, the space may be made a complete void to the very ridge, or the upper part may be thrown into a cylindric arch.

A curb roof has great advantages over a common roof, on account of the lower rafters pitching almost perpendicularly to their bases, and forming very nearly a continuation of the walls: whereas, in common roofs, the great inclination of the sides, and the quantity of head-room required, diminishes the space for lodging, in the breadth of the building; in most cases there will be a loss of about 15 or 16 feet at least, and consequently, in small houses, no lodging-room whatever.

Curb roofs are generally lighted from dormer windows in the lower side.

The following contains the theory and practice of curb roofing, which is perhaps one of the most interesting parts in the science of carpentry:

Proposition I. *Figure* 1. The position of several rafters, A B, B C, C D, D E, &c., being given in a vertical plane, and movable about the angular points B, C, D, E, &c., while the points A and G remain stationary; it is required to find the proportion of the forces at the angles, so that the rafters may be kept in equilibrio.

Through the points B, C, D, &c., draw the vertical lines B *i*, C *m*, D *p*, &c., the direction of the forces; make B *i* of any indefinite length, and complete the parallelogram B *h i k*; make C *l* equal B *k*, and complete the parallelogram C *l m n*. Proceed in this manner with all the remaining parallelograms, making the two opposite forces in the direction of each rafter equal, and the diagonals B *i*, C *m*, D *p*, &c., will represent the forces required, as is evident from the construction. Then, to find the proportion of the weights upon any two angles, the sine of any angle is the same with the sine of its supplement; therefore, the sine of the angle A B C is the same as the sine of B *k i*, and the sine of B C D the same as the sine of C *m n*; likewise, the sine of the angle C *m l* is equal to the sine of the alternate angle *m* C *n*, and the sine of the angle D *p o* is equal to the sine of the angle *p* D *q*; moreover, the sine of the angle *i* B *k* is equal to the sine of the angle *m* C *l*, and the sine of the angle *m* C *n* is equal to the sine of the angle *p* D *o*, and so on: then, because the sides of the triangle are the same as the sines of their opposite angles, it will be, by trigonometry,

B *i* : B *k*, or C *l* : : S.B *k i*, or A B C : S.B *i k*, or *i* B *h*.
C *l* : *l m*, or D *o* : : S.C *m l*, or *m* C *n* : S.*m* C *l*, or *i* B *k*.
D *o* : *o p*, or E *r* : : S.D *p o*, or *p* D *q* : S.*p* D *o*, or *m* C *n*.
E *r* : S *r*, or F *u* : : S.E *s r*, or *v* F *u* : S.E *s r*, or *p* D *q*.
F *u* : F *v* : : S.F *v u*, or *v* F *w* : S.*v u* F, or E F G.

Therefore, B *i* : F *v* : : S.A B C × S.*v* F *u* × S.*v* F *w* : S.*i* B *h* × S *i* B *k* × S.E F G.

$$\text{Therefore, B } i : \text{F } v :: \frac{\text{S.ABC}}{\text{S.}i\text{B}h \times \text{S.}i\text{B}k} : \frac{\text{S.EFG}}{\text{S.}v\text{F}u \times \text{S.}v\text{F}w}.$$

That is, the weights on any two angles are as the sines of these angles directly, and reciprocally as the product of the sines of the two parts of these angles formed by the vertical lines.

Corollary 1. Hence the weights on any two angles are as the sines of the angles directly, and as the produce of the co-sines of the angles of elevation reciprocally. For, draw B H perpendicular to B *i*, and produce *i* B and A B to I and K, then will the angle K B I, equal the angle *h* B *i*, be the complement of the angle H B K, viz., the complement of the angle of elevation of the rafter A B above the horizon ; and because C B I is the supplement of C D *i*, the angles C B I and C B *i* have the same sine, and the angle C B I is the complement of the angle H D C, viz. the angle of elevation of the rafter B C.

Corollary 2. Hence also the weights on any two angles are as the sines of the angles directly, and as the products of the secants of elevation jointly ; for the secants of any two angles are reciprocally as the co-sines of these angles.

Corollary 3. The force which any rafter makes in its own direction, is as the secant of its elevation. For, make A P equal to D *h*, draw the lines P N, *k* H, *n* L, &c., parallel to the vertical lines B *i*, C *m*, &c., and draw A N, B H, C L, &c., parallel to the horizon ; then because the angles N A P, H B *k*, L C *n*, &c., are the angles of elevation, and A N, B H, C L, &c., are all equal, if A N, B H, C L, &c., be considered as radii, A P, B *k*, C *n*, &c., are the secants of elevation, and also represent the forces on the rafters.

Corollary 4. Hence the horizontal pressures at A and C are equal; for all the perpendiculars drawn from the opposite angles of each parallelogram to meet the vertical diagonal, are all equal.

Corollary 5. Hence, if the position of any two rafters, and the proportion of the weights be given, the position of the remaining rafters may be determined.

Corollary 6. If the vertical line S D V be drawn, the horizontal line A V O and the lines A S, A R, A Q, A T, &c. be drawn parallel to the rafters A B, B C, C D, D E, &c. meeting the vertical lines in S, R, Q, T ; then will A S, A R, A Q, A T, represent the forces, and S R, R Q, Q T, the forces upon the angles ; for A S, A R, A Q, A T, &c. are the secants of the elevation, and the triangles A S R, A R Q, A Q T, are all similar to the triangles *h* B *i*, *l* C *m*, *o* D *p*, &c.

Corollary 7. In every roof kept in equilibrio by the weight of the rafters, if U, V, W, &c. be the centres of gravity of the rafters, and also represent their weights, then the weight pressing vertically on B, will be

$$\frac{AU \times U}{AB} + \frac{VC \times V}{BC}, \text{ and the weight on } C = \frac{VB \times V}{BC}$$

$$+ \frac{WD \times W}{CD}, \text{ and so on. Hence } \frac{AU \times U}{AB} + \frac{VC \times V}{BC}$$

$$: \frac{VB \times V}{BC} + \frac{WD \times W}{CD} : : \quad \frac{S.ABC}{S.hBi \times S.iBK} : \frac{S.BCD}{S.lcm \times S.mcn}$$

Corollary 8. Hence, if the rafters be prismatic figures, the weights on the angles B, C, D, &c. will be respectively as A B+B C, B C+C D, C D+D E, and so on.

Proposition II. *Figure* 2. Given, the vertical angle of a roof, and the proportion of the rafters on each side ; to describe the roof of a given width, so that it shall be equilibrio.

Let the proportion of the rafters from the bottom, upwards, be as 4, 3, 2 :

Then 4+3=7 represents the weight on G.
3+2=5 represents the weight on H.
and 2+2=4 represents the weight on I.

Now let F B E be half the given angle, produce E B through C to D, draw F A M perpendicular to E D cutting E D at A ; make A E equal to A B, and join E F ; let B E represent the weight on the vertical angle : E B, B C, C D, to one another as 4, 5, 7 ; join F D, F C, F E ; from any scale of equal parts make F G=7 ; draw G H parallel to F C, equal to 5 parts, and H I parallel to F B, equal to 4 parts, and the contiguousl ines F G, G B, H I, will be similar to the half roof. The other half will be found by drawing the vertical line I N, and ordinates perpendicular thereto, from the points G H, to L and K, and making the distances on both sides of I N equal. This figure may be reduced or enlarged to any given width, by making a similar figure upon a given line.

Proposition III. *Figure* 3. The angular points at the meeting of every two rafters of a roof in equilibrio, by equal weights hung at the angles, in directions equidistant from each other, are in the curve of a parabola.

Let A B C D E, &c. be kept in equilibrio, by equal weights suspended at the angular points B, C, D, E, &c., in the equidistant directions B F, C G, D H, E I, &c., the points A, B, C, D, E, &c., are in the curve of a parabola.

For, let the lines B F, C G, D H, and E I, meet A N at F, G, H, I : draw A K parallel to D E, A L parallel to C D, and A M parallel to B C, cutting F B at K, L, M. Draw B Q, C P, D O, parallel to A N, cutting the middle line I E at Q, P, O.

Then, because that the weights on the angles are equal, F K, K L, L M, M B, are as the numbers 1, 2, 2, 2, therefore, F K, F L, F M, F B, are as the odd numbers 1, 3, 5, 7 ; but because of the equidistant lines B F, C G, D H, and parallels D O, C P, B Q, the triangles A F K, A F L, A F M, are respectively equal and similar to the triangles D O E, C S D, B R C ; therefore F K is equal to O E, F L equal to S D equal to O P, F M equal to R C equal to P Q, and lastly, B F is equal to Q I ; therefore E O, O P, P Q, Q I, are to one another as the numbers 1, 3, 5, 7, and E O, E P, E Q, E I, are as the square numbers 1, 4, 8, 16, but the lines O D, P C, Q B, are to one another as 1, 2, 3, 4 ; therefore the abscissas E O, E P, E Q, E I, are as the squares of the ordinates O D, P C, Q B, and the points A, B, C, D, E, are in the curve of a parabola.

In the same manner it may be shown that this is the case, whatever be the number of ordinates.

Corollary.—Hence a roof of this construction may be described to any given height and vertical angle, or to a given width and height with any number of rafters on each side.

Example.—To describe a roof with any given number of rafters on each side, of a given width and height, so that all the weights suspended from the angular points of the rafters in vertical equidistant lines, may keep the rafters in equilibrio.

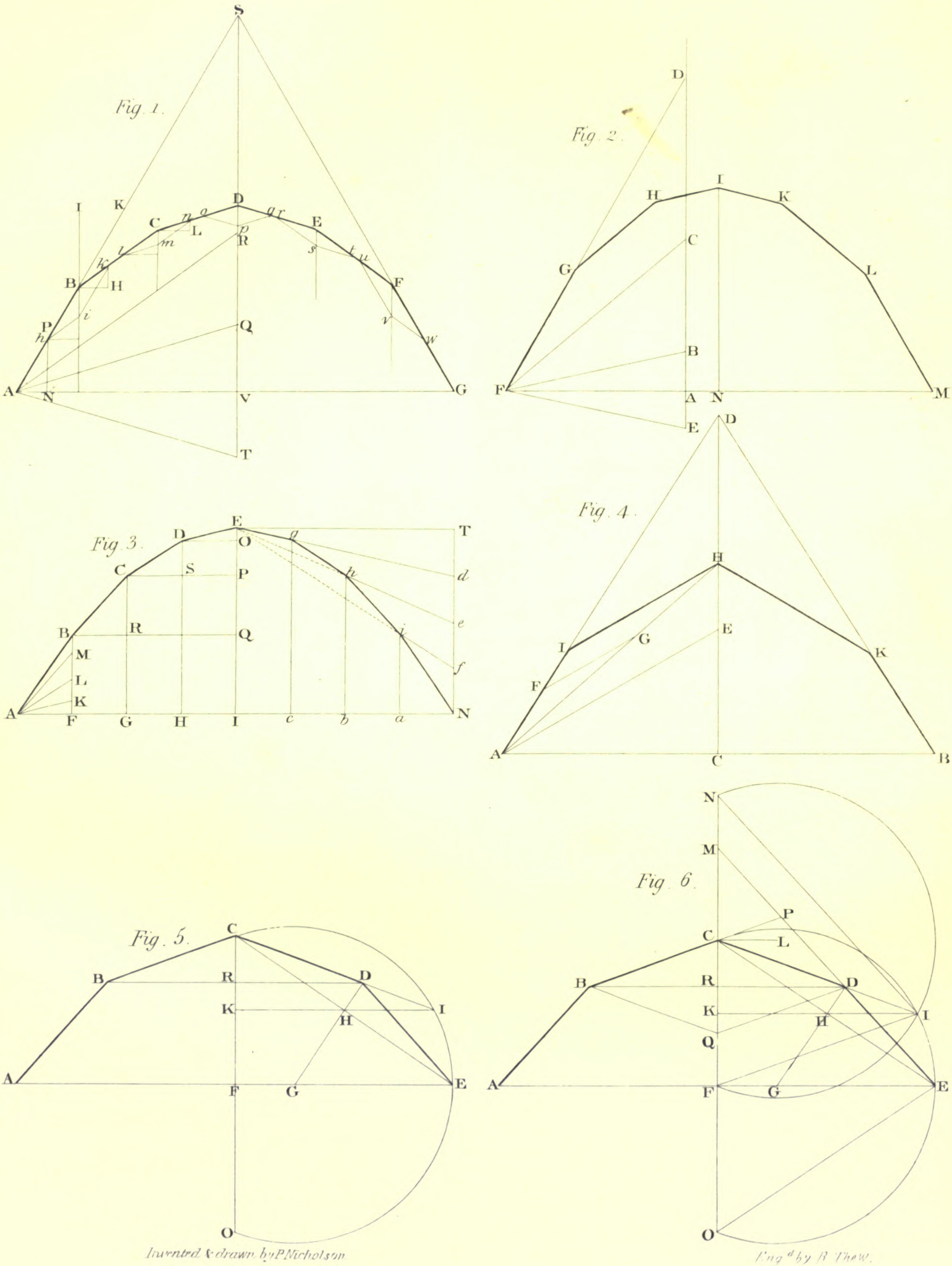
Figure 3.—Let there be four rafters on each side, let I N be half the width, and I E, the height. Draw N T and E T parallel to I E and I N ; divide N T into four equal parts, N *f*, *f e*, *e d*, *d* T, and draw *d g* E, *e h* E, *f i* E : likewise divide I N into four equal parts, I *c*, *c b*, *b a*, *a* N, and draw *c g*, *b h*, *a i*, parallel to I E. Join E *g*, *g h*, *h i*, *i* N, and these lines will be the rafters of half the roof required. For the demonstration, see the article CONIC SECTIONS.

Proposition IV. *Figure* 4.—Suppose it were required to construct a curb roof to have the bottom rafter to the upper rafter as 2 to 3, to a given vertical angle at the top, and a given width A B.

Now the weight on the upper angle is to the weight on the lower angle, as $\frac{2\,HI}{2}$ is to $\frac{HI+IA}{2}$ that is, $\frac{3+3}{2}=3$ is to $\frac{3+2}{2}=2\frac{1}{2}$, this is in the proportion of 6 to 5, or the half weight at H is to the bottom weight at I, as 3 to 5.

Bisect A B by the perpendicular C D, and make the angle

CURB ROOF.



Invented & drawn by P. Nicholson.

Eng.d by R. Thew.

AEC equal to half the vertical angle, or the angle EAC, equal to its complement. Make ED to EG as 5 to C; join DA and DB; in AD, take any point, F; draw FG parallel to AE, making AF to FG as 2 to 3; draw AGH, cutting CD at H, and HI parallel to FG or EA, cutting AD at I; make BK equal to AI, and join KH, then AIHKB is the contour of the roof required. This is so evident from its construction, that its does not require demonstration.

Proposition V. *Figure* 5.—To describe a roof with four equal rafters, that shall be in equilibrio by the weight of the rafters, of a given width AE, and height FC.

Join CE, and bisect it in H by a perpendicular, DHG, meeting AE in G; on G, as a centre, with the distance GE or GC, describe the circle CEO. Draw KHI parallel to FE, to meet the vertical line OC in K, and the circle in I. Draw IDC, and join DE, than make the side CBA similar to CDE, and AB, BC, CD, DE, will be the rafters of the roof required.

For, in *Figure* 6, complete the parallelogram CDQB, and join BD, IF, and draw OL perpendicular to CF, and equal to FG; on L, with the distance OE describe the circle NIF, meeting the vertical line at N and F; produce ED to meet it also in M, and BC to P.

Then because KF is equal to KC, and RC equal RQ, the triangles GIF and CDQ, are similar; therefore IF is parallel to DQ, and because the two segments NIF and CEO are equal to one another, the angle NIF is equal to the angle GEO, equal to twice the angle CEF, or twice the alternate angle ECL, equal to ECD + DCL; but ECD is equal to half the external angle MDC, and DCL is half the angle DCP; equal to DCQ. Therefore the angle NIF is equal to the angles MDC + CDQ, equal to the angle MDQ, consequently, CF : CN : : CQ : CM, but CF and CN are equal, therefore CQ and CM are equal; but CQ is to CM as the weight on C is to the weight on B or D, therefore the weights on C and D are equal, and the rafters AB, BC, CD, DE, are in equilibrio.

CURB STONES, (sometimes written *Kerb* or *Kirb*,) those common to the foot and carriage pavements in a street.

CURIA, a court of justice. *See* BASILICA.

CURLING STUFF, that which is occasioned by the winding or coiling of the fibres round the boughs of the tree, where they begin to shoot out of the trunk.

The double-iron plane, now in use, is a most complete remedy against cross-grained and curling stuff; this plane, if well set, will work nearly as smooth against the grain as with it.

CURRENT, the necessary slope of a piece of ground or pavement, for discharging the water from the surface.

CURSOR, a point screwed on a beam-compass, and which may be moved or slid along the beam, for striking greater or less arcs of circles. It is also that part of a proportional compass which holds the two legs together, and by which the points are set in any given ratio. The sliding parts of the trammel, rood, or ellipsograph, are also called *cursors*. *See* COMPASSES.

CURTAIL STEP, the first step by which a stair is ascended, finishing at the end in the form of a scroll, following the plan of the hand-rail. *See* the article STAIR.

CURTAIN, (from the French *courtine*,) in fortification, that part of the rampart which is between the flanks of two bastions, bordered with a rampart five feet high, behind which the soldiers stand to fire on the covered way, and into the moat.

CURTICONE. *See* FRUSTUM and TRUNCATED CONE.

CURULE, a sort of raised, embellished chair or seat of ivory, gold, &c., placed in a chariot, wherein the chief officers of Rome were wont to be carried into council. It was also a mark of distinction for dictators, consuls, prætors, censors, and ediles, who were from this circumstance called *curules*. Curule chairs were of various shapes, but the one generally used was a stool without a back, so made as to be folded up, and opened again in the manner of a camp stool.

CURVATURE, that degree in a curve, in which the curve recedes in a perpendicular from a tangent, at a given distance from the point of contact; and consequently if two curves, or two parts of the same curve, have each a tangent, and if any equal distance from each point of contact be taken, and a perpendicular be drawn from each point of distance to the curve; then, in each of these curves, or portions of the same curve, the intercepted perpendicular being greater or less, the curvature will also be greater or less.

CURVE, a line, such that only one straight line can be made to touch, without cutting it, when the straight line is extended on both sides of the point of contact; or a curve is a line in which, if a point be taken, only one straight line can pass that point without cutting the line in which the point is taken. The straight line so drawn is called *a tangent* to the curve.

The circle is the most simple of all curves, depending only upon the arbitrary extension of its radius, which, if given, the circle is determined in magnitude. Its circumference is one uniform curve, or has its curvature everywhere equal, and equally distant from the centre.

In every curve line whatever, it is evident that a very small portion may be taken as a circular arc at any point; or that there is a certain circular arc at that point which has the same curvature as an indefinitely small portion of the curve, but a greater curvature than an indefinitely small portion of the curve upon the one side of the point, and also a less curvature than the nearest indefinitely small portion on the other side of the point. The radius of a circle of equal curvature to the curve at any proposed point, is called the *radius of curvature* at that point, and is the measure of the curvature of all curves. The circle of equal curvature with the curve, is called the *equicurve circle*, or the *osculating circle*. Hence, if the osculating circle and the curve have a common tangent, no other circle whatever can be drawn between the two curves; and when the curve is continually upon the increase or decrease in its curvature, the arc of the osculating circle will be on the concave side of the curve on one side of the point of contact, and on the convex side on the other side of the said point; or the curve will be between the tangent and the circumference of the osculating circle on the one side of the point of contact, but the circumference of the osculating circle will be between the tangent and the curve on the other side of the point of contact.

The principal curves that are useful in architecture, are the conic sections, namely, the circle, the ellipsis, the parabola, and the hyperbola; also, the cycloid, the conchoid, the spiral of Archimedes, and the logarithmic spiral. The definitions and the most useful properties, will be found under each word.

CURVE OF DOUBLE CURVATURE, a curve, of which all its parts are not in the same plane.

Thus, if the surfaces of two cylinders of the same diameter intersect each other, and their axes also intersect each other, the common intersection will be a curve, of which its parts are all in the same plane; or if the surface of a cylinder and cylindroid intersect each other, and their axes also intersect each other; and if the semidiameter of the cylindroid be perpendicular to a plane passing through the two axes, and equal to the radius of the cylinder, then the parts of the curve formed by the two surfaces, are likewise in one plane: or if the surface of one cylindroid meet that of another cylindroid, and their axes intersect each other; and if the semi-diameters of both cylindroids, perpendicular to a plane passing through the two axes be equal to each other, the curve formed by the intersection of the cylindroidic surfaces will have all its parts in one plane: not any of these thus defined, are curves of double curvature. But if the surfaces of two cylinders of unequal diameters meet in a common line, this line is a line of double curvature: of this description are cylindro-cylindric groins. Many other instances of two geometrical solids meeting each other, producing lines of double curvature, may be laid before the reader, but perhaps what has already been adduced will be sufficient.

Curved Surface of a Solid, that in which, if any point be taken, and if the solid can be cut by a plane through the point, and thence form a section, such section is terminated by a curve: Thus a cylinder or a cone may be cut by a plane, through any given point, so as to make the common section of the cylinder or cone with the plane, a curve, or a straight line; but if a sphere, spheroid, or any of the conoids be cut by a plane through any point, the common section of the plane, and the surface of any such solid will be a curve.

CURVILINEAR, (from the Latin *curvus*, a curve, and *linea*, a line) or Curvilinear Figure, a superficies bounded by curve lines, or by a curve and straight line, when the properties of the curve depend upon the straight line.

The circle and ellipsis are entire curves, or such as have no straight line in their boundary; but the parabola and hyperbola are both bounded by a curve and a straight line.

Curvilinear Angle. *See* Angle.

Curvilinear Roof, that which is erected upon a curvilinear plan, as a circular, or elliptical, or portions of these curves.

Curvilinear Superficies of a Solid. *See* Curved Surface of a Solid.

Curvilinear Triangle, one whose sides are curves.

CUSHION RAFTER. *See* Principal Brace.

CUSP, (from the Latin *cuspis*,) one of the pendants of a pointed arch, or one of several pendants forming what may be denominated a polyfoil; two cusps form a trefoil, three a quatrefoil, four a cinquefoil, &c. In other words, the term may be explained as the points generated by the intersection of the small arcs or segments of circles, forming the foliations which frequently terminate the internal curves of Gothic arches, more especially window arches, in the shape of trefoils and other polyfoils.

This name was first given by Sir James Hall, of Dunglass, in an *Essay on the Origin of Gothic Architecture*. He says, in a note at the bottom of page 23, that "assemblages of these cusps are spoken of in the descriptions of Gothic works, by the means of trefoil, quatrefoil, semitrefoil, &c.; but no proper word has been used to describe the form, wherever it occurs, or however combined."

CUSTOM-HOUSE, an edifice in some chief city, or port, for the receipt of the customs and duties of importation and exportation imposed on merchandise, by the authority of the sovereign. The custom-house in Dublin is a very elegant edifice.

CUT, in inland navigation, the same with canal, branch, or arm.

Cut Brackets, such as are modelled on the edge.

Cut Roof, a truncated roof.

Cut Standards, for shelves, are those whose front edge is cut into mouldings.

Cut Stone, hewn stone, or that which is brought into shape by the mallet and chisel.

Cut-water, the lower portion of the pier of a bridge, where the two sides meet at a point, so disposed to meet the current, and offer as little resistance as possible to the force exerted by it against the pier.

CUTTING PLANE, a plane supposed to cut or divide a solid into two parts, in any position.

CUVILLER, FRANÇOIS, an architect, born in the year 1698, at Soissons, in France. He was employed by the elector of Munich in many public buildings, and continued in the service of that court till his death, which happened in the year 1760, leaving behind him many plans and designs, which were afterwards engraved by different artists, and published by his son, François Cuviller, who was born at Munich, and succeeded his father as architect to the court.

CYCLOGRAPH, (from the Greek, κυκλος, *a circle*, and γραφειν, *to describe*) in practical geometry, an instrument for describing the arc of a circle to any chord and versed sine; but chiefly used in flat segments, or those whose curvatures approach to straight lines. There are several constructions of cyclographs, of which the following is one. The principle consists of two rules, A B, and C D, connected by a folding joint, E, the pin, *k*, of which projects upwards, and is mortised to receive a bar, *h g*, which is fastened, but movable round the centre of the folding joints; upon the connected rules, A B and C D, at equal distances, from the centre of the folding joint, are fastened the ends I and K, of two other equal bars *c* I, *c* K, connected by a movable joint, *c*, so as to form a rhombus, *h* K *c* I, movable round each of the joints, *c* I *h* K; then the bar, *h g*, which passes through the centre, *h*, of the two first rules, being made also to pass through a projection of the pin, *c*, of the opposite angle of the rhombus, is made to slide into the mortise as at *c*. The use of the bar is to fasten the instrument in any position by means of a screw inserted from the middle of the top of the upright pillar at *c*, which receives the sliding end of the bar.

The instrument being supposed to be placed upon a level plane, and the pin, *h*, of the folding joint being made to project upwards; another bar, L M N, bent to a right angle with a longitudinal slit, O P, is fitted upon it, so as to have a motion upon the pin *h*, in the section of the slit, but may be fastened at any required point, by means of a screw from the top. The other end, N, of this bar is mortised in the direction of the slit, to receive the lower bar, *h g*, so as to have a longitudinal motion. The middle line of the upper bar stands in the same vertical plane with the middle line of the lower bar, and these two lines are parallel in all positions of the instrument.

The end of the bar, L M, at the external side of the folding joint, has a deep socket for holding a pin or pencil, perpendicular to the plane of the instrument. The advantage of the upper bar being movable, to which the pin or pencil is attached, is to admit the point of the pin or pencil to be brought into the intersection of the sides B A, C D, of the instrument.

To describe the segment of a circle by means of the cyclograph, fasten two pins in the plane, or steel edges made on purpose, and adjust the angle of the instrument; place the outer edges upon the pins, and the angle close upon one of them; move the instrument laterally close to the pins, and a pen or pencil will describe the curve.

The principle of this instrument is founded upon the twenty-first proposition of the third Book of Euclid's Elements, in which it is announced and proved that "the angles in the same segment of a circle, are equal to one another."

This instrument may also be applied to the drawing of lines to any inaccessible points, by means of the middle bar, which always bisects the angle, and therefore will be indispensably useful in the practice of perspective.

CYCLOID, (from the Greek κυκλος, *a circle*, and ειδος, *form*) a figure described by rolling a circle upon a plane, along a straight edge; then the moving point will trace the curve called a *cycloid*, or *trochoid*. The middle portion of this figure is very appropriate for the arch of a bridge, which requires to have its roadway raised on the top, as the extrados of this curve has a gentle convexity.

CYCLOPEAN ARCHITECTURE, that practised by the early colonists of Greece, more remarkable for its massive construction than any other feature, whence also its name. *See* Pelasgian Architecture.

CYCLOSTYLAR, a term applied to those erections which consist of a circular range of columns, without a central building.

CYLINDER, (from the Greek κυλινδειν, *to roll*) a solid formed by moving a straight line in the periphery of a circle, parallel to another straight line, which passes through the centre, and which makes any given angle with the plane of the circle, until the line come again into its first position.

The surface described by the moving line from the circle to any indefinite extension, is called *a cylindric surface;* the straight line which passes through the centre of the circle is called the *axis* of the cylinder, and the circle the *base* of the cylinder.

If the axis be at right angles to the plane of the base, the cylinder is called *a right cylinder;* but if at oblique angles, then it is called *an oblique cylinder.*

Euclid confines his definition only to a right cylinder, and defines it to be a solid formed by revolving a rectangle round one of its sides.

It is evident from this definition, that all sections passing through the axis, or parallel to the axis, have their opposite sides parallel; viz., those which are formed by the cutting plane and the cylindric surface. From the definition here given, the following consequences may be drawn, as being too obvious to require any formal demonstration. If a plane, parallel to another plane, drawn along the axis of a cylinder, touch the periphery of the base, the plane so posited will touch the surface of the cylinder, and will meet it in a line parallel to the axis; but if such plane cut the plane of the base of the cylinder within its periphery, it will cut the cylindric surface in two parallel lines, and the common section of the plane and the cylinder will be a parallelogram, and, lastly, the common section of a plane, parallel to the base, with the cylindrical surface, is a circle with its centre in the axis. Let us now consider the property of a section which will meet the plane of the base of the cylinder, but which will neither pass along the axis, nor be parallel thereto.

Figure 1.—Let AMLB be a section of the cylinder through the axis, cutting the section proposed, and let the cutting plane meet the plane of the base AFEDNO in RS: through the centre D of the base, draw the diameter AB, at right angles to RS. Let the plane be drawn through AB and the axis DH of the cylinder, meeting the cutting plane in the line MHOLT, and the surface of the cylinder, in AM and BL. Through H and any other point, O, in ML draw QK and IP parallel to RS; through KQ and DH, draw the plane KQOF, and through IP draw the plane IPNE, parallel to the plane KQOF, cutting AB at C; and because KQ and IP are parallel to RS, the planes KQOF and IPNE, are also parallel to RS; therefore FO and EN, are respectively parallel to KQ and IP; consequently, the figures KQOF and IPNE, are parallelograms, and therefore KQ is equal to FO, and IP equal to EN: because EN is parallel to RS, it is at right angles to AB, and hence it is plain that IP is bisected by ML. Now the triangle AMT, has the side AT cut into several parts by the intermediate points D, C, B, and MT cut into other parts at the intermediate points H, G, L, by lines parallel to the side AM, and therefore the parts AD, DC, CB, are respectively in the same ratio with the parts MH, HO, OL; these being premised, we have therefore

$$AC : AD :: MG : MH$$
$$CB : AD :: GL : MH$$

Therefore $AC \times CB : AD^2 :: MG \times GL : MH^2$

but $AC \times CB = EC^2 = GI^2$ & $AD^2 = HK^2$

consequently $GI^2 : HK^2 :: MG \times GL : MH^2$

therefore the section is an ellipsis.

But this demonstration, which is in principle that commonly given, only shows the general property in respect of the axis, or at most in respect of only two conjugate diameters, of which one must be parallel to the base; and as we have never seen a general proof of this valuable property for any two conjugate diameters drawn from simple principles, without being under the disagreeable necessity of drudging through nearly a whole treatise of conic sections, before we are able to arrive at the conclusion, we therefore subjoin the following demonstration.

Figure 2.—Let there be any cylinder, right or oblique, standing upon the base GEAPQD, and let C be the centre of the base; through C draw GQ at pleasure, and ACD at right angles to GQ. Through GQ and the axis CM draw the plane GQSH, cutting the section proposed in the straight line HS, also through AD and the said axis draw the plane ADNK, cutting the section in the straight line KN. In one of the diameters, AD, of the base, take any point, B, between A and C, and draw EP parallel to GQ, and the plane EPRF, parallel to the plane GQSH, cutting the section in FR.

From the construction of the cylinder, it is evident that the lines KN, FR, HS, are each divided into parts, which are as the parts of the lines AD, EP, GQ. Therefore as EP, GQ, and AD, are bisected, so will FR at L, HS at M, and KN at M.

From the premises we have . . . . $AB : AC :: KL : KM$

and by proportional lines . . . . $BD : AC :: LN : KM$

Now, by multiplying the homologous terms . . . . $AB \times BD : AC^2 :: KL \times LN : KM^2$

But from the property of the circle . . . . $AB \times BD = EB^2$ & $AC^2 = GC^2$

Therefore, by substitution, we have . . . . $EB^2 : GC^2 :: KL \times LN : KM^2$

Now again, by proportional lines . . . . $EB : GC :: FL : HM$

Squaring the terms of the last analogy . . . . . . $EB^2 : GC^2 :: FL^2 : HM^2$

but by the fourth analogy, we have . . . . $EB^2 : GC^2 :: KL \times LN : KM^2$

And by comparing the antecedents and consequents of the last two analogies we obtain . . . . $FL^2 : HM^2 :: KL \times LN : KM^2$

which is a general property of every two diameters, formed by the intersection of planes passing along the axis at right angles to each other. These diameters, it is evident, will be parallel to tangents to the curve, at the extremities of each other. For, suppose two planes touching the cylindric surface, each in a line which passes from the extremities of each radius at a right angle with each other, these tangent planes will be respectively parallel to each plane passing along the axis and through the said radii; the two tangent planes, and the two planes passing along the axis, will be at right angles to each other, or each opposite pair will be parallel; therefore, if these be cut by a fifth plane, the intersections of the opposite planes with such fifth plane, in any position, will be parallel lines; and since the touching planes do not cut the surface of the cylinder, the lines at the extremities of each diameter will be parallel to the curve, and are what are termed *conjugate diameters.*

A cylinder is a species of prism, because all its parallel sections are equal, and every section parallel to the base is equal to that base; therefore the solidity of a cylinder is determined by multiplying the area of an end by the parallel distance between the two ends.

Example I. What is the solidity of a cylinder, whose height is 10 feet, and the diameter of the base 2 feet 6 inches?

in.
$6 = \frac{5}{10} = .5$ in decimals
$2.5 =$ the diameter
2.5
———
125
50
———
6.25
.7854
———
2500
3125
5000
4375
———
4.908750
10
———
49.087500

Example II. What is the solidity of a cylinder, the circumference of the base being 7.85 feet, and the height 15 feet?

7.85
7.85
———
3925
6280
5495
———
61.6225
.07958
———
4929800
3081125
5546025
4313575
———
4.903918550
15
———
24519592750
4903918550
———
73.558778250

The curved surface of every cylinder is equal to a rectangle, one of whose dimensions is the length of the axis, that is, equal to the length of the side of the cylinder, and the other dimension equal to the perimeter or girt. This is a general principle, whether the cylinder have its ends perpendicular or oblique to the axis; and hence the following—

Rule. Multiply the girt of the cylinder by the length of the axis, and the product will be the cylindric surface.

Example. Suppose a cylinder, girt 5 feet 9 inches, and the length of its axis, or side parallel to the axis, be 9 feet 7 inches, what is the superficial content of the surface?

Cross Multiplication.	Decimals.
ft. in.	
5 9	9.583
9 7	5.75
5 3	47915
35	67081
81	47915
12) 121	55.10225
	12
10 1	
45	1.22700
	12
55 . 1 . 3	
	2.724

See the first method in this example under the article Cross Multiplication, and the second method, under Decimal Multiplication. These two methods would have agreed exactly, but no decimal corresponding to 7 inches can be precisely found.

The method by the girt is what every man in practice would naturally prefer, if the object be before him, since the girt can be as easily measured as the diameter, and with equal accuracy, by means of a string; nor would any person, whose mind is crowded with the affairs of business, take the additional trouble of finding the circumference from the diameter, when it may be so expeditiously obtained another way. However, for the satisfaction of those who wish to be informed of every mode of operation, we shall add the following, as some cases may occur, in which the perimeter cannot be obtained without the diameter; though the contrary might as likely be the case.

If the cylinder be a right cylinder, find its circumference, which will then be the same as its ends; then proceed as before to multiply the circumference by the axis, and the product is the superficial content. This is so easy as not to require an example. But where the axis is inclined to the base, the section of the cylinder will be elliptic, the diameter of the circular ends will be the greater axis, the lesser one will depend upon the inclination of the cylinder, and may be thus found:—

As the radius
is to the sine of inclination,
so is the diameter of the circular ends
to the shorter axis of the ellipsis.

From the two axes being now found, find the perimeter of the ellipsis, then proceed as in the first rule.

Example. Suppose the length of the axis to be 22 feet, and the inclination of the same to the plane of the base 50 degrees, and the diameter of each end 3 feet 6 inches; required the area of the curved surface.

	By logarithms.
Then as radius	10.000000
is to the sine of 50°	9.884254
so is 3.5	544868
	10.428322
	10.

to the shorter axis .428322 = nat. num 2.68

2.68
3.5

2)6.18

3.09 mean diameter.

$3\frac{1}{7}$

9.27
.44

9.71 elliptic primeter.
22

1942
1942

213.62 the area required.

The above method of finding the extension of the elliptic primeter being the most expeditious, is the most useful for practical purposes, but those who wish to work with greater accuracy may consult the word *Ellipsis*.

A cylinder is said to be given in position, when its base and magnitude, and the inclination and length of its axis, are given.

A point is said to be given on the surface of a cylinder, when its distance from that point to the base, measured in a line parallel to the axis is known, and the point on the circumference of the base given.

Figure 3.—*Given a right cylinder and three points on its surface to find the section of the cylinder, by a plane passing through the three points.* Let the straight lines, A, B, C, be the distances of the three points, the circle D E F K, the base of the cylinder ; L the centre of the base. Through the points D and F draw the straight line P O ; perpendicular thereto draw each of the lines D O, E H, F I, respectively equal to A, B, C. Draw D E Q and G H Q, intersecting at Q ; also draw G I O, meeting P O in O, then Q O, which is the intersection of the cutting plane. Through L draw R L S T, cutting Q O at T. In G O take any point *m*, draw *m u* perpendicular to G O, produce *u m* to M in O P, and draw M U perpendicular to P O, cutting Q O at U. From the point O, with the distance O U, describe an arc, cutting *m u* at *u;* perpendicular from R T, draw R P and L N, cutting P O at P and N. Draw P *p* and N *n* perpendicular to P O, cutting O G produced at *p*, and *n*. Parallel to *u* O, draw the lines *p r* and *f n l h ;* make O *t* equal to O T and *p r* equal to P R, and draw *r l s t;* make *l s* equal to *l r*, and *l g* and *l h* each equal to R L, the semi-diameter of the base, then will *l r l f* be the semi-axis of the elliptic section.

Demonstration.—It is shown under the article INCLINED PLANES, that if D, E, F, be any three points, and the lines A, B, C, the height of three points in the space above the plane D E F, that Q O will be the intersection of the plane in space with the original plane P O Q or its continuation : under the article STEREOGRAPHY and STEREOTOMY it is shown, that if P O Q and P O *p* be any two plane angles, to be placed at a right angle with each other, that the plane angle G O *u*, will be the hypothenusal plane, and consequently when the three planes, P O Q, P O *p*, and *p* O *u* are turned into their position ; the straight line O *u* will coincide with O U ; therefore, if a plane be perpendicular to the intersection of two planes, it will be at right angles to each of these planes ; and that the section of any vertical line, whose seat is given, will be found by drawing a line on the original plane, parallel to the intersection from the seat, to the intersecting line of the vertical plane; thence a line perpendicular to this intersection to the common intersection of the vertical and cutting planes, and thence a line from this point parallel to the cointersection ; then, by making this line equal to the line drawn from the seat to the common intersection of the original and inclined planes, and thus the point R being the seat of *r*, and *l*, the seat of L, and the plane passing through R L S T, being perpendicular to Q O, the common intersection of the inclined and original planes, *r l s t* will be the intersection of a plane passing through the axis and at right angles to the intersection O Q, and therefore perpendicular to O *u* ; consequently *r s* and *f h* are at right angles to, and bisect each other, and are therefore the axes of the ellipsis.

The segment of a cylinder is any portion of the cylinder made by a plane parallel to the axis.

The plane parallel to the axis is called the *chord-plane.*

The two lines of concourse formed by the cylindric surface and the chord-plane, are termed the *sides* of the chord-plane, and the other two lines of concourse made by the chord-plane and the two ends of the solid, are termed the *bases or ends* of the chord-plane.

A line of position is said to be given, when the said line is drawn through a given point on each side of the chord-plane, or to make a given angle at a given point in the base of the chord-plane, or in the base continued.

The position of the cutting plane is said to be given, when the line of position through which the cutting plane passes, and the angle which the cutting plane and chord plane make with each other, are known.

Figures 4 and 5.—*To find the section of the segment of a cylinder ; given its base and the position of the cutting plane.*—Let A B C be the base of the solid, A D and C E the sides of the chord plane perpendicularly situated in respect of A C, the chord of the base, and let D E be the line of position of the cutting plane. Through any point *f* in D E draw *h f g*, at right angles to D E ; make the angle *g f k* equal to the inclination which the planes of the chord plane and section make with each other ; take any point *m* in *f g*, *Figure* 4, or *f h*, *Figure* 5, and draw *m k* parallel to D E, cutting *f k* in *k*, and *m n* parallel to C A, cutting D E at *n ;* make *f h* equal to *f k*, and join *h n*. Parallel to E C draw *m q*, cutting A C at *p*, and *n r*, meeting it at *r :* make *p q* equal to *m k*, and join *r q*. To find any point in the curve of the section, take any point, *a*, in the arc A B C ; draw *a b* parallel to *q r*, cutting A C at *b ;* draw *b c* parallel to C E, cutting D E at *c*, and draw *c d* parallel to *n h ;* make *c d* equal to *b a*, and the point *d* is in the curve.

In the same manner, as many points may be found as will be sufficient to draw the curve with accuracy.

This method is an improvement upon that published in *The Carpenter's Guide*, in the year 1792 ; but as that method has been very generally employed, it will be well to insert it likewise in the plate, as the connection of the principle may be clearly deduced from the one to the other.

Figures 6 and 7.—*To find the section of the segment of a cylinder, by another and older method, supposing everything given as before.*—Let A B C, No. 2, be the inclinations of the planes of the chord plane and section. In No. 2, draw B D perpendicular to B A, and make B D equal to the distance between the parallel lines E F and Z M, No. 1, and draw D C parallel to B A. Through any point, *d* in I K, No. 1, draw N V at right angles to I K; make *d* N equal to D C, No. 2, and *d* V, No. 1, equal to B D, No. 2. In No. 1 draw N O parallel to F E, meeting I K at O, and join O V. Draw N Q and O L parallel to K F, meeting E F at Q and L; produce N Q, meeting Z M produced at Y, and join L Y. Draw any number of lines *a a*, *b b*, *c c*, &c., parallel to O L, cutting the lines E F and I K, at the points *a*, *b*, *c;* from the points *a*, *b*, *c*, in I K, draw the lines *a* 1, *b* 2, *c* 3, &c., parallel to O V, and through the points *a*, *b*, *c*, in E F, draw the lines *a* 1, *b* 2, *c* 3, &c., parallel to L Y. Make all the lines *a* 1, *b* 2, *c* 3, &c., from I K, equal to their corresponding distances *a* 1, *b* 2, *c* 3, &c., from E F. A curve being drawn through the points 1, 2, 3, &c., the extremities of the ordinates from I K, will give the section I V K I of the segment of the cylinder. Or take any point point L in E F, and draw L O parallel to F K, the one side of the rectangle, cutting I K at O; produce O L to M, and draw Z M parallel to E F, to touch the base in M. In No. 2, draw B D at a right angle with B A; make B D equal to L M, and draw D C parallel to B A. In No. 1, draw G H parallel to I K, at the distance D C, No. 2; draw O N parallel to E F, cutting G H at N; draw N Q parallel to O L, cutting E F at Q; produce N Q to meet Z M produced at Y, and join L Y; draw N V at right angles to I K, cutting I K at *d;* make *d* V equal to B C, and join O V; then proceed to find the ordinates as before.

The difference between the old and the first method is, that in the old method, the breadth of the segment or base of the solid is limited, in order to find the dissecting lines of the ordinates, and two diagrams are employed in the construction; whereas in the first method, one diagram only is used, and the angle of inclination of the planes of the section and chord being made as directed, the measure of the first side of the hypothenusal side of the right-angled triangle formed by it, is arbitrary; by this the other parts are regulated. The reader must observe, that it is only the angles which are required; the length of the lines is of no other consequence than, if they be too long, they will be rather cumbrous, and if too short they will not be a sufficient guide for drawing the ordinates. This limitation has been the occasion of some not understanding the principle, by supposing the point V to be in the curve, which may be either on the one side or the other, according to this method.

A knowledge of the sections of prisms, which include segmental cylinders, is an acquisition of the first importance to the carpenter and joiner, and is the very essence of the art of constructing hand-railings and groins.

The method by having the position of the cutting plane, is not so well adapted to practice, as that of having three given points on the surface of the segmental cylinder.

Under such given data we have already shown how the section is to be found for a whole cylinder, by describing the curve through the extremities of the axis, which are given in position. We shall now show how the curve is to be obtained by ordinates in the segmental cylinder from the same data.

In a segment of a cylinder are given three points, one on each common line of the chord-plane, and curved surface, and one upon the intermediate curved surface itself, to find the section passing through these three points.

Figures 8 and 9.—In both figures let A B C be the base of the solid, and A, B, C, the seats of the given points, draw A D and C E perpendicular to A C: make A D equal to the height of the point upon its seat A, and C E equal to the height of the point upon its seat C; also from C E take C F equal to the height of the intermediate point, from its seat B. Draw F G parallel to A C, cutting D E in G; draw G H parallel to E C, cutting A C at H; join H B. Produce C A and E D to meet in I; in E I, *Figure* 8, also in E I produced *Figure* 9, take any point, N, and draw N M perpendicular to N E; produce M N to meet I C at K, *Figure* 8; in *Figure* 9, M N will cut C I, produced in K. In both figures draw K L perpendicular to K C, and I L parallel to H B; from I, with the distance I L, describe an arc, cutting N M, at M; join I M.

To find any point in the curve of the section; take any point *a*, in A C, and draw *a b* parallel to L I, cutting the arc A B C at *b*, draw *a c* parallel to C E cutting D E in *c;* draw *c d* parallel to I M; make *c d* equal to *a b*, and *d* is a point in the curve. In the same manner as many points may be found as will be sufficient to complete the section.

Another method *Figure* 10, let A B C be the base of the segment as before; also, let A, B, C, be the seats of the three points, as before; and F G H their respective heights. Draw A D, B P, C E, each perpendicular to A C, respectively equal to F, G, H; draw A B I and D P I, also A C K and D E K; then draw the intersection I K. In D K take any point L, and draw L M perpendicular to D K; produce M L to meet A K at N; draw N O perpendicular to A K, cutting I K at O. From K, with the distance K O describe an arc, cutting L M at M, and join K M.

Then, to find any point *d*, in the curve of the section; in A C take any point *a;* draw *a b* parallel to K O, meeting the arc A B C at *b;* draw *a c* parallel to A D, meeting D E at *c;* draw *c d* parallel to K M, and make *c d* equal to *a b;* and thus for any other point.

The very same description of words applies to *Figure* 11, except that the point L is in D K produced, instead of between D and K, and also the point N, in A K produced, instead of between A and K. The same is also the case with the preceding method.

Figure 12. To form the edge of the envelope of a cylindric surface, terminated by a line, so that, when the envelope is folded upon the cylindric surface, the edge formed may coincide with a plane passing through three given points, one in each common line of the chord-plane and curved surface, and the other in the intermediate curved surface itself.

Let A B C be the base of the solid; draw A D and C E perpendicular to A C, making A D equal to the height of the point, whose seat is A, and C E equal to the height of the point, whose seat is C; make C F on C E equal to the height of the point, whose seat is B, and join D E. Draw F G parallel to C A, cutting E D at G; draw G H parallel to E C, cutting C A at H, and join H B. Divide the arc A B C into any number of equal parts, and extend them upon A C produced to I, marking the points of division at *a*, *b*, *c*, &c., to I; the corresponding points of 1, 2, 3, &c., on the arc C A B.

To find any point in the line of the envelope required, suppose that which corresponds to its seat 1, on the base of the solid.

Draw 1 *h* parallel to B H, cutting A C in *h;* draw *h h* parallel to C E, cutting E D at *h;* also draw *a p* parallel to C E, and make *a p* equal *h h*, then *p* is a point in the line required; and thus the whole line E *p q r s t u v* K is obtained, and this line is the edge of the envelope E C I K required.

CYLINDER, *Scaline.* When the axis of a cylinder stands at oblique angles with its base, it is called *a scaline* or *oblique* cylinder.

CYLINDRICAL, something peculiar, similar, or relating to a cylinder.

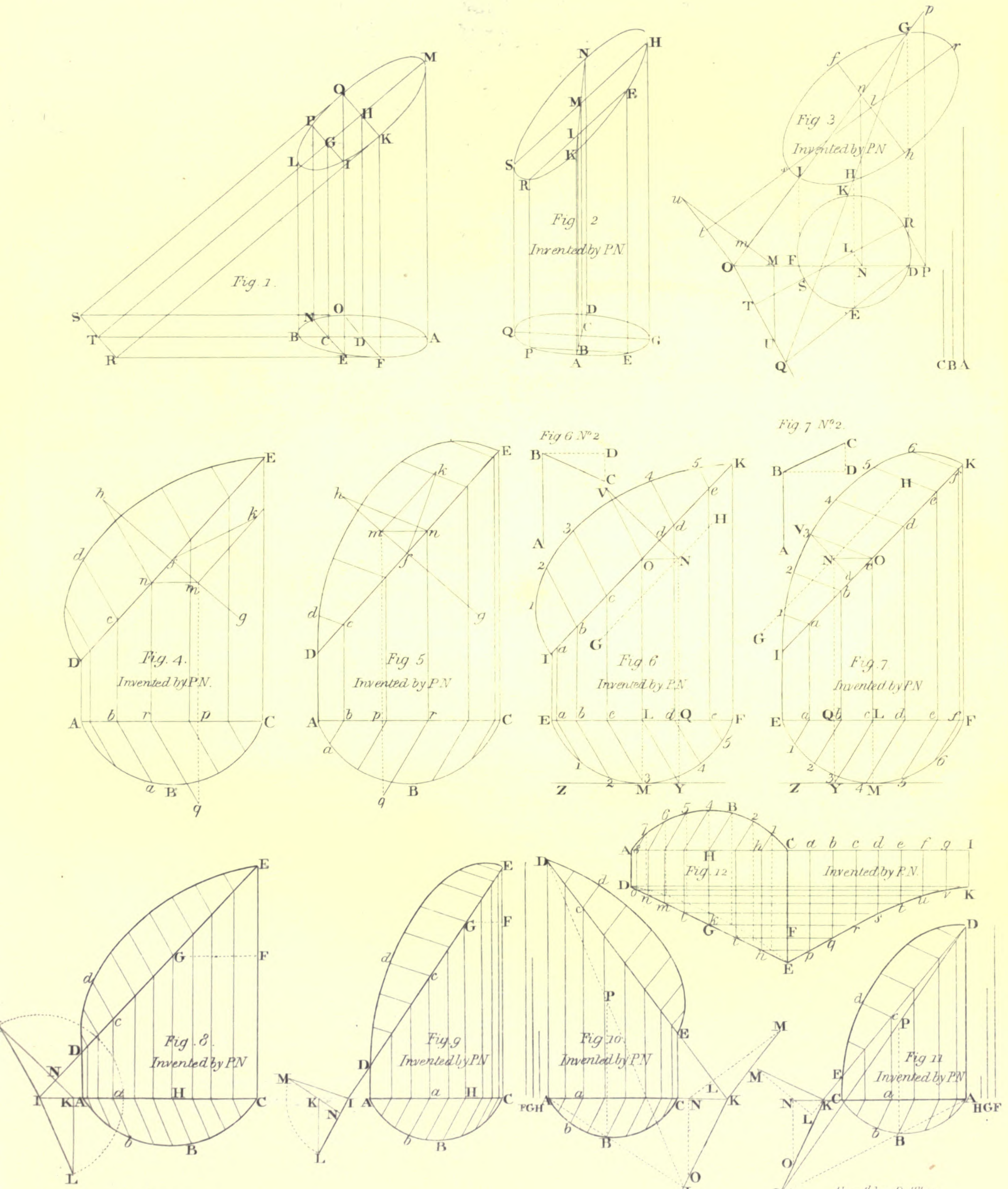
CYLINDRICAL CEILING, a ceiling which is either a semi-cylinder, or a segment less than a semi-cylinder.

Cylindrical ceilings are vulgarly called by some workmen *waggon-headed ceilings.*

When an apartment is sufficiently high, a semi-cylindric

CYLINDER.

PLATE I.



Drawn by P. Nicholson. Engd by R. Thew.

coving ought to be adopted, as it rises from the surface of the wall, which forms a tangent plane to the curvature at the springing of the arch; whereas the tangent plane at the springing of a ceiling, which is less than a semi-cylinder, always forms an angle with the plane of the wall, and excites the idea of lameness or imperfection. This kind is therefore only employed when the height of the apartment is not sufficiently great to admit of a semi-cylindric ceiling.

A semi-cylindrical ceiling admits of being pierced by lunettes, which are windows or openings of less height than the ceiling, and consequently form cylindro-cylindric arches, by the intersection of the curved surfaces.

No traces of cylindrical ceilings are to be found among the ruins of Grecian edifices, but numerous instances are to be met with among the Romans, in their small temples and the side-branches of the larger ones. The ceiling of the temple of Æsculapius, in the palace of Dioclesian, at Spalatro, in Dalmatia, is a decided instance. The proper decorations for cylindrical ceilings are coffers, separated at regular intervals by bands or *arcs doubleux*, or, as called by some, *soffits*, which are enriched with guilloches.

Cylindrical Column. *See* Column.

Cylindrical Vaulting, a vault which is the portion of a cylinder. Its section is generally a semicircle, though sometimes, for want of room, it is a smaller segment. In cylindrical vaulting, the equilibrium of the arch and the horizontal thrust of the piers must be attended to.

Cylindrical Walling, is that erected upon a circular plan, which of course forms a cylinder, or a portion of a cylinder, according as the plan is an entire circumference, or only a segment.

Cylindrical walling is generally estimated at about half as much more than the price of plain walling; but the price or ratio ought to depend upon the diameter, and should be greater as the diameter is less.

Cylindrical Work, any kind of work, partaking of the shape of a cylinder, of any material, whether stone, brick, wood, &c.

Cylindrical Work, in joinery. *See* Joinery.

CYLINDROID, (from *κυλινδρος*, *cylinder*, and *ειδος*, *form*) a solid of such property, that all sections parallel to either end, are equal and similar ellipses, and that a straight line, called the *axis*, will pass through the centre of the ellipses.

All the axal sections of a cylindroid, and every section parallel to an axal section, are parallelograms or rectangles.

All parallel sections of a cylindroid are equi-angular, and of equal length to the axis.

If an oblique cylinder be cut by a plane perpendicular to the axis, near to each end, it will be cut into three parts, of which the middle portion will be a cylindroid.

The cylindroid is frequently employed in vaulting, instead of a segmental cylinder, less than the half, where the height would not admit of a semi cylinder. It is frequently employed in the composition of groins, and where the transverse openings vary in their horizontal dimensions, and where it is required to keep the angles of the groin straight, one of the simple vaults is necessarily a semi-cylindroid.

The solidity of a cylindroid is found, as in the prism or cylinder, by multiplying the area of one of the ends by the distance between the two.

The superficial content of the curved surface is found by multiplying the girt by the length of the axis, as in the cylinder.

The method of finding the envelope is the same as that of a cylinder with an edge, so that when the envelope is lapped round the solid, its edge may coincide with a plane passing through three given points.

The method of finding the envelopes of cylinders and cylindroids, is one of the most useful parts of Stereography, not only in forming the coverings of bodies, but in forming the angles of all parts of work, where the surfaces of two different solids meet each other.

CYMA-RECTA. *See* Cymatium.

CYMATIUM, Cima, Cyma, or Sima (from *κυματιον*, *undula*, the diminutive of *κυμα*, *a wave*) a moulding, whose section is a curve of contrary flexure; it is commonly denominated by workmen *an ogee*. This is the strict sense in which the term ought to be employed, though Vitruvius uses it for any subordinate moulding which terminates a principal member, and the particular form is specified by prefixing another word, as Doric cymatium, Lesbian cymatium. In the same sense also he uses the word *Cysis*, which signifies *separation*. But notwithstanding this great authority, in the general usage of the term we shall abide by the definition as above, signifying an *undulated form*, as being most generally understood.

When the concave part of the moulding projects beyond the convex part, the cymatium is denominated a *sima-recta*; but when the convex part has the greatest projection, the cymatium is denominated a *sima-inversa*. The sima-recta is otherwise called *gula-recta*, or *doucine*, and the sima-inversa, *gula-inversa*, or *talon*. Palladio distinguishes the cymatium of the cornice by the name *intavolata*. Our architects, in speaking of the uppermost member of a cornice, call it *cima*, *cyma*, or *cymatium*; but we see no reason for the word being appropriated to this situation, as the propriety of terms consists in their proper application to definite forms.

The cymatia which are particularized by the terms *Tuscan*, *Doric*, and *Lesbian*, mentioned by Vitruvius, are not defined by this ancient author, and their meaning is only guessed at by his commentators and readers.

The Tuscan is supposed to be an ovolo, or quarter-round; the Doric, an ovolo, or cavetto; and the Lesbian, the sima-inversa, or talon.

Philander makes two Doric cymatia, one of which, he says, is that said to be Tuscan. The projecture allowed to the Doric and Lesbian cymatia, is subduple of the height.

CYMBIA, a fillet. *See* Fillet.

CYPHERING. *See* Chamfering, which is most in use.

CYZICENE, Triclinium, or Hall, an apartment of ancient Grecian houses, in the porticos, which look towards the north.

It is thus explained by Vitruvius, book vi. chap. vi. "There are some *œci*, not made in the Italian manner, these the Greeks call *cyzicenus*. They are situated towards the north, generally have a view of the garden, and have valved windows in the middle. They are of such length and breadth, that two triclinia, with their surrounding appendages may be placed opposite to each other; they have also valved windows on the right and left, that the garden may be seen through the space of the windows: their height is equal to one and one-half their breadth."

The cyzicenus or cyzicena, were of the same use among the Greeks, that the triclinia and cœnacula were among the Romans.

CYZICUM MARMOR, a species of marble, so called by the ancients, from the great use made of it by a statuary named *Cyzicus*. It was white, with fine narrow veins of black, and was also called *proconnessium*.

D.

DADO (an Italian word, signifying a *die*), a term for the die or plain face of a pedestal; that part of a room comprehended between the base and surbase. The dado employed in the interiors of buildings, is a continuous pedestal, with a plinth and base moulding, and a cornice or dado moulding surmounting the die. This continuous pedestal with its moulding is sometimes only made of stucco or plaster; but in well-finished rooms is constructed of wood, and is usually about the height of the back of a chair. Its present purpose, when employed, is to protect the stucco-work or paper of the walls, but originally it was used as an architectural decoration to a room.

The dado is made of deal boards, glued edge to edge, the heading joints ploughed and tongued together, and the back keyed; the stuff generally employed for this purpose is whole deal; the keys are always made to taper in their breadth, and may be about three inches broad in the middle; they are let into the back of the dado by a transverse groove, which is either wider at the bottom than at the surface, or it is first made of a square section, which is again grooved on each side next to the bottom. Though the keys should shrink, those of this last form will always keep their inner surface close to the bottom of the grooves.

Some workmen prefer the broad end of the key to be placed downwards; the lower end should rest firmly, either upon the ground or floor, and the dado should be left at liberty to slide downwards upon the keys. Others, again, prefer the wide end of the key to be placed upwards, and the dado to be fixed by this; the key, as it shrinks, will fall down from its own weight.

The dado should be grooved and tongued at the internal angles, and mitred, or made with a lap and mitre, at the external ones.

The dado is also framed with panels, but this mode is seldom seen in London; it is, however, very frequently so prepared in the country.

DAGOUNG, or SHŒDAGON, *temple of* (signifying temple of Golden Dagon) an edifice situated about two miles and a half north of Rangoon, the chief port of the Birman empire. It is a very elegant building, and though not so high by 25 or 30 feet, is much more ornamental than that of Shœmadoe, at Pegue.

It is surrounded by a terrace, which stands upon a rocky eminence, considerably higher than the circumjacent country. The building is ascended by 100 steps, which are now very much in decay; its elevated situation makes it a conspicuous object for many miles. The top and the whole spire are richly gilt, so that when the sun shines, they exhibit a most splendid appearance.

DAIRY, the name usually given to the place where the milk of cows is kept, and converted into butter or cheese. The occupation is sometimes called *dairying;* and the land which is chiefly appropriated to feed cows for this purpose, is called a *dairy-farm.*

"A dairy-house," observes a writer in the Penny Cyclopædia, "should be situated on a dry spot somewhat elevated, on the side of a gentle declivity, and on a porous soil. It should be on the west or north-west side of a hill, if possible, or at least sheltered from the north, east, and south, by high trees. In some countries, where there are natural caverns with an opening to the west, and springs of water at hand, the best and coolest dairies are thus prepared by nature. Artificial excavations in the sides of freestone rocks are sometimes formed for the purpose of keeping milk, and more frequently wine. Where no such natural advantages exist, the requisite coolness in summer, and equal temperature in winter, which are essential in a good dairy, may be obtained by sinking the floor of the dairy some feet under ground, and forming an arched roof of stone or brick. In cold climates flues around the dairy are a great advantage in winter; and an ice-house in warm summers is equally useful. But these are only adapted to those dairies which are kept more as a luxury than as an object of profit. In mountainous countries, such as Switzerland, where the summers are hot in the valleys, and the tops of the mountains or high valleys between them are covered with fine pastures, the whole establishment of the dairy is removed to a higher and cooler atmosphere, where the best butter and cheese are made. Coolness is also produced by the evaporation of water, an abundant supply of which is essential to every dairy. It is also a great advantage, if a pure stream can be made to pass through the dairy, with a current of air to carry off the effluvia, and keep the air continually renewed."

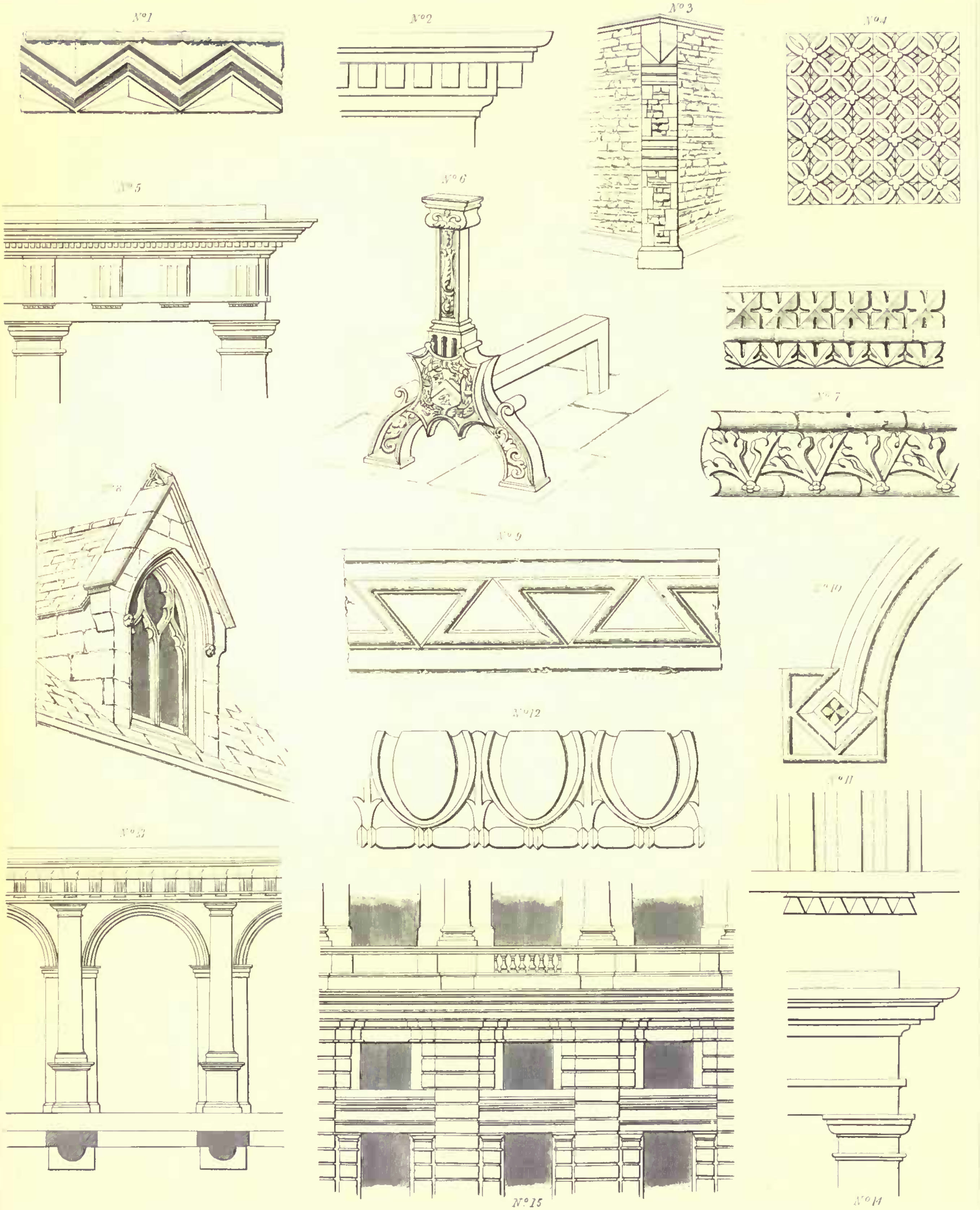
The dairy, in farm building, should be so situated, with respect to other offices, as to be convenient, and to prevent unnecessary labour.

A milk dairy requires at least two good rooms, one for the reception of the milk, and another for the purpose of serving it out, and for scalding, cleaning, and airing the different utensils.

The entrance to the dairy should communicate with the scalding-room, which should have a copper, for heating water and other purposes, placed in a shed adjoining, in order that the heat may be kept at as great a distance as possible from the milk. In the bottom of the copper is fixed a cock, for conveying the hot water through a trough or pipe, across the scalding-room, in which another cock should be fixed, for the convenience of washing smaller utensils; the heated water passes through the wall into the milk-leads for the purpose of scalding the whole range of pans, trays, or coolers, and may be retained at pleasure. The trough for the passage of the water through the walls of the dairy, should be of sufficient dimensions to admit the discharging a pailful of milk into it with safety, having a hair-sieve so placed in it, that the whole of the milk of the cows may be made to pass through it into the necessary trays or coolers, in which it is to stand in order to keep it clean. A trough, pipe, or some other contrivance, should be introduced, for the purpose of conveying the waste milk, whey, &c., from the dairy-house to the cisterns containing the wash for the pigs.

The temperature may be regulated either by double walls and roofs, or by means of hollow walls; and for common purposes, by having 8 or 10 inches in width from the wall to the lath and plaster, as is suggested by Mr. Loudon, in his *Treatise on Country Residences.*

The size of milk-houses should be regulated by the number of cows. The usual dimensions in the Gloucester dairy-houses, for 40 cows, are 20 feet by 16, and for 100 cows, 30 feet by 40. To accomplish the objects of convenience, the situation of the dairy should be near the cow-standings, so that the milk may be readily conveyed to them. See



Gilbert Arch^t del

Nº 1 Dancette Moulding	Nº 5. Ditriglyph	Nº 9. Dovetail Moulding	Nº 13. Engaged Column
Nº 2 Dentil	Nº 6. Dogs	Nº 10. Dripstone	Nº 14. Entablature
Nº 3 Diagonal Buttress	Nº 7. Dogtooth Moulding	Nº 11. Drops	Nº 15. Entresole
Nº 4 Diaper	Nº 8. Dormer	Nº 12 Eggs	

Dr. Young's *Calendar of Husbandry*, and Mr. Loudon's *Treatise on Country Residences*.

Gentlemen's dairies are often built expensively, and highly ornamented; but they seldom unite all the conveniences essential to a good dairy, generally from a want of practical knowledge of the subject in those by whom they are designed. In Switzerland and Holland, the cow-house and dairy often have a very neat appearance within a short distance from the principal residence. In the common dairy-farms in Holland, the farmer and his family frequently live under the same roof with the cows; in north Holland and Friesland, a cow-house is as clean as any dwelling-house, and the family often assemble and take their meals in it.

The following description of a cow-house and dairy under one roof, combines all that is useful, with considerable neatness internally and externally. "It is a building about sixty feet long, by thirty wide, with a veranda running round three sides of it. The dwelling is not here attached, as it usually is in common dairies, and the building is not surrounded by a farm-yard; these are the only circumstances in which it differs from that of a common peasant. The dairy-room is sunk below the level of the soil, and is paved with brick. The sides are covered with Dutch tiles, and the arched roof with hard cement. The cow-house, like all in Holland, has a broad passage in the middle, and the cows stand with their heads towards this passage, which is paved with clinkers or bricks set on edge. Their tails are towards the wall, along which runs a broad gutter sunk six or eight inches below the level of the place on which the cows stand. This gutter slopes towards a sink covered with an iron grate, which communicates by a broad arched drain with a vaulted tank into which all the liquid flows. The gutter is washed clean twice a day before the cows are milked. The cows stand or lie on a sloping brick-floor, and have but a small quantity of litter allowed them, which is removed every day, and carried to the dung-heap, or to the pig-sties, to be more fully converted into dung. Whenever the litter is removed, the bricks are swept clean, and in summer they are washed with water."

In Holland, the cows never leave the house from November till May. In summer they are driven home to be milked, if in pastures near to the cow-house, but if the pastures are far off, they are milked there, and the milk is brought home in boats. This is thought not so good for the butter, which is then churned from the whole quantity of the milk, without allowing the cream to rise. The finest butter is always made from the cream as fresh as possible, and the milk should, to make this cream rise, be set as soon as milked. The best quality of butter is churned from cream skimmed from the milk after six hours setting; an inferior kind, from a second skimming.

The utensils of the dairy, such as pails, churns, vats, &c. are usually made of white wood, and require to be kept, as does everything about a dairy, scrupulously clean and neat. Utensils of brass and tin are sometimes used; in Holland, the milk is invariably carried in brass vessels. There is some danger in the use of brass utensils, but a very little attention will obviate it. Cast-iron pans have been invented, tinned inside; but there is nothing so safe, or so neat, as well-glazed white crockery ware of the common oval from.

A dairy for cheese, well constructed, should consist of four rooms: one for the reception of the milk; another for the scalding and pressing of the cheese; a third for the purpose of salting; and the fourth for stowing the cheese, which last may be a loft made over the dairy, though it is sometimes placed at a distance, which makes it inconvenient.

The butter dairy should consist of three apartments, namely, a milk-room, a churning-room, and a room for the different utensils, and for cleaning and airing them in. The churning-room should be fitted up with the necessary apparatus.

DAIS, or Deis, the raised platform or wooden flooring which was laid at the upper end of a large hall or banqueting room, such as is still seen in college-halls, and in most of the halls belonging to the city-companies in London, and those of the inns of court.

In royal halls, there were more than one *deis*. At a dinner which Charles V. of France gave to the emperor Charles IV. in 1377, there were *five deis*. The principal table in entertainments of state is always placed on the dais.

Also a seat with a high back, and sometimes with a canopy, for those who sat at the upper table. Sometimes the canopy itself.

DAM, a boundary or confinement; as, to dam up, or, to dam out.

Dam, a bank, or mole, constructed of stone, timber, or any other materials, for penning up water, in order to divert its course into another direction, for turning a mill, or other purpose. *See* Embankment.

DAMPER, a valve inserted in a flue to regulate the draught.

DANCETTE, a name applied to a moulding very frequently employed in Norman architecture, and otherwise termed the *chevron* or *zigzag moulding*.

DARK TENT, a portable camera obscura, formed like a desk, and fitted up with optic glasses, to take prospects of buildings and fortifications.

DATUM-LINE, the base line of a section from which all the heights and depths are calculated.

DAY, or Bay, one of the lights or compartments in great windows of the pointed style of architecture, from mullion to mullion, clear of any intermediate one.

In the Saxon and early Norman styles, windows of moderate dimensions were without mullions; but upon the introduction of the pointed arch, windows becoming long and narrow, two of these lancets placed together, in order to transmit a sufficient quantity of light, suggested the idea of a single mullioned window, which therefore contained two days or bays. From this junction, windows with two or more mullions, and three or more days or bays, succeeded, until the number of days or bays were multiplied to seven, or even nine. The windows thus comparted, were decorated with an endless variety of tracery, consisting principally of trefoils, quatrefoils, Catharine-wheels, &c.

From the time of king Henry VIII., mullioned windows were superseded again by plain windows. And thus the rise and fall of the great eastern and western windows in our cathedrals.

DEAD SHOAR. *See* Shoaring.

DEAFENING, a term used in Scotland for sound boarding; sometimes also used in wooden partitions for the same purpose, viz. for preventing the communication of sound.

Deafening, in plastering, a term used in Scotland, for Pugging, which see.

DEAL (from the Dutch, *deel*) the wood of the fir-tree, as cut up for the use of building, which is of two kinds, yellow and white.

Deals are chiefly imported from Christiana, and other parts of Norway; from Dantzig, and several parts of Prussia; from Petersburg, Archangel, and various parts of Russia. They are sold by the piece or standard.

In London, stuff that is kept on hand, consists generally of deals of various lengths, most commonly three inches thick, and seldom exceeding nine inches wide. They are broken or cut down into various thicknesses, called *boards* or *leaves*, so that a deal will always have one cut less than there are leaves.

When the leaves are thinner than half an inch, the deal will divide into five or more parts, and is therefore termed *five-cut stuff*, and thus the qualifying word is applied according to the number of pieces. Whole deal is one inch and a quarter thick, and slit deal the half of that.

Deals are formed by sawing the trunk of a tree into longitudinal pieces, of more or less thickness, according to the purpose they are intended to serve. They are rendered much harder by throwing them into salt-water as soon as they are sawn, keeping them in three or four days, and afterwards drying them by exposing them to the air: but neither this nor any other method will preserve them from shrinking.

The quality and well-seasoning of deals are very essential to the construction of buildings. They are employed in naked flooring, partitions, the boarding of floors, doors, windows, architraves, cornices, mouldings, dados, plinths, bases, surbases, wainscoting, linings, columns, pilasters, chimney-pieces, &c.

White deal should only be used for inside work, as in bedchambers; it is less liable to shrink than yellow, and being a cheaper article, is to be preferred in panelling. Yellow deal, on account of its hardness, from being saturated with turpentine, is more fit to endure violence and exposure to the weather.

DEBASED, a term applied to that style of English architecture, so to speak, which succeeded the Late or Perpendicular Gothic, and in which some peculiarities of the Italian style began to be introduced. For more detailed information, *See* Gothic Architecture.

DECAGON (from δεκα, *ten*, and γωνία, an *elbow* or *corner*) a plane figure, with ten sides and angles. If all the sides and angles be equal, it is called *a regular decagon*, and may be inscribed in a circle: the method is thus: first describe a pentagon, as is shown under that article; bisect each of the arcs, of which the sides of the pentagon are chords; join every point of bisection to the extremity of each adjacent chord, and the decagon will be completed.

If the side of a regular decagon be 1, its area will be $\frac{5}{2}\left(5+2(5)\right)^{\frac{1}{2}}=7.6942088.$

To find the area of a regular decagon: multiply the square of the side by 7.6942088, and the product will give the area: or, for practical use, multiply the square of the side by 7.6942.

Example. What is the area of a decagon, the side of which is 25 feet?

```
      25
      25
     ----
     125
     50
     ----
     625
  7.6942
  -------
    1250
   2500
  5625
 3750
4375
---------
4808.8750 equal the area required.
```

This figure may also be measured by the general rule of finding the superficial content of any polygon whatever. *See* Polygon.

DECAHEDRON (Greek, δεκα, *ten*, and εδρα, *a base.*) A solid figure contained by ten sides.

DECAMETRE (Greek, δεκα, *ten*, and μετρον, *measure*,) a French linear measure containing ten metres, and equal to 393.71 English inches.

DECANICUM, a prison in which ecclesiastical offenders were confined.

DECASTYLE, or Decastylos (from the Greek, δεκα, *ten*, and ςυλος, *a column*) a colonnade, or front of a portico, consisting of ten columns.

DECEMPEDA (from the Greek, δεκαπους; or from the Latin, *decem*, ten, and *pes*, *pedis*, foot) a ten-foot rod, used by the ancients: the foot was subdivided into twelve inches, and each inch into ten digits. This rod was used by architects to give the proper dimensions and proportions to their buildings.

Horace (lib. ii. od. 15) blaming the magnificence and delicacy of the buildings of his time, observes, that it was otherwise in the times of Romulus and Cato; that in the houses of private persons, there were not then known any porticos measured out with the decempeda, nor turned to the north to take the cool air.

The decempeda was also used in land-measuring, in the same manner as our chain.

DECIMAL (from the Latin, *decimus*) any number increasing by the order of tens.

Decimal Arithmetic, the art of computing by fractions whose denominator is 10, 100, &c. Decimal fractions differ from vulgar fractions in this; that the denominator is not written; instead of writing $\frac{4}{10}$, or $\frac{15}{100}$, the fraction would be written decimally, .4 or .15. The decimal point before it is used to distinguish it from whole numbers.

To reduce any vulgar fraction to a decimal, say,

As the denominator of the vulgar fraction
is to the denominator of the decimal,
so is the numerator of the vulgar fraction
to the numerator of the decimal.

Example. To reduce $\frac{2}{3}$ to a decimal fraction, whose denominator is 10.

It will then be as 3 : 10 : : 2

```
   10
  ----
 3) 20
  ----
    6
```

so that 6 is the numerator required: but then there is a remainder of 2, consequently the numerator is more than 6, but less than 7; therefore $\frac{6}{10}$ is the nearest decimal fraction, whose numerator consists of a single unit. In order to come nearer to the truth, we must then suppose the denominator of the decimal to be divided into more parts, say 100.

Then again 3 : 100 : : 2

```
    2
  -----
 3) 200
  -----
    66
```

but here is still a remainder of 2, that is, 66 is too small and 67 too great, therefore the decimal fraction $\frac{66}{100}$, is still too small; 66 is, however, a greater portion of 100, than 6 is of 10: we have therefore come nearer to the truth in the latter operation than in the first. We shall thus find, that if the number arising by multiplying the denominator of the decimal fraction by the numerator of the vulgar fraction, be not divisible by the denominator of the vulgar fraction, an increase of the denominator of the decimal will give a more exact portion of the unit, than when fewer figures are used; and thus, if worth the trouble, the numerator of a decimal fraction may be found to any degree of exactness at pleasure, by augmenting the number of figures in the denominator, either till the division terminate, or till as many figures be found as will render the operation sufficiently exact for the intended purpose.

A decimal fraction may be sufficiently denoted, by throwing away the denominator, and using any character or mark instead of it, since the denominator is always 1, followed by one, two, three, or a series of ciphers, which is the only thing that is variable; to ascertain this point, the number expressed by the numerator, is always less than the denominator, and always consists of as many figures as there are ciphers; therefore, if a point be placed before the numerator of a decimal fraction, it will show that the number following it is a decimal fraction, and by reckoning a cipher for every figure, and supposing unity placed before them, the number thus expressed will show how many decimal parts the unit is divided into, and the figures themselves that portion of these parts taken.

Thus $\frac{6}{10}$ is represented by .6
$\frac{66}{100}$ " " .66
$\frac{785}{1000}$ " " .785
$\frac{85}{1000}$ " " .085

But instead of saying 66 hundredths, 785 thousandths, &c., say, as in the second, 6 tenths and 6 hundredths; as in the third, 7 tenths, 8 hundredths and 5 thousandths; and as in the fourth, 8 hundredths and 5 thousandths, as the cipher, 0, occupies the place of tenths;

for $\frac{6}{10}+\frac{6}{100}=\frac{66}{100}$

and $\frac{7}{10}+\frac{8}{100}+\frac{5}{1000}=\frac{785}{1000}$

also $\frac{8}{100}+\frac{5}{1000}=\frac{085}{1000}$

The point is not only useful in marking the following number to be a decimal fraction, but is likewise necessary in separating the decimal parts from integers, when both are concerned.

From what has been said, it is observable that decimal fractions decrease in the same order from unity towards the right hand, that integers increase towards the right.

Thus, in 348.5683, unity is the place where the numbering commences both for integers and for decimals; going over the places of the integers, we have units, tens, hundreds, 348; then, numbering the decimals, we have units, tenths, hundredths, thousandths, ten thousandths, which is 5 tenths, 6 hundredths, 8 thousandths, and 3 ten thousandths; in this notation of the fractions, the unit's place was not reckoned, as being already counted into the whole numbers.

Supposing now, that the notation is completely understood, we will proceed to the reduction of decimal fractions.

To reduce a vulgar fraction to a decimal: set down the numerator of the fraction, with a point upon the right side of it, add as many ciphers in succession, towards the right-hand, as may be thought necessary; then, if the denominator consist of one single figure, or of two, not exceeding 12, draw a horizontal line below the row of figures so set down, and a vertical line upon the left side of the left-hand figure: set down the denominator upon the left of this line, proceed as in short division, placing a point under the other, then if the succeeding figures towards the right begin under the first figure after the point, these figures will be the decimal, but if not, the number corresponding to the upper row must be made out, by adding a cipher to the left hand.

Example I. Required the decimal of $\frac{1}{4}$.

4) 1.00
.25 the decimal required.

Example II. Required the decimal of $\frac{1}{2}$.

2) 1.0
.5 the decimal required.

Example III. Required the decimal of $\frac{3}{4}$.

4) 3.00
.75 the decimal required.

The reader who wishes to employ decimals in his calculations, should have the decimals .25, .5, .75, of $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, fixed on his memory.

Example IV. Required the decimal of 1 inch in terms of a foot. Here 1 inch is the twelfth part of a foot, therefore the vulgar fraction is $\frac{1}{12}$.

12) 1.00000
.08333

Example V. Required the decimal of 2 inches. Now 2 inches is $\frac{2}{12}$ or $\frac{1}{6}$; therefore

12) 2.00000 or 6) 1.00000
.16666 .16666

Example VI. What is the decimal of 3 inches? 3 inches is equal to $\frac{3}{12}$ or $\frac{1}{4}$, therefore the decimal will be .25, as above.

Example VII. Required the decimal of 4 inches. 4 inches is equal to $\frac{4}{12}=\frac{1}{3}$, therefore,

12) 4.00000 or 3) 1.00000
.33333 .33333

In this manner, the decimals for every number of inches under twelve are to be found, as the following table shows:

The decimal of 1 inch	=	.08333
2	=	.16666
3	=	.25
4	=	.33333
5	=	.41666
6	=	.5
7	=	.58333
8	=	.66666
9	=	.75
10	=	.83333
11	=	.91666

In most practical cases, three figures of decimals will be found sufficient.

When inches, seconds, thirds, &c. are to be reduced to a decimal, the best method is to reduce the feet, inches, &c. to the last denomination, then divide as often by 12 in succession as there are denominations, and the last quotient will be the decimal required.

Example I. Required the decimal of 9 firsts, or inches, and 6 seconds.

Now here are two denominations, therefore

9 6
12

12) 114 seconds in the whole.

12) 9.5

.79166 the decimal required.

Example II. To find the decimal of 5 seconds and 4 thirds.

Now in this example, there are three places of duodecimals, therefore

```
   0  5  4
     12
   ----
12) 64 number of thirds in the whole.
   ---------
12) 5.33333
   ---------
12)  .44444
   ---------
     .03703
```

And thus for any other number of denominations whatever.

If each foot of our measuring-rules for taking the lineal dimensions were divided into ten parts, instead of twelve, and each of these ten parts again into ten others, we should have no occasion for reduction of decimals, as the rule itself would give the decimal. In most cases we should not then have occasion to work with more than two places of decimals; the tenth part of the tenth part, that is, the hundredth part of a foot, is very nearly equal to the eighth part of an inch, or the ninety-sixth part of a foot, being only a small matter less than the eighth of an inch. Were measuring-rules thus divided, the work by decimals would be much shorter than any other denomination whatever. The principal reason of operations in measuring by decimals being longer than duodecimals, arises from the necessity of reducing the duodecimals to decimals, and this in many cases cannot be done with the same accuracy, without having four or five denominations. In practical cases there are never more than three places of duodecimals, and if rules were divided decimally, there would not be more than three places.

A decimal part of a foot being given, to find its equivalent in duodecimals.

Multiply the decimal by 12, cut off as many decimals from the product as there are places of figures in the multiplicand, from the right-hand to the left, and the figure or figures remaining on the left, if any, will show the number of inches: multiply the number of decimals so cut off, if any, again by 12, and cut off as many figures from the left-hand of the new product as there are decimal places in the multiplicand, and the remaining figures on the left will show the seconds, if any. Proceed in this manner as often as there is a remainder, or as often as may be thought necessary to obtain a sufficient degree of accuracy, and the places cut off will be equivalent to the given decimal, if no remainder, and very nearly so if there is, but in this case something less.

Example. Reduce .44005 of a foot to a decimal.

```
 .44005
     12
-------
5.28060
     12
-------
 3.3672
     12
-------
 4.4064
     12
-------
 4.8768
```

To add decimals; write down the several parts under their respective denominators, viz., all the points in a vertical line, the tenths in a succeeding vertical line, and so on; add the several columns, as in common addition, from right to left; place a point under the column of points, or cut off as many decimal parts from the right-hand figure towards the left, as there are columns, and the figure or figures upon the left-hand side of the point, if any, will be integers, and those upon the right-hand side of the point will be decimals.

Example I. Add the following decimals together, viz., .7854, .07958, .5236.

```
 .7854
 .07958
 .5236
--------
1.38858 the sum required.
```

To subtract decimals; place the numbers as in addition, the less under the greater, and perform the operation as in subtraction of integers.

Example I. Subtract .25 from .75.

```
.75
.25
---
.50 the number required.
```

If the parts of a foot are given in feet, inches, &c., they must be reduced to the farthest denomination from the place of feet.

To multiply in decimals, proceed as in multiplication of integers, and point as many figures, beginning with the first figure from the right in the product, as the number of decimals in both factors; and the remaining figures, if any, upon the left-hand, will be integers; but if there are not as many figures in the product as in both, the deficiency must be made up by the addition of one or more ciphers.

Example I.

```
Multiply .9087
by        .852
        ------
         18174
        45435
       72696
      --------
Product .7742124
```

In large decimals, the work may be contracted thus: Write the units' place of the multiplier under that place of the decimals in the multiplicand, whose place you would reserve in the product; write the other figures in the multiplier in a contrary order.

Begin with the figure of the multiplier nearest the right hand, and multiply by the next figure towards the right of it, in the multiplicand, if any; and if this product be five, or above five, in the number of tens in the product, carry one more than there are tens in the last product to the next product; then set down the overplus above the tens for the first figure, and carry the tens to the next place, and proceed through the line as in common multiplication. Proceed with every other line in the same manner, observing, however, to place the first figure of every line directly under the first figure of the last line, and the product so found will be the answer.

Example I.—What is the product of .9087 multiplied by .852, in order to retain four places of decimals?

```
By contraction.                    By the common method.
 .9087                                   .9087
 258.0                                    .852
 -----                                  ------
  7270 = 908 × 8 + 6                     18172
   454 =  90 × 5 + 4                    45435
    18 =   9 × 2 + 0                   72696
 -----                                --------
 .7742                                .7742122
```

In this example, the multiplier being placed as directed, begin with 8, the first figure of the multiplier, and multiply it by 7, the next figure to the right of it in the multiplicand, and the product is 56, which is more than 5 above 5 tens, therefore carry 6: multiply 8 by the next figure, 8 towards the left, the product is 64, and 6 carried, makes 70, set down a cipher for the first figure, and carry 7 to the next; proceed thus for the whole line, and 7270 will be the product. Proceed with the remaining figures of the multiplier, in the same manner, writing down the left-hand figures of every row under each other.

To divide a decimal or mixed number by a decimal or mixed number: divide as in whole numbers, and cut off as many figures from the right-hand of the quotient as the decimal places of the dividend exceed those of the divisor.

If the number of figures in the quotient be less than the excess of the decimal figures in the dividend above those of the divisor, the defect must be supplied by prefixing ciphers on the left hand. Should there be a remainder, annex ciphers to it, and thus the quotient may be carried to any degree of exactness, observing, however, that every cipher annexed in carrying out the work, must be accounted a decimal place in the dividend.

Example I.—Divide 43.95 by 5.

```
.5)43.95
   ------
     8.79 the quotient required.
```

Example II.—Divide 4.368 by .0078.

```
.0078)4.3680 (560
       390
       ---
        468
        468
        ---
        ...0
```

Decimal Scale, a scale divided into tenths. Scales thus divided are much used in designs. A $\frac{1}{4}$ inch scale is that wherein the $\frac{1}{4}$ inch is divided into ten parts: a $\frac{1}{2}$ inch scale is when the $\frac{1}{2}$ inch is divided into ten equal parts. One drawing may be made greater or less than another, by using two different scales made to the proportion of each drawing; but the best method of reducing or enlarging drawings, is by means of a pair of proportional compasses, which give both greater accuracy and expedition, with much less trouble, than working by scales.

DECIMETRE, a French linear measure equal to the tenth part of a metre. or 3.9371 English inches.

DECLINATION, of the Doric mutules, is the acute angle which the planes of the wall and soffit make with each other, by which the soffit is lower at its projecting extremity, than in the receding extremity, whence it commences. All the ancient examples of the Doric order have declining mutules.

DECLINATOR, an instrument used in dialing, whereby the declination, inclination, and reclination of planes are determined.

DECLINING DIALS, are those which either cut the plane of the prime vertical circle, or the plane of the horizon, obliquely.

The use of declining vertical dials is very frequent, because the walls of houses whereon dials are commonly drawn, generally decline from the cardinal points. Incliners and recliners are very rare, and more particularly decliners.

DECOR, a term used by Vitruvius, signifying *propriety*, arising either from disposition of the parts of an edifice, or from due observance of custom. *See* Decorum.

DECORATED, the title given to the most perfect style of Gothic architecture, which prevailed during the reigns of the first three Edwards, from the close of the thirteenth century. It is otherwise named the *middle-pointed*, or *pure Gothic*.

The various styles of Gothic architecture are so implicitly connected the one with the other, that it has been deemed advisable, at the risk of extending the article to a greater length than is customary in works of this nature, to consider them all under one head. *See* Gothic Architecture.

DECORATION, anything that adorns or enriches any part of an edifice. A tasteful combination of ornamental details employed in the enrichment of a building.

True decoration consists not in the mere addition of ornament, but rather in its appropriate and judicious application. Decoration, when artistically applied, possesses not only richness, but also meaning, not only a body, but a soul; it delights the eye, and at the same time, engages and instructs the mind. No artists, perhaps, so highly excelled in the just and tasteful employment of decorative detail, as did those of what are vulgarly termed the dark ages; in the glorious monuments of their skill, which have been preserved to us, we find specimens of the most delicate enrichment, all of which exhibit the reasonableness of its introduction; and the majority, a depth and tone of feeling rarely to be met with in other works.

The application of the Classic orders, however, as a means of decoration, is frequently resorted to, and not without success; they may be applied both internally and externally, and are themselves likewise frequently charged with further decorations.

Plain surfaces, when very extensive, are often decorated with paintings.

DECORATION EXTERNAL, the Building act, (7 and 8 Victoria, cap. 84), requires, that in external decorations, every coping, cornice, facia, window-dressing, portico, balcony, balustrade, or other external decoration or projection whatsoever, to any building now or hereafter to be built, or to any addition or enlargement of any such building, shall externally be of brick, stone, burnt-clay, or artificial stone, stucco, lead, or iron; except the cornice and dressings to shop-windows: and it is further provided with regard to buildings hereafter to be built or rebuilt, in reference to projections therefrom:—

As to copings, parapets, cornices to overhanging roofs, blocking-courses, cornices, piers, columns, pilasters, entablatures, facias, door and window-dressings, or other architectural decorations, forming part of an external wall, all such may project beyond the general line of fronts in any street or alley, but they must be built of the same materials as are by this act directed to be used for building the external walls to which such projections belong, or of such other proper and sufficient materials, as the official referees may approve and permit.

And as to all balconies, verandas, porches, porticos, shop-fronts, open inclosures of open areas, and steps and water-pipes, and to all other projections from external walls not forming part thereof, every such projection (except part of shop-fronts, and the frames and sashes of the windows and doors, in reference to the necessary wood-work thereof) may stand beyond the general line of fronts in any street or alley, but they must be built of brick, stone, tile, artificial stone, slate, cement, or metal, or other proper and sufficient fire-proof materials; and they must be so built as not to overhang the ground belonging to any other owner, nor so as to obstruct the light and air, or be otherwise injurious to the owners or occupiers of the buildings adjoining thereto on any side thereof.

Projections from walls of buildings over public ways.

And with regard to all buildings hereafter to be built or rebuilt, in reference to projections from the walls of such buildings, including-steps, cellar-doors, and area inclosures, the walls of all such buildings must be set back, so that all projections therefrom, and also all steps, cellar-doors, and area inclosures, shall only overhang or occupy the ground of the owner of such building, without overhanging or encroaching upon any public way.

Projected buildings beyond the general line of buildings, and from other external walls.

And with regard to buildings already built, or hereafter to be rebuilt, as to bow windows or other projections of any kind.

Such projections must neither be built with nor be added to any building on any face of an external wall thereof, so as to extend beyond the general line of the fronts of the houses (which general line may be determined by the surveyor, except so far as is herein before provided with regard to porticos projected over public ways; and with regard to projections from face-walls and shop-fronts, not so as to overhang the ground belonging to any other owner, nor so as to obstruct the light and air, or be otherwise injurious to the owner or occupiers of the buildings adjoining thereto on any side thereof.

Projections from insulated buildings.

Provided always, with regard to any insulated buildings, that if the projection be at the least 8 feet from any public way, and if they be at least 20 feet from any other building not in the same occupation, then such projections are excepted from the rules and directions of this act.

Wooden shop-fronts and shutters.

And with regard to shop-fronts and their entablatures, their shutters, and pilasters and stall-boards made of wood.

If the street or alley in which such front is situate, be of less width than 30 feet, then no part of such shop-front must be higher in any part thereof than 15 feet; nor must any part, except the cornice, project from the face of a wall, whether there be an area or not, more than 5 inches; nor must the cornice project therefrom more than 13 inches.

If the street or alley be of a greater width than 30 feet, then no part of such shop-front, except the cornice, must project from the face of a wall, whether there be an area or not, more than 10 inches; nor must the cornice project therefrom more than 18 inches.

And the width of such street or alley must be ascertained by measuring the same, as directed by the act.

And the wood-work of any shop-front must not be fixed nearer than four and a half inches to the centre line of a party wall.

And with regard to such wood-work, if it be put up at such distance of four and a half inches, then a pier or corbel built of stone or of brick, or other incombustible material, and of the width of four and a half inches at the least, must be fixed in the line of the party wall, so as to be as high as such wood-work, and so as to project one inch at the least in front of the face thereof.

And the height of every shop-front must be ascertained by measuring from the level of the public foot pavement in front of the building.

And every sign or notice-board fixed against or upon any part of any house or other building standing close to any public way, must be so fixed that the top shall be within 18 feet at the most above the level of such public way.

Decoration of the Scenery of a Theatre, is the representation of the subject by which the scenes are charged.

The ancients used two kinds of decoration in their theatres, the one called *versatiles*, with three sides of faces, which were turned successively to the spectators; the other, called *ductiles*, showing a new decoration, by drawing or sliding another before it.

The latter kind is still in use, and the change is almost made in an instant; whereas the ancients were obliged to draw a curtain whenever a change of decoration was required.

DECORUM, or Decor, in architecture, is the suitableness of a building, and the several parts and ornaments thereof, to the station and occasion. "It consists," says Vitruvius, (book i. chap 2.), "in the proper appearance of a work, and its being compounded of approved and authorized parts. This has regard, either to station, which the Greeks call *thematismos*, custom, or nature. To station, when temples which are erected to Jove the Thunderer, the heavens, the sun, or the moon, are built uncovered and exposed to the air, because the influences and effects of those deities are perceived in the open air; when to Minerva, Mars, Hercules, Doric temples are built; for, on account of the attributes of these deities, edifices constructed without delicacy are most suitable. To Venus, Flora, Proserpine, and the nymphs of the fountains, the Corinthian kind are erected with propriety; for by reason of the delicacy of those goddesses, the graceful, gay manner, with foliage and ornamented volutes, give a due decorum to the work. To Juno, Diana, Bacchus, and such other deities, Ionic temples are constructed, as holding a position between the two; for being tempered of the severity of the Doric, and the tenderness of the Corinthian, they become most suitable. Decor, with regard to custom, is observed when the internal parts of edifices being magnificent, the accesses are also made suitable and elegant: for, if the interior parts be elegant, and the approaches mean and ignoble, it will not have decor. So, likewise, if dentils be carved in the cornice of the Doric epistylium, or in the abacus of the capital, or if triglyphs be represented in the epistylium of Ionic columns, transferring the characteristics of one kind of work to another; it offends the eye, because custom has established a different order of things.

"Decor, with regard to nature, consists in all temples being placed in a salutary situation, with fountains of water in the places where the fane is built; but especially the temples of Æsculapius, of Health, and such deities, by whose healing influences numbers of sick appear to be recovered. For the diseased bodies being removed from an unhealthy to a healthy situation, and the salutiferous water of the fountains being administered, they are soon restored. By this means it will happen, that the natural effects of the place will increase the received opinion of the power of the divinity.

"Decor, with regard to nature, is also observed, when chambers and libraries receive their light from the east; baths, and winter apartments, from the west; picture-galleries, and such apartments as require as steady light, from the north; because that region of the heavens is rendered neither lighter nor darker by the course of the sun, but is equal and immutable the whole day."

DEDICATION, the act of consecrating a temple, altar, statue, palace, &c., to the honour of some deity.

DEFINITION, (*definire*, to mark out a boundary), is the process of stating the exact meaning of a word, by means of other words, or an enumeration of the principal attributes of a thing, in order to convey or explain its nature; thus, a circle is defined to be a figure whose circumference is every where equidistant from its centre. Wolfius defines a real definition to be a distinct notion, explaining the *genesis* of a thing; that is, the manner wherein the thing is made, or done; such is that of a circle, whereby it is said to be formed by the motion of a right line round a fixed point; on which footing, what was before instanced as a real definition of a circle, amounts to no more than a nominal one.

This notion of a real definition is very strict and just; and affords a sufficient distinction between a real and a nominal one. But though it has the advantages of analogy, distinctness, and convenience, on its side; yet being only itself a nominal definition, *i. e.*, a definition of the term *real definition*, we must consider it in the light of an idea fixed arbitrarily to that word, and which Wolfius always denotes by that word in the course of his book.

Of the parts enumerated in a definition, some are common to other things beside the thing defined; others are peculiar thereto: the first are called *the genus*, or *kind;* and the second, *the difference.* Thus, in the former definition of a circle, by a figure whose circumference is everywhere equidistant from its centre; the word *figure* is the kind, as being a name common to all other figures as well as to the circle; the rest the difference, which specifies or distinguishes this figure from every other. And hence arises that rule of F. de Colonia, for the making of a definition. "Take," says he, "something that is common to the thing defined with other things, and add to it something that is proper, or peculiar to it; *i. e.*, join the genus and specific difference, and you will have a definition." The special rules for a good definition are these:— 1. A definition must be universal or adequate, that is, it must agree to all the particular species, or individuals, that are included under the same idea. 2. It must be proper, and peculiar to the thing defined, and agree to that alone. These two rules being observed, will always render a definition reciprocal with the thing defined, that is, the definition may be used in the place of the thing defined; or they may be mutually affirmed concerning each other. 3. A definition should be clear and plain; and, indeed, it is a general rule concerning the definition both of names and things, than no word should be used in either of them which has any difficulty in it, unless it has been before defined. 4. A definition should be short, so that it must have no tautology in it, nor any words superfluous. 5. Neither the thing defined, nor a mere synonymous name, should make any part of the definition.

DEFLECTION, a term applied to the distance by which a curve departs from a straight line, or from another curve. It is used where any "*bending off*" takes place; the word deflection, in fact, means "bending off."

DEINCLINING DIALS, such as both decline and incline, or recline.

DELUBRUM, in Roman antiquity, a temple with a large space of consecrated ground round it. Also that portion of a temple in which the altar or idol was placed. *See* TEMPLE.

DEMI-RELIEVO, a term applied to that class of sculpture in which the figures are raised only halfway above the surface.

DEMONSTRATION, (from the Latin) in mathematics, a method of reasoning, whereby the truth of an assertion is shown by two, or a series of propositions, whose truth is already established.

Thus the 47th proposition of the first book of Euclid demonstrates a certain property of a right-angled triangle, on the supposition:—1, that all the preceding propositions are true; 2, that the axioms used in geometry, whether expressed or implied, are true also. It makes the consequence as certain as the premises, by means of the indubitable character of the connecting process. This strict use of the term demonstration belongs to the science of logic, which is the art of demonstrating from premises, without reference to the truth or falsehood of the premises themselves. In effect, the demonstrations of mathematicians are no other than series of enthymemes; everything is concluded by force of syllogism, only omitting the premises, which either occur of their own accord, or are recollected by means of quotations. To have the demonstration perfect, the premises of the syllogisms should be proved by new syllogisms, till at length you arrive at a syllogism, wherein the premises are either definitions, or identical propositions.

Indeed, it might be demonstrated, that there cannot be a genuine demonstration, *i. e.*, such a one as shall give full conviction, unless the thoughts be directed therein according to the rules of syllogism. Clavius, it is well known, resolved the demonstration of the first proposition of Euclid into syllogism: Herlinus and Dasipodius demonstrated the whole first six books of Euclid, and Henischus, all arithmetic, in the syllogistic form.

Yet the generality of persons, and sometimes even mathematicians, imagine, that mathematical demonstrations are conducted in a manner far remote from the laws of syllogism; so far are they from allowing that those derive all their force and conviction from these. But men of the greatest ability have taken our view of the question. M. Leibnitz, for instance, declares that demonstration to be firm and valid, which is in the form prescribed by logic; and Dr. Wallis confesses, that what is proposed to be proved in mathematics is deduced by means of one or more syllogisms; the great Huygens, too, observes, that paralogisms frequently happen in mathematics, through want of observing the syllogistic form.

Problems consist of three parts: a proposition, resolution, and demonstration.

In the proposition is indicated the thing to be done.

In the resolution, the several steps are orderly rehearsed, whereby the thing proposed is performed.

Lastly, in the demonstration, it is shown, that the things enjoined by the resolution being done, that which was required in the proposition is effected. As often, therefore, as a problem is to be demonstrated, it is converted into a theorem; the resolution being the hypothesis, and the proposition the thesis; for the general tenor of all problems to be demonstrated is this: that the thing prescribed in the resolution being performed, the thing required is done.

The schoolmen make two kinds of demonstration: the one τȣ διοτι, or *propter quod;* wherein an effect is proved by the next cause; as when it is proved, that the moon is eclipsed because the earth is then between the sun and moon. The second, τȣ οτι, or *quia;* wherein the cause is proved from a remote effect; as when it is proved that fire is hot, because it burns; or that plants do not breathe, because they are not animals; or that there is a God, from the works of creation. The former is called *demonstration à priori*, and the latter *demonstration à posteriori.*

DEMONSTRATION, *Geometrical*, is that framed of reasonings drawn from the elements of geometry.

DEMONSTRATION, *Mechanical*, is that, the reasonings whereof are drawn from the rules of mechanics.

DENDERAH, the Tentyra of the ancients, a ruined town of Upper Egypt, celebrated for its temple, which is one of the most splendid remains of antiquity in all Egypt. Dr. Richardson, Belzoni, and others, have given descriptions of this temple, which the first-named traveller considers to have been erected in the period of the Ptolemies. Its remains occupy a vast extent of ground, and consist of various buildings, besides the temple itself. These are enclosed within a wall built of sun-dried bricks, in some places 35 feet high, and 15 feet thick. The portico in front of the temple is formed of 24 columns, ranged in four rows, having quadrangular capitals, on each side of which is a colossal head, surmounted by another quadrangular member, containing in each face a temple doorway with two winged globes above, and other decorations. The shafts of the columns are cylindrical, and of equal diameter throughout. The whole height, including capital, &c., being a little above 48 English feet.

The front is adorned with a beautiful frieze, covered with figures, over the centre of which the winged globe is predominant. The walls, columns, ceilings, and also the interior chambers, are in the same manner covered with hieroglyphics and sculptures, in which the figure of Isis is repeated in numberless instances. The light in the chambers comes in through small holes in the wall; the sanctuary itself is quite dark. The ceiling of the portico is occupied by a number of figures, by some travellers supposed to be the signs of the zodiac, but with greater accuracy shown by Dr. Richardson and recent travellers and archæologists, to be merely a collection of mythological emblems, without any reference to astronomy.

On the ceiling of one of the apartments in the upper story, under the roof of the temple, there was another assemblage of mythological emblems, similar to those already mentioned, but fewer in number, and differently arranged. This was called a planisphere or zodiac, because in the middle of it figures resembling those usually adopted to represent the signs of the zodiac were observed. The opinion of well-informed travellers, however, with respect to this collection of figures, as to the former, is that it is only a representation of gods and goddesses, and religious processions, and has no astronomical meaning whatever.

The so-called circular zodiac, which was sculptured on a kind of sandstone, was cut out of the ceiling by a Frenchman, with the permission of the pasha, and conveyed to France; when it was purchased by the French government, and deposited in the Museum, at Paris.

DENDROMETER, (from δένδρον, *a tree*, and μετρεω, *I measure*), an instrument for measuring trees.

The same name has also been applied, though improperly, to instruments contrived for measuring distances and magnitudes from a single station.

DENTICLES. *See* Dentils.

DENTILS, (from the Latin, *dens*, a tooth) a row of similar and equal solids in a cornice, disposed at equal intervals, each presenting four sides of a rectangular prism, the sides parallel to the vertical face, and the one parallel to the soffit, being attached to the vertical and horizontal planes of an internal right angle.

The surfaces of the vertical face are therefore all in the same plane: and those of the soffits are in the same horizontal plane.

The whole series of dentils in the same range, is called *the denticulated band.*

The proportions given by Vitruvius are, that "the denticulus is to be equal in height to the middle facia of the architrave, and its projection to be the same as its height; the width of the dentils is one-half of its height, and the interval between them two-thirds of this quantity."

The proportions of some of the best examples where dentils are to be found, are as follows:—

In the Ionic temple of Bacchus, at Teos, the dentils are in height about one-fourth of that of the cornice, exclusive of the inferior bead and fillet next to the architrave: the breadth of the dentils is about two-thirds of their height, and the breadth of the interval about two-thirds of that of the dentil: their projection is about one-fourth of the height of that part of the cornice between their soffits and the summit of the cornice: the angle is vacant.

The dentils in the Ionic order of the temple of Minerva Polias, at Priene, are something less than one-fourth of the height of the cornice, or nearly equal to two twenty-fifths of that of the entablature; their projection is three times the half of their height; their breadth, two-thirds of their height; the breadth of the interval, about four-fifths of that of the dentils: the corner is without a dentil, and the soffit over the vacant angle is enriched with a honeysuckle.

In the Corinthian order of the Choragic monument of Lyscirates, at Athens, the dentils of the cornice are in height nearly two-sevenths of that of the cornice, exclusive of the terminating ornament; their breadth is two-thirds of their height; and the interval between them, two-thirds of their breadth; the angle of the cornice at the dentil band is vacant.

In the temple of Jupiter Stator, at Rome, the height of the dentil is nearly one-fifth of the whole cornice; its breadth, two-thirds of its height; and the breadth of the interval, about one-half of that of the dentil; the angle of the dentil-band is filled with a dentil.

The reader who wishes to see the rules of Vitruvius, respecting the placing of dentils, may consult the article Cornice.

In the frontispiece of the door-way of the Tower of the Winds, at Athens, the inclined cornices, as well as the level one, have dentils, contrary to the doctrine of Vitruvius.

In the interior cornice of the same tower, both dentils and modillions are employed; the dentils occupying the superior part of the cornice, agreeably to the Vitruvian theory, but contrary to every other antique example.

The only ancient example of the Doric order, in which dentils are to be found, is in the theatre of Marcellus, at Rome.

The examples of the Ionic order which have denticulated cornices, are, the temples of Bacchus, at Teos; of Minerva Polias, at Priene; the aqueduct of Adrian, at Athens; the temple of Fortune, and the theatre of Marcellus, at Rome; and the arch of Constantine; the temple of Concord, at Rome, has both dentils and modillions in the cornice.

The following edifices of the Ionic order, are without dentils in the cornice, viz., the Ionic temple upon the Ilissus, the temple of Minerva Polias, and that of Erechtheus, at Athens; and in the Coliseum, at Rome, the dentil-band is uncut. Examples of the Corinthian order, which have denticulated cornices, are, the monument of Lysicrates, the arch of Adrian at Athens, and the ruins at Salonica. Both dentils and modillions are to be found in the following Corinthian edifices: the temples of Jupiter Stator, and of Peace, the piazza of Nerva, and the baths of Diocletian, at Rome; the lower range of the interior, and the porticos of the temple of Jupiter, and the vestibulum to the peristylium, at Spalatro; all the ruined edifices at Balbec, and at Palmyra, excepting the interior order of the temple of the Sun, among the latter.

The following edifices of the Corinthian order have the dentil-band uncut, viz., the Coliseum, the portico of the Pantheon, the temple of Antoninus and Faustina, and the portico of Septimius Severus, at Rome.

Examples of the Composite order, which have denticulated cornices, are, the arch of Septimius Severus, and that of the Goldsmiths, at Rome, and the upper range of the temple of Jupiter, at Spalatro; but in the arch of Titus, at Rome, both modillions and dentils are to be found.

The frontispiece to the door-way of the Tower of the

Winds, at Athens, though it cannot be classed as a regular order, has dentils in the cornice.

A denticulated cornice is employed in the Caryatic portico of the temple of Pandrosus, at Athens.

Thus it may be observed, that dentils and modillions are frequently employed in Corinthian and Composite cornices; and sometimes both are omitted, as in the temple of Vesta at Tivoli, and in the temple of Antoninus and Faustina, and the little altars within the Pantheon, at Rome.

In very small work, it would be better to omit modillions and dentils: and, indeed, it is the opinion of some, that though the work be ever so large, it would be better to employ one of them only; as, were all the members to be admitted in a Corinthian cornice, and if the individual parts of the cornice bear the same proportion to the whole height, as in the Doric or Ionic orders, the cornice would either be too high for the entablature, or the entablature too high for the column; consequently, the cornice must either be too great a load for the entablature, or the entablature too great a load for the column; which, in either case, is contrary to the laws of strength: for it would be giving the greater burden to the slender column, and the lighter burden to the more massive. *See* CORNICE.

DEPARTMENT, (from the French) that part of an edifice destined to some peculiar purpose, as, in a palace, the department of a kitchen, of the stables, &c.

DEPÔT, (French) in military architecture, an edifice for the preservation and reservation of stores, provisions, &c., also a station for the reception and training of recruits.

A depôt should contain a great number of bomb-proof buildings, the lower tier of which should be reserved as store-rooms for provisions requiring to be kept cool, and, if possible, be below the surface of the area; the ground-floor should be allotted for artillery and ordnance-stores; the walls and piers being furnished with strong wooden battens (projecting a little, to obviate the danger of damp) for the support of muskets, carbines, pistols, swords, halberts, bayonets, pikes, and other descriptions of small-arms. The second floor should be devoted to the reception of camp-equipage, and the upper to the lodgment of ready-filled cartridges. The great magazines for powder should be separate: the whole of the principal body should be casemated for the accommodation of troops, and pierced through, perhaps masked, for the reception of heavy cannon. The out-works should be of the best materials, and constructed on the most compact system of defence.

DESCRIBENT, (from the Latin, *describo*, to describe) in geometry, a line or surface which produces a plain figure by motion.

DESCRIPTION, of a building, an explanation of all the materials, specifying their qualities, proportions, how used, sizes of timbers, &c.

The following articles are most frequently employed in buildings, in the carpenter's department:—

Carpentry.

- Timber in foundations
  - Piling
  - Planking
    - Spikes
- Bonding
  - Sleepers
  - Bond-timbers in brick walls
  - Templets
  - Wall-plates
    - Under-sleepers
    - Under-joists
    - Under-roof
  - Lintels
- Common naked flooring
  - Sleepers
  - Joists
    - Trimmers
    - Trimming-joists
    - Strutting-pieces
- Framed naked flooring
  - Girders
  - Binding-joists
  - Bridging-joists
- Common roofing
  - Rafters
  - Ceiling-joists, ties, or tie-beams
  - Collar-beams
  - Puncheons
  - Hips
  - Valleys
  - Ridge pieces
  - Beams for platforms
  - Beams for skylights
  - Boarding
    - for slates, ¾-inch thick
    - for platform, for gutters — 1⅛-inch thick
    - Arris fillet
  - Bearers for gutters
- Trussed roofing
  - Wall plates
  - Diagonal ties
  - Dragon-beams
  - Tie-beams
  - Pole-plates
  - Hammer-beams
  - Truss-posts
    - King-posts
    - Queen-posts
  - Braces
  - Struts
  - Auxiliary rafters, or principal braces
  - Studs
  - Principal rafters
  - Hip-rafters
  - Valley-rafters, or valleys
  - Collar-beams, or straining-beams
  - Purlins
  - Camber-beams
  - Straining-sill
  - Common rafters
  - Boarding, generally ¾-inch thick
  - Arris fillet, ¾-inch by 3 inches
- Sound boarding
  - Nails, what kind
  - Fillets, 1½ inch by 1 inch, nailed at 1 foot distance
  - Boarding, ¾-inch thick, with or without nails
- Nine-inch brickwork
  - Wood bricks, 2½ inches by 4 inches
- Brick-nogging
  - Quarterings
  - Nogging-pieces
  - Lintels
- Common wooden partitions
  - Sills
  - Quarterings
  - Top-pieces
- Truss partitions
  - Sills, or plates
  - Door-posts
  - Truss-posts
    - King-posts
    - Queen-posts
    - Side-posts
  - Braces
  - Inter-tie, or straining-piece
  - Common quarterings, 1½ inch thick

- **Battening for walls**
  - Plugging, at what distances
  - Battens, 2 inches by ¾-inch
  - Nails
- **Grounds**
  - for windows, edge-chamfered or grooved
  - for mouldings
  - for chimneys
  - for doors
  - for cupboards
- **Angle-staff**
  - Square
  - Beaded
- **Ribbing**
  - Ceiling-joists
  - Bracketing 1½ inch thick
- **Lath**
  - on walls
  - on ceilings
  - behind shutters
  - and back of skirtings

Joinery.

- **Sash-frames**
  - Pulley-pieces
  - Inside facings, or linings
  - Outside linings
  - Back linings
  - Heads
  - Sills
  - Beads
- **Sashes**
  - Primed
  - Glazed, with oil-putty
  - Pulleys
  - Weights
  - Lines of the best quality
- **Skylights**
  - Hatch windows
  - Square skylights
  - Polygonal skylights
  - Circular or elliptic conic skylights
- **Boarding for floors** (brads 19lb. per M.)
  - Boards: grooved and tongued, or straight-jointed
  - Battens: grooved and tongued, or doweled together
- **Boarding for walls** (used in shops, water-closets, &c. When less than the whole height a coping is used)
  - Plugs
  - Battens
  - Boards
  - Nails
- **Cupboard linings**
  - Sides
  - Backs
- **Miscellaneous**
  - Door stops
  - Shelving
  - Dado
    - Framed
    - Plain, glued together
- **Door linings**
  - Jambs
  - Soffits
- **Doors**
  - Stiles, Rails, Munnions, or Mountings: Mouldings laid in or planted, or moulded on one or both sides of framing, or bead and flush, or bead and butt.
  - Panels, flat or raised, or with planted beads
- **Dado**
  - plain, framed: Keys
- **Recess to windows**
  - Backs
  - Elbows
  - Soffits
  - Boxings
  - Back-linings
- **Shutters**
  - Front shutters
  - Closers
- **Mouldings**
  - of interior doors, framed doors, linings, backs, elbows, soffits, and shutters, to be all similar.
- **Finishings**
  - Base of rooms
    - Skirtings
    - Base mouldings
  - Surbases
  - Architraves
    - single faced
    - double faced
    - Blocks to be used or not
  - Pilasters
    - plain
    - sunk
  - Facings
  - Belts
  - Skirtings
  - Wood moulding upon stone skirting
  - Jamb mouldings
  - Chimney-pieces
  - Hatch-boards
- **Kitchen**
  - Kitchen dresser
  - Belting round kitchen
  - Wired or latticed windows for larder
- **Water-closet**
  - Flap, clamps, as also the top seat
  - Riser, framed bead and flush
- **Water conveyances**
  - Troughs, with hooks and bolts
  - Water trunks
  - Cover for rain-water pipes
- **Stair**
  - Risers
  - Treads
  - Rail, of deal or mahogony.

A clause in specification, describing the quality of wood.

Joiner to take the plaster work off the plasterer's hand, or to make it good if damaged by his men.

Time of finishing the joinery.

DESCRIPTIVE CARPENTRY, the art of forming a diagram on a plane by the rules of geometry, in order to construct any piece of carpentry of a known property, from certain given dimensions of the thing to be constructed.

This branch is only the application of stereography to Carpentry: and, indeed, the only difference between stereography and descriptive carpentry, is, that in the former, the bodies are entire solids, but in the latter, the bodies to be formed consist of ribs, disposed in parallel lines or planes, or in lines tending to a point, or in planes tending to an axis; so that descriptive carpentry shows the methods of forming the separate pieces in order to construct the whole body or solid. Stereography is, therefore, not only employed in the construction of individual pieces, but also in the whole, when brought into a mass, or taken as one body. This branch is a necessary qualification to an architect, not only to enable him to anticipate the effect, but to judge of the propriety of the execution of any proposed work.

It is too often the case, that young men professing to be studying the science of architecture, will not submit to that which they are pleased to deem the drudgery of the profession. Instead of acquiring, by constant practice and studious diligence, the necessary elements of descriptive and constructive knowledge of the various parts of an edifice, they attempt, before they are qualified by such knowledge, to design edifices, fanciful in conception, as they would be ridiculous if executed.

The result of this want of careful training, is well described by Mr. Bartholomew, in the following passage:—" Taken from school at an age in which he cannot have imbibed in any degree sufficient of a polite and liberal education, the architectural pupil, frequently with no knowledge whatever of geometry, never acquires any beyond the mere manual dexterity of drawing circular and plain lines; abandoned by his master while yet scarcely arrived at manhood, forced into premature and profitless practice with all the expenses of a separate establishment, it cannot be wondered at, that the adolescent architect sometimes has, in after-life, bitter cause to repent the circumstances and the rashness, which led him to acquire practical design and practical construction, solely by his youthful failures; for it is then, with deep repentance, that he perceives the confusion of styles into which he has fallen, the whole chronology of gothic arches which he has paraded in the same façade, the mixture of Roman forms and luxury with the severe and elegant simplicity of the Greeks; in many a breaking up and fracture, he has the mortification to find that inventions upon which he has relied for eternal duration, have not survived their inventor's ruin; that he has formed his pinnacles with graduated outlines, as if Rosslyn chapel or some other impure source were his only pursuit; he regrets that he has placed his columns opposite apertures, instead of opposite piers; he regrets that, from false bearing, want of plumb and equipoise, his work is so fractured, that even a man of more experience than himself cannot restore it; he perceives too late, that his patronage of mean and fragile stone, and pretended substitutes for it, his reliance on bad timber, has added something to the wreck of his country's architecture; he perceives with deep mortification, that his want of mathematical and mechanical skill, both theoretical and practical, has led him to perform that which a professor of more experience would avoid; broken arches, tie-less roofs, walls thrust from their right position, partitions falsely trussed, and groaning beneath loads which, formed otherwise, they might have borne unflinchingly, and a foundation which fails in all directions from want of sufficient spread to the footings, or from the building being carried up piecemeal, or from other causes—these are a few of the faults and disasters, which in after times make a precocious practitioner wish he had studied five or ten years more, before he had risked himself or his employer's property."

This was not the case formerly; men endeavoured in those days to qualify themselves for the practice of their profession, by long study, practice, and unceasing diligence.

Architects, among the ancients, were highly accomplished characters, being skilled in all the geometrical and mechanical knowledge of their time; and in this country they have had much claim to eminence as late as the reign of Queen Anne. Since that time, however, a gradual declension of the art is equally perceptible in all public edifices, as well as in all works of architectural literature.

Though travelling adds to the accomplishment of a judicious architect, it is among the least of the necessary qualifications; a careful observer will lay up greater stores of knowledge at home, than he who has travelled, with inferior abilities; and, indeed, if the architect have no farther views, than that of travelling, in order to produce what he calls drawings of taste, he will, in most instances, become ostentatious, and will ultimately lose the good opinion of his employers. Travelling improves the man of science, but inflates the sciolist with vanity, and renders him ten times more a subject of commiseration than before.

As those parts of carpentry which are objects of description, are placed under their proper denominations, the reader is referred to each particular term, for further information upon this useful subject.

DESCRIPTIVE GEOMETRY, the art of representing a definite body upon two planes, at right angles with each other, by lines falling perpendicularly to the planes from all the points of the concourse of every two contiguous sides of the body, and from all points of its contour; and, *vice versa*, from a given representation to ascertain the parts of the original object.

Descriptive geometry may therefore be considered synonymous with *orthographical* projection, upon which subject, with the exception of a treatise by Mr. P. Nicholson, (first published in 1795, and re-published with improvements in the year 1809), nothing had appeared in the English language, until the publication of this Dictionary.

About the year 1794, the celebrated Monge, who has been called the inventor of *descriptive geometry*, published in France his *Géométrie Descriptive*, one of the most elegant and lucid elementary works in existence. Previous to the appearance of this work, the science of perspective and many other applications of geometry to the arts, had required isolated methods of obtaining lines, angles, or areas, described under laws not readily admitting of the application of algebra, and its consequence, the construction of tables. The descriptive geometry of Monge is a systematized form of the method by which a ground-plan and an elevation are made to give the form and dimensions of a building. The projections of a point upon two planes at right angles to each other being given, the position of the point itself is given. From this it is possible, knowing the projections of any solid figure upon two such planes, to lay down on either of those planes, a figure similar and equal to any plane section of the solid.

This necessary and neglected part of education, had been also much cultivated by Mr. Nicholson, and with such success, that his works have always been referred to by succeeding writers as authorities. In addition to the treatise above mentioned, and also some parts of the carpentry in Rees' Cyclopædia; the numerous valuable articles in this Dictionary attest the sound practical knowledge of the writer, and his perfect acquaintance with the subjects on which he has written. It is due to his memory, to state that he had at that time no knowledge of any foreign work on Descriptive Geometry, and that the treatise by Monge did not fall into his hands until the year 1812. While strongly recommending that work, however, to the study of all those who are desirous of attaining truth in delineation, he considers his own views, differently conceived, as undoubtedly they were, from those of Monge, to have equal claims to originality.

As we are desirous of omitting nothing that may tend to enlarge the bounds of science, we shall here insert so much of Monge's work as we conceive to be conducive to this end, referring Mr. Nicholson's own ideas on this branch of geometry, to the article PROJECTION, a name better understood in this country than that of Descriptive Geometry.

To facilitate the knowledge of this subject, the reader should be well acquainted with the eleventh book of *The Elements* of Euclid, which treats particularly of planes, and the manner in which solids are constituted.

"*Figure* 1.—If from all the points of an indefinite right line, however situated in space, we imagine perpendiculars to be dropped upon a given plane, L M N O, all the points of these perpendiculars will fall upon the plane in another indefinite right line, *a b*, for they will be all comprised in the plane described by A B, perpendicular to the plane L M N O, and can only meet the latter in the line of intersection common to both planes, which is a right line.

"The right line *a b*, which passes through the projections of all the points of the right line A B, upon the plane L M N O, is called the projection of the right line A B upon this plane.

"As two points are sufficient for determining the position of a right line; it is only necessary, in constructing the projection of a right line, to construct the projections of two of its points, and the line which they describe will be the required projection.

"Hence it follows, that if the proposed right line be perpendicular to the plane of projection, its projection will be reduced to a single point, which will be that in which it falls upon the plane.

"*Figure* 2.—The projections *a b*, *a′ b′*, of the same indefinite right line, A B, being given upon two planes, not parallel, L M N O, L M P Q, this right line is determined; for, if from one of the projections, *a b*, we imagine a plane perpendicular to L M N O, the position of this plane being known, it would necessarily pass through the right line A B. The position of this right line, which is found at once upon both the known planes, consequently at their mutual intersection, is therefore absolutely determined.

"What we have just stated is to be understood as independent of the planes of projection, and takes place, whatever may be the angle formed by the two planes. But if the angle formed by the two planes of projection be very obtuse, that formed by their perpendiculars will be very acute: very trifling mistakes in this respect, will, in practice, lead to very grave errors in determining the position of the right line. To obviate this cause of inaccuracy, at least in the absence of better means, it is usual to have the planes of projection perpendicular to each other: besides which, as most artists, who use projections, are familiar with the position of a horizontal plane and the direction of a plumb-line, they generally represent one plane of projection as horizontal, and the other vertical.

"The necessity of representing, in drawings, the two projections upon the same sheet, and in larger operations upon the same area, has farther determined artists to represent the vertical plane as turning and folding down, as upon a hinge, at its intersection with the horizontal plane, so as that the two may form but one plane, upon which they construct their projections.

"The vertical projection is thus, in fact, traced upon a horizontal plane, and it must ever be kept in mind, that it must be corrected and put in its place, by turning it one-fourth of a revolution round its intersection with the horizontal plane: to do which accurately, care must be taken to trace this intersection very plainly upon the design.

"Thus, in *Figure* 2, the projection *a′ b′* of the right line A B, could not be drawn upon a real vertical plane; but if we conceive the plane to be turned about the right line L M, so as to bring it in contact at L M P′Q′, we shall readily execute the vertical projection *a′ b′*.

"Besides the facilities of execution presented by this disposition, it possesses the additional advantage of abridging the labour of projections. Thus, suppose the points *a*, *a′*, to be the horizontal and vertical projections of the point A, the plane indicated by the right lines A *a*, A *a′*, will be perpendicular to the two planes of projection at the same time, because it passes along the right lines perpendicular to them: consequently, it will be perpendicular to their common intersection L M; and the right lines *a* C, *a′* C, according to which they cut these two planes, will be themselves perpendicular to L M.

"Now, if the vertical plane be turned about L M, as upon a hinge, the right line *a′* C, still continues perpendicular to L M; and the case is still the same, when the vertical plane, laid down, assumes the position C *a″*. Thus the two right lines *a* C, C *a″*, passing both by the point C, and being both perpendicular to L M, are in prolongation to each other; the case is similar with the right lines *b* D, D *b″*, as to every other point, as B. Hence it follows, that when we have obtained the horizontal projection of a point, the projection of this same point upon the vertical plane, supposed to be laid down, will be in the right line drawn along by the horizontal projection perpendicularly to the intersection, L M, of the two planes of projection, and this reciprocally.

"This result very frequently occurs in practice.

"We have hitherto considered the right line, A B, *Figure* 2, as indefinite; in which case we should only have to do with its direction; but we must now consider it as terminated by the points A B, which will bring us to take its extent into our calculation. We shall, therefore, examine how this may be deduced from a knowledge of its two projections.

"When a right line is parallel to one of the planes on which it is projected, its length is equal to that of its projection on the plane; for the line and its projection, being both terminated at two points perpendicular at the plane of projection, are parallel to each other, and comprised between parallels. In this particular case, therefore, the projection being given, the length of the right line, which is equal to it, is also given.

"A right line is always parallel to one of the two planes of projection, when its projection upon the second is parallel to the first of its planes.

"If the right line be at the same time oblique upon two planes, its length will be greater than that of either of its projections; but the true length may be obtained by a very simple operation.

"*Figure* 2.—Let A B be the right line; *a b*, *a′ b′*, its given projections: to find its true length. From one of the extremities of the right line A, in the vertical plane falling from it, imagine a horizontal line, A E, stretching out till it meet in E the vertical line falling from the other extremity at B; this will give the rectangular triangle, A E B, which must be constructed in order to obtain the length of the right line A B, which is its hypothenuse. In this triangle, independently of the right angle, we know the side A E, which is equal to the given projection, *a b*. And if, in the vertical plane, we draw from the point *a′*, the horizontal line *a′ e′*, which is the projection of A E, it will cut the vertical line *b′* D at the point *e*, which will be the projection of the point E. Thus *b′ e* will be the vertical projection of B E, aud consequently of an equal length with it. Having ascertained, by these means, the two sides of the triangle, it will be easy to construct the triangle, whose hypothenuse will give the length of A B.

"*Figure* 2.—being drawn in perspective, has no affinity to constructions done in the manner of projections. We shall here give the construction of this first question in all its simplicity.

"*Figure* 3.—The right line L M being supposed to be the intersection of the two planes of projection, and the lines *a b*, *a″ b″*, the given projections of a right line; to find the length of this line. Draw through the point *a″*, the indefinite horizontal H *e*, which will cut the line *b b″*, at the point *e*, and upon it measure the length of *a b*, from *e* to H. Draw the hypothenuse H *b″*, and its length will be that of the right line required.

"As both the planes of projection are rectangular, this operation, which is performed upon one of the planes, may be also done upon the other, and will yield a similar result.

"From what has been said, the reader will perceive, that whenever we have the two projections of a body, terminated by plane surfaces, by rectilinear angles, and by the apices of solid angles (projections which are reducible to the system of rectilinear angles) it will be easy to ascertain the length of any of its dimensions: for this dimension will either be parallel to one of the two planes of projection, or it will be at the same moment oblique to them both. In the first case, the required length of the dimension will be equal to its projection; in the second, it may be reduced from the two projections, by the method just described.

"We come now to describe the mode by which the projections of solids, terminated by planes and rectilinear angles are constructed; though there is no general rule for this operation: indeed, the construction of these projections will be more or less easy, according to the method in which the position of the apices of the angles of the solid is defined; the nature of the operation being governed by that of the definition. The case is precisely here as in algebra, in which there is no general method of reducing a problem to equations. In every particular instance, the process depends on the mode in which the relation between the given quantities and those sought for, is expressed: and it is only by a variety of examples that young students can learn how to lay hold of these affinities, and to express them in equations. So likewise, in descriptive geometry, it is only by a multitude of examples, and by the use of the rule and compasses in our schools, that we can acquire the habit of forming constructions, or accustom ourselves to make choice of the most familiar and elegant methods in each particular case. We may farther observe, that, as in analyses, when a problem is reduced to equations, there are methods of treating those equations, and of deducting from them the value of each unknown quantity; so also, in descriptive geometry, when the projections are made, there are certain general methods of constructing whatever may result from the terms, and respective positions of bodies.

"Nor is this comparison between descriptive geometry and algebra altogether useless: for these sciences are intimately connected. There is no construction of descriptive geometry, but what may be reduced to an analysis; and when questions require no more than three unknown quantities, each analysis may be looked upon as the record of a spectacle in geometry.

"It is much to be wished, that these two sciences were studied together: descriptive geometry would carry that evidence which is its peculiar characteristic, into the most complicated analytical operations; while on the other hand algebraical analyses would give to geometry, that generality which it stands in need of.

"The principle upon which we ground the theory of projections is convenient for describing the position of a point in space or that of an indefinite or terminated right line, and, consequently, for representing the form and position of a body terminated either with plain faces, rectilinear arrêtes, or the apices of solid angles; for when once we are acquainted with the position of all its arrêtes and of the apices of all its angles, the body itself is entirely known. But were all bodies bounded, either by an uniformly curved surface, all whose points were governed by the same law, as in spheres, or by an unconnected assemblage of several parts of differently curved surfaces, as in a body turned on a lathe; this principle would not only be inconvenient, impracticable, and destitute of the advantage of forming an idea of the shape, but would also be insufficient through want of variety.

"For instance: it is easy to perceive that this principle by itself, would be inconvenient and impracticable, if we wished to describe all the points of a curved surface; because it would be necessary not only to indicate each of them, as well by its horizontal, as its vertical projection, but also to have the two projections of the same point united together, in order to avoid a combination of the horizontal projection of one point with the vertical projection of another; and the most ready mode of thus uniting these projections, being to join them by one perpendicular right line to the line of intersection of the two planes of projection, the draught would become surcharged with a prodigious number of lines, and cause a confusion, which would increase in proportion as we would aim at accuracy and precision.

"We shall now prove this method to be insufficient, and destitute of the requisite copiousness.

"Amongst the vast variety of differently-curved surfaces, there are some which extend only through a finite and circumscribed portion of space, and whose projections are limited, as to extent, in every direction; as in the case of a sphere, the extent of whose projection on a plane is reduced to that of a circle, having its circumference equal to that of the sphere; and we must allow the plane, on which the projection falls, to be of dimensions sufficient to receive it. But all cylindric surfaces are as indefinite in a certain direction, as the right line by which they are generated; and the plane itself, the most simple of all surfaces, is indefinite in two ways. There are likewise a great number of surfaces, whose protuberant particles (*nappes*) shoot at once into all the regions of space. Now, as the planes on which projections are received, are unavoidably of a limited extent, this mode of describing the nature of a curved surface, had we no other than that of the two projections of each of the points by which it passes, could be only applicable to those of which the points of the surface correspond to the size of the planes of projection; all beyond this, could neither be expressed nor known: consequently, this mode would be insufficient. Lastly, it would want variety, because we could not deduce from it anything relative either to tangent planes to the surface, nor to its normals, nor to its two curvatures in each point, nor to its lines of inflection, nor to its returning arrêtes, nor to its multiplied lines and points, nor, in a word, to any of the affections necessary to be considered in operating on a curved surface.

"It is therefore necessary, that we should have recourse to some new principle, not only compatible with the former, but also capable of supplying its place, whenever it becomes in itself insufficient for our purpose. It is this new principle that we are now about to lay down.

"Every curved surface may be considered as generated by the movement of a curved line, either inflexible in form when its position is changed, or variable both in form and situation. As the universality of this proposition may render it difficult of comprehension, we shall explain it by some familiar examples.

"Cylindric surfaces may be generated in two principal ways, viz., either by the movement of a right line, which keeps constantly parallel to a given line whilst in motion, yet inclining always towards a given curve; or by the movement of the curve itself, taken in the foregoing instance as the conductor, which so moves, as that while from one point it inclines towards a given line, all its other points may describe parallels to this line. In both these modes of origin, the generating line, which is a right line in the first case, and a curve, of whatever description, in the second, invariably retains its form; only changing its position in space.

"Conical surfaces have, in like manner, two principal modes of being generated. First, they may be considered as generated by an indefinite right line, which being forced to pass always upon a given point, moves so as to lean constantly towards a given curve, that directs its movement. The only point through which it always passes the right line, is the centre of the surface, improperly called its *apex* or *head*. In this mode, the generating line still preserves its identity, never ceasing to be a right line.

"Conic surfaces may also be generated in another way, which, for greater plainness, we shall here apply only to those with circular bases. The surfaces may be considered as bounded by the circumference of a circle, moving with its plane always parallel to itself, and its centre upon a right line passing through the apex; its radius being, in every movement, proportionate to the distance of the centre from the apex. Here it is evident, that if in its motion, the plane of the circle tends towards the apex of the surface, the radius of the circle will decrease, till, in passing the apex, it will be an absolute nullity, after which it will again increase indefinitely, in proportion as the plane, having passed the apex, is withdrawn farther and farther from it. In this second mode of generating, the circumference of the circle, which is the generating curve, not only changes its position, but its form also, at every motion; for, changing its radius, it consequently varies both in curvature and extent.

"Let us take a third example.

"A circular surface may be generated by the movement of a plane curve, turning about a right line; drawn in any direction upon its plane. In this way, we find the generating curve inflexible in form, but changeable in position. We may also see it generated by the circumference of a circle, moving with its centre always on the axis, and its plane being perpendicular to this axis, the radius will be uniformly equal to the distance of the point in which the plane of the circle cuts the axis, from that in which it cuts a given curve in space. Here the generating curve changes both in form and position.

"From these three examples, we may perceive that all curved surfaces may be generated by the movement of certain curved lines, and that there are none of which the form and position may not be accurately described from an exact and complete definition of its generation. This new principle forms a complement to the method of projections; and in proceeding, we shall have frequent occasion to be convinced of its simplicity and copiousness.

"It is not, therefore, by merely giving the projections of individual points, through which a curved surface passes, that we are enabled to determine its form and position; but by being able to construct for any point the generating curve, according to the form and position it would have in passing such point. And here we may remark, 1. That as every curved surface may be generated in an infinite number of different ways, it must depend upon the dexterity and knowledge of the operator, to make choice, among all the possible generations, of such as will require the most simple curve, and least complex considerations. 2. That long experience has taught us, instead of considering only one generating principle of a curved surface, as prescribed by the laws of motion and of the change of form in its generation, it is frequently more simple to take two generating principles, and to indicate for each point the construction of the two generating curves.

"Thus, in descriptive geometry, in order to express the form and position of a curved surface, it is only necessary, for any point of such surface, of which the projections may be taken at pleasure, to give the manner of constructing the horizontal and vertical projections of two different generators, which pass that point.

"We shall now proceed to apply these general principles to the plane, of all surfaces the most simple, and the most frequently in use.

"A plane is generated from the motion of a given right line, of a known position, which moves so that all its points may describe lines parallel to a second given right line. If this second line be itself in the plane in question, it may be also said that the plane is generated by such second right line moving so that all its points may describe lines parallel to the first.

"We have therefore an idea of the position of a plane, from an observation of the two right lines, each of which may be considered as its generator. The position of these two right lines in the plane which they generate, is altogether indifferent; it is only necessary, therefore, for projections, to make choice of such as are of the most simple construction. Hence, in descriptive geometry, the position of a plane is indicated by giving the two right lines along which it cuts the planes of projection. It is easy to recollect that these two right lines must meet the intersection of the two planes of projection in one and the same point, and that, consequently this must be the point, in which they meet themselves.

"As we shall have frequent occasion to bring planes under our consideration, we shall, for the sake of brevity, adopt the term *traces* to describe those right lines, by which they cut the planes of projection, and by which their position is indicated.

"Having settled these preliminaries, we now proceed to the solution of various questions, which will at once serve as exercises on the method of projections, and facilitate our farther progress in descriptive geometry.

"*First Question.—Figure* 4. A point, whose projections are D, *d*, and a right line, whose projections are A B and *a b*, being given; to construct the projections of a second right line, drawn from the point given, parallel to the first.

"*Solution.*—The two horizontal projections of the given right line, and of the line sought, must be parallel to each other; being the intersections of two vertical planes, parallel to a common plane. It is also the same with the vertical projections of similar right lines. Therefore, as the right line sought for must necessarily pass through the given point, its projections must also pass through those of the point respectively. If, then, from the point D, E F be drawn parallel to A B, and if from the point *d*, *e f* be drawn parallel to *a b*, the lines E F and *e f* will be the projections required.

"*Second Question.—Figure* 5. A plane whose two traces are A B, B C, and a point, whose projections are G, *g*, being given: to construct the traces of a second plane, drawn from the given point, parallel to the first.

"*Solution.*—The traces of the plane sought for, must be parallel to the respective traces of the given plane, because these traces taken in pairs, are the intersections of two planes parallel to a common plane. We have, therefore, only to find, for each of them, one of the points through which they respectively pass. To obtain this, from the given point, conceive a horizontal right line in the plane sought for; this line will be parallel to the trace A D, cutting the vertical plane in a point, which will be one of those of the trace of the plane sought for on it; and we shall have its two projections, by drawing the indefinite horizontal *g* F from the point *g*, and the right line G I from the point G, parallel to A B. If G I be produced to meet the intersection, L M, of the two planes of projection in the point I, such point will be the horizontal projection of the intersection of the horizontal right line with the vertical plane. This point of intersection, therefore, will be found upon the vertical line I F, drawn from the point I. But as it must also be found upon *g* F, it will be discovered at the point F, of intersection of the two latter right lines. Lastly, by drawing a line from F parallel to B C, we shall have upon the vertical plane the trace of the plane required; and if this trace be produced till it meet L M in the point E, and E D be drawn parallel to A B, we shall have the trace of the same plane upon the horizontal plane.

"If, instead of a horizontal right line in the plane sought for, a line parallel to the vertical plane were conceived, the construction following, by parity of reasoning, would be obtained:

"Draw from the point G, parallel to L M, the indefinite right line G D; from the point g, draw g H parallel to C B, producing it till it cut L M in the point H, whence draw H D perpendicular to L M: this latter will cut G D in D, whence if a parallel be drawn to A B, one of the traces of the plane sought for will be obtained; and if, having produced this trace to meet L M in E, E F be drawn parallel to B C, we shall have the trace on the vertical plane.

"*Third Question.—Figure* 6. A plane whose two traces are A B and B C, and a point whose two projections are D, d, being given; to construct, 1, the projections of the right line falling perpendicularly from the point upon the plane; 2, the projection of the point of coincidence of the right line with the plane.

"*Solution.* The perpendiculars D G, dg, falling from the points D and d upon the respective traces of the plane, will be the indefinite projections of the right line required: for if, along the perpendicular, a vertical plane be conceived, such plane will cut both the horizontal and the given planes, in two right lines, both of them perpendicular to the common intersection, A B, of the two planes; now, the first of these lines, being the projection of the vertical plane, is also that of the perpendicular which is included; therefore the projection of this perpendicular must pass through the point D, and the perpendicular to A B.

"The same demonstration will serve for the vertical projection.

"As to the point of coincidence of the perpendicular with the plane, it is evident that it must be found at the intersection of this plane, with the vertical plane drawn along the perpendicular; such intersection being projected indefinitely upon E F. By obtaining the vertical projection, fe, of this intersection, we shall find it to contain that of the point required; and as this point must be projected upon the right line dg, it will be found at the intersection, g, of the lines fe and dg. It remains, therefore, only to discover the right line fe: now, the intersection of the given plane with the vertical plane, which are perpendicular to each other, will meet the horizontal plane in the point E, whose vertical projection, e, will be found by dropping E e perpendicularly upon L M; and it will meet the vertical plane of projection in a point, whose horizontal projection is the intersection of the line L M with D G, produced, if necessary, and whose vertical projection must be at once upon the vertical line Ff and the trace C B; of course, it will be at the point, f, of their intersection.

"The vertical projection, g, of the foot of the perpendicular being found, the construction of its horizontal projection will be easy; for by dropping the indefinite perpendicular g G upon L M, a right line will be obtained, which will contain the point required: and as the line D F must also contain it, it will be found at the point, G, of intersection of these two right lines.

"*Fourth Question.—Figure* 7. A right line whose two projections are A B, $a\,b$, and a point whose two projections are D, d, being given; to construct the traces of a plane drawn from the point, perpendicularly to the right line

"*Solution.* We have seen from the preceding question, that the two traces must be perpendicular to the respective projections of the two right lines: it remains to be discovered what points each of them ought to pass through. For this purpose, let an horizontal line from the given point be conceived in the plane required, produced so as to meet the vertical plane of projection, and we shall find its vertical projection, by drawing the indefinite horizontal d G through the point d, and its horizontal projection by drawing a perpendicular to A B, through the point D, produced till it cut L M in H, which will be the horizontal projection of the point of coincidence of the horizontal with the vertical plane of projection. This point of coincidence, which must be found in the vertical line H G, and the horizontal line d G, and consequently at the point, G, of the intersection of these two lines, will be one of the points of the trace on the vertical plane; we shall then find this trace by drawing the line F C, from the point G, perpendicular to $a\,b$; and if from the point C, where the first trace meets L M, C E be drawn perpendicular to A B, we shall have the second trace required.

"The same process would discover the point of coincidence of the plane with the right line.

"Were it necessary to drop a perpendicular from the given point upon the right line, we should construct, as has just been described, the coincidence of the right line with the plane drawn by the given point, and which would be perpendicular to it; and we should obtain, from each of the two projections of the required perpendicular, two points through which it must pass.

"*Fifth Question.—Figure* 8. Two planes being given in position, by means of their traces A B and A b for one, and C D and C d for the other; to construct the projections of the right line upon which they intersect each other.

"*Solution.* All the points of the trace A B being found in the first of the two given planes, and all those of the trace C D being found in the second, the point E, of intersection of these two traces is evidently in the two planes, and is consequently one of the points of the required right line. In like manner, the point, F, of intersection of the two traces upon the vertical plane, is also another point of this right line. The intersection of the two planes is therefore so placed as to meet the horizontal plane in E, and the vertical plane in F.

"If, therefore, the point F be projected on the horizontal plane, which may be performed by dropping the perpendicular F f on L M, and if the line f E be drawn, it will be the horizontal projection of the intersection of the two planes. So, if the point E be projected on the vertical plane, by dropping the perpendicular E e on L M, and if the right line e F be drawn, it will be the vertical projection of the same intersection.

"*Sixth Question.—Figure* 9. Two planes being given, by means of the traces A B and A b for the first, and C D and C d for the second; to construct the angles formed by them.

"*Solution.* Having constructed, as in the preceding question, the horizontal projection, E f, of the intersection of the two planes; by conceiving a third plane perpendicular to them, and consequently perpendicular to their common intersection; this third plane will cut the two given planes in two right lines, containing between them an angle equal to the one required.

"The horizontal trace of this third plane will be perpendicular to the projection, E f, of the intersection of the two given planes, forming with the other right lines a triangle, of which the angle opposed to the horizontal side will be the one required. It remains, therefore, only to construct this triangle.

"It is quite indifferent through what point of the intersection of the two first planes the third passes; and we are at liberty to mark its trace upon the horizontal plane, at pleasure; provided that it be perpendicular to Ef. Suppose then, the line G H be drawn perpendicular to Ef, terminating, in G and H, at the traces of the two given planes, and meeting Ef, in the point I; this line will be the base of the triangle intended to be constructed. In fact, let us suppose that the plane of this triangle turns on its base, G H, as on a hinge, to adapt itself to the horizontal plane; in this motion, its apex, which was in the first instance placed on the intersection of the two planes, continues in the vertical plane drawn through such intersection, because the vertical plane is perpendicular to G H; and when the plane of the triangle is laid down, this apex will be found on one of the points of the line E f. It therefore remains only to discover the heights of the triangle, or the extent of the perpendicular dropped from the point I, on the intersection of the two planes.

"But this perpendicular is comprised in the vertical plane drawn from E to f; if, therefore, we conceive this plane to revolve about the vertical line f F, in order to apply itself to the vertical plane of projection; and if we carry f E from f to e, f I from f to i, the line e F will be the extent of the portion of the intersection comprised between the two planes of projection; and if from the point i, the perpendicular $i\,k$ be dropped upon this line, it will give the height of the required triangle.

"Hence, by carrying $i\,h$ from I to K, and completing the triangle G K H, the angle in K will be equal to the angle formed by the two planes.

"*Seventh Question.—Figure* 10. Two right lines intersecting each other in space, being given by their horizontal projections A B, A C, and by their vertical projections $a\,b$, $a\,c$; to construct the angle formed between them.

"Before we enter on the solution of this question, we may remark, that as the two given right lines are supposed to intersect each other, the point, A, of the coincidence of their horizontal projections, and the point, a, of the coincidence of their vertical projections, will be the projections of the point in which they cross each other, and will, consequently, be in the same right line, a G A, perpendicular to L M. Were the two points A and a not in the same perpendicular to L M, the given right lines would not intersect each other, and of course would not be in the same plane.

"*Solution.* Conceive the two given right lines to be produced so as to meet the horizontal plane, each in a point, and then construct these two points of coincidence. To perform this, produce the lines $a\,b$ and ac, till they cut L M in the points d and e, which will be the vertical projections of these two points of coincidence. From the points d and e, draw upon the horizontal plane, and perpendicularly to L M, two indefinite right lines, d E and e E, which, as they must pass through one of these points, will determine their positions by their intersections, D and E, with the respective horizontal projections A B and A C, produced if necessary.

"This done, draw the right line D E, which, with the two parts of the given lines comprised between their intersecting point and the points D and E, will form a triangle, of which the angle opposite to D E will be the angle required: we have, therefore, only to construct this triangle. To do so, having dropped from the point A, the indefinite perpendicular A F, upon D E, conceive the plane of the triangle to turn as upon a hinge on its base D E, till it lie flat on the horizontal plane; the apex of this triangle, during its movement, will not depart from the vertical plane described by A F, and will at length apply itself in some degree upon the prolongation of F A in a point, H, of which it remains only to find the distance from the base D E.

"Now the horizontal projection of this distance is the right line A F, and the vertical height of one of its extremities above that of the other is equal to a G; hence, according to the property of *Figure* 3, if upon L M, A F be measured from G to f, and if the hypothenuse $a\,f$, be drawn, such hypothenuse will be the distance required. Finally, if $a\;f$ be carried from F to H, and if from the point H the two lines H D and H E be drawn, the triangle will be complete, and E H E will be the angle sought for.

"*Eighth Question.*—The projections of a right line, and the traces of a plane, being given; to construct the angle formed by such line and plane.

"*Solution.* Suppose a line perpendicular to the given plane to be drawn from a certain point in the given right line, the angle formed by such perpendicular with the given right line, would be the complement of the required angle, the construction of which will resolve the question.

"Now, if upon the two projections of the right line, two points be taken, in the same perpendicular with the intersection of the two planes of projection; and if lines be drawn from these two points, perpendicular to the respective traces of the given plane, they will describe the horizontal and vertical projections of the second right line. The question will therefore be reduced to the construction of the angle formed by two right lines which cut each other, and will be of the same nature with the former.

"It is usual, in projecting a chart of a country, to imagine the remarkable points to be connected by means of right lines forming triangles, which are to be transferred to the chart on a smaller scale, but placed in the same relative order as those they represent. The operations necessary to be made on the earth consist chiefly of the measurement of angles, and of these triangles; and in order to the angles being described correctly on the chart, they ought each to be in a horizontal plane, parallel to that of the chart. If the plane of the angle be oblique to the horizon, it must not be represented, but its horizontal projection must be taken, which may always be found, if after measuring the angle itself, those angles which its two sides form with the horizon be also measured. Hence we derive the following operation, known under the appellation of *the reduction of an angle to the horizon.*

"*Ninth Question.*—The angle formed by two right lines, and the angles formed by such lines with the horizontal planes, being given; to construct the horizontal projection of the first of these angles.

"*Solution.—Figure* 11. Let A be the horizontal projection of the apex of the angle sought for, and A B that of one of its sides, so that the other side may be represented by A E. Conceive the vertical plane of projection to pass along A B; and having drawn the vertical indefinite line A a, through the point A, any point, as d, may be taken at pleasure, as the vertical projection of the apex of the angle observed. If from the point d, the right line d B be drawn, so as to make with the horizontal line, an angle d B A, equal to that made by the first side with the horizon, the point B will be the coincidence of this side with the horizontal plane. Also, if from the point d, the line d C be drawn, so as to make with the horizontal line an angle, d C A, equal to that made by the second side with the horizon; and if from the point A, as from a centre, with the radius A C, the indefinite arc of a circle, C E F, be described, the second side can meet the horizontal plane only in the points of the arc C E F. It remains, therefore, only to ascertain the distance between this point and some other, as B.

"Now this latter distance is in the plane of the angle observed. If, therefore, the right line d B be drawn, so as that the angle D d B may be equal to the angle observed, and if *d* c be carried from *d* to D, the right line D B will be equal to such distance.

"Therefore, taking B as a centre, and, at an interval equal to C D, describing the arc of a circle, the point E, where it will cut the first, will be the point of coincidence of the second side with the horizontal plane; consequently, the right line A E will be the horizontal projection of such side, and the angle B A E that of the angle observed.

"The nine preceding questions barely convey an idea of the method of projections; they are inadequate to a display of all the resources: but in proportion as we rise to more general considerations, we shall take care to introduce such operations as will be most conducive to this object.

"*Of planes tangent to curved surfaces, and of normals.*

"There is no curved surface but what may be generated in several ways, by the movement of curved lines; therefore, if from any point of a surface, two generating lines be supposed to spring in the position they would naturally have in passing each other through such point, and if the tangents be supposed in this point, to each of the two generators, the plane described by such two tangents is *the tangent plane.* The point of the surface in which the two generators cut each other, and is at the same time common to the two tangents and to the tangent plane, is *the point of contact* between the surface and the plane.

"The right line drawn through the point of contact, perpendicularly to the tangent plane, is said to be *normal* to the surface. It is perpendicular to the ground of the surface, because the direction of such ground coincides, in every part, with that of the tangent plane, which may be considered as its prolongation.

"A knowledge of tangents and of normals to curved surfaces, is very useful in a great number of arts; in many, it is indispensable. We shall here adduce only a single example of each case, selected in architecture and painting.

"The several portions which compose vaults of hewn stone, are called *voussoirs*, and the faces on which two contiguous voussoirs touch each other, are denominated *joints*, whether the voussoirs form but a single course, or whether they be comprised in two successive courses.

"The position of the joints of vaults is subject to several conditions, which must necessarily be complied with, and which we shall demonstrate in succession, in the sequel of this discourse; but at present we must confine our attention to the object more immediately before us.

"One of the conditions required in the position of joints, is, that they be all perpendicular to each other, and to the surface of the vault. Any material deviation from this rule, not only destroys the general symmetry of the structure, but also diminishes the firmness and durability of the vault. For instance, if one of the joints be made oblique to the surface of the vault, one of the two continuous voussoirs will form an obtuse angle, and the other, an acute one; and in the reaction which these voussoirs would exert against each other, the two angles would present an unequal resistance, whence, in consequence of the fragility of the materials, the acute angle would bilge, and spoil the shape of the vault, as well as endanger the edifice. The reduction of vaults into voussoirs, therefore, absolutely requires a knowledge of planes tangent and normals to the curved surface of the arch.

"Let us take another example, from an art, which, at first view, seems to require a much less rigid attention to this rule.

"Painting is generally considered as consisting of two parts. The one is, properly speaking, *the art;* its object is to excite in the spectator a determinate emotion, to create in him a given idea, or to place him in a situation the most favourable for receiving a certain impression; it supposes in the artist a great knowledge of philosophy; exacts, on his part, a most intimate acquaintance with the nature of things, the mode in which they affect us, and the movements, even involuntary, by which such affection manifests itself. This can only be the result of a very refined education, such as no one receives, and such as we are far from giving to young artists: it is governed by no general rule, but is subject solely to genius.

"The other part of painting may be properly called *the trade:* its object is a correct execution of the conceptions of the former. Here nothing is arbitrary; all is foreseen, by the help of sound reasoning, as the necessary result of determinate subjects and given circumstances. When the form and position of an object are ascertained; when its nature, and the number and positions of all the bodies by which it may be illumined, whether by direct light or reflected rays, are understood; when the position of the eye of the spectator is determined; and when, in a word, every circumstance that can influence the vision, is well established and known, the tint of each of the points of the visible surface is absolutely determined. Whatever relates to the colour of this tint, or its brightness, depends on the position of the plane tangent in this point, with respect to the illuminating bodies and to the eye of the spectator. This may be discovered by mere reasoning, and when so determined should be applied with accuracy. Every diminution, or exaggeration, will change the appearances, alter the forms, and produce an effect quite different from that intended by the artist.

"I am aware that the rapidity of execution, which is often necessary, rarely admits of the use of a method which deprives the genius of all corporeal succours, and leaves it to the exercise of its faculties alone, as well as that it is much more easy for the painter to look at objects, to observe their tints, and to imitate them: but were he accustomed to consider the positions of tangent planes, and the two curvatures of surfaces in each of their points (curvatures which will form the subject of subsequent lessons) he would not fail to derive from this material method, a more advantageous result: it would enable him to supply effects which the omission of some circumstances had prevented him from producing, and to suppress others which had arisen from extraneous incidents.

"In conclusion, we may remark, that the vague expressions, such as *flats*, which painters are in the constant habit of using, are standing evidences of the need in which they are of more accurate knowledge, and of deeper reflection.

"Besides its utility in the arts, the knowledge of planes tangent and normals to curved surfaces, is one of the most fertile methods employed in descriptive geometry for the solution of questions, which it would be very difficult to resolve by any other process, as will appear from the following examples.

"The general mode of determining the plane tangent to a curved surface, consists, as we have already remarked, in conceiving at the point of contact, the tangents with two different generating curves, which would pass through this point, and in constructing the plane that would pass through these two right lines. In some particular cases, in order to shorten the construction, the strict letter of this mode is departed from, but an equivalent is always adopted.

"As to the construction of the normal, we shall not dwell upon it particularly, as it reduces itself merely to that of a right line perpendicular to the tangent plane, which is sufficiently understood.

"*First Question.*—From a supposed point on a cylindric surface, of which the horizontal projection is given, to draw a tangent plane to that surface.

"*Solution.—Figure* 12. Let A B, *a b*, represent the horizontal and vertical projections of the given right line, to which the generator of the cylindric surface must be parallel; let E P D be the given curve in the horizontal plane, on which the generator must constantly rest, and which may be considered as the outline of the cylindric surface; lastly, let C be the given horizontal projection of the point supposed on the cylindric surface, from which the tangent plane must be drawn.

"Next, from the supposed point on the surface, whose horizontal projection is in C, imagine the generating right line in the position it would have, if it passed through that point: this generator being a straight line, will be its own tangent, and consequently one of the two right lines by which the position of the tangent plane will be determined; also, it will be parallel to the given right line: its two projections, therefore, will be respectively parallel to A B and *a b*: then, if from the point C, an indefinite line be drawn, parallel to A B, as E F, we shall have the horizontal projection of the generator. To obtain its vertical projection, we must suppose the generator to be produced upon the cylindric surface, till it meet the horizontal plane, which it can only do in a point, that will be at once on the projection E F, and on the curve E P D, and consequently the intersection of these two lines: thus the point will be determined by producing E F till it cut some part of the curve E P D.

"Two cases here present themselves: either the line E F will cut the outline of the cylinder in a single point, or it will cut it in several points. In examining these two cases separately, we shall suppose, in the first instance, that to whatever length the line E F may be produced, it shall cut the curve E P D only in the single point D.

"The point D being the trace of the generator, if it be projected on the vertical plane, by means of the perpendicular D *d*, and if from the point *d*, the line *d f* be drawn parallel to *a b*, we shall obtain the vertical projection of the generator. We are thus in possession of the two projections of one of the right lines, through which the required tangent plane must pass. The vertical projection of the point of contact ought to be on the line C *c'*, drawn from the given point C, perpendicularly to L M; it should also be on *d f*; consequently it will be in the intersecting point, *c*, of those two lines.

"If the line E F cut the trace, E P D, of the cylindric surface in several points, as D and E, we must proceed for each in the same manner as that just directed for the point D, considered by itself, and we shall obtain the vertical projections, *d f*, *e f*, of as many generating lines, and the vertical projections, *c c'*, of as many points of contact, as there are points of intersection between the line E F and the trace E P D.

"In the instance of *Figure* 12, the trace of the cylindric surface in the circumference of a circle, which has the property of being cut by a right line in two points; so that the vertical line elevated from the given point C, must meet the surface twice; first, in a point whose vertical projection is *c*, through which the generator passes when it touches upon the point D; and, secondly, in another point, whose vertical projection is *c'*, through which the generator passes when it rests on the point E of the trace. These two points, although they have the same horizontal projection, are nevertheless very distinct, and should each have a particular correspondent tangent plane. Indeed, for each of the two points of contact, we must find the second right line, by which the position of the tangent plane is to be determined. Were we strictly to follow the general method, by considering the trace as a second generating line, it would be necessary to conceive it as passing successively through each of the points of contact, and to construct a tangent for each of such points; but in the present case of cylindric surfaces, a much more simple process may be pursued. For example: the plane tangent to the point C, *c*, touches the surface, throughout its extent, of the generating right line which passes from this point; it touches it, then, in D, which is a point of such generating line, and ought therefore to pass through the tangent to the trace at the point D. By parity of reasoning, we shall find that the plane tangent, C, *c'*, ought to pass along the tangent to the trace in E. Therefore, if from the two points D, E, we draw the trace of the two tangent planes D K, E G, produced till they cut the line L M in two points K, G, we shall have, in the horizontal plane, the traces of the two tangent planes.

"It only remains to discover the traces of the same planes on the vertical plane; and having already for one of these traces the point K, and for the other, the point G, we have only to determine a single point for each of them.

"With this view, operating for the first of the two tangent planes, imagine the point to be constructed, to be one in which a horizontal line drawn upon the plane through the point of contact, would meet the vertical plane; we shall have the horizontal projection of such line, by drawing from the point C, a line parallel to the trace D K, which may be produced till it meet the line L M in the point I; and we may obtain its vertical projection by drawing from the point *c* an indefinite horizontal line. The point of coincidence of the vertical plane with the horizontal, will be found at once both upon the vertical line I *i* and the horizontal line *c i*, and will be at the point, *i*, of their intersection; therefore, if through the points *i* and K a line be drawn, it will give the trace of the first plane tangent to the vertical plane. By a similar process for the second tangent plane, we shall find its trace on the vertical plane, by drawing from the point C a line, C H, parallel to the horizontal trace E G, which may be produced till it cut L M in the point H, upon which the vertical line H *h* may be raised; from the point *c'* draw a horizontal line to cut the vertical line H *h*, in the point *h*, from which, and from the point G, by drawing the line G *h*, we shall obtain the trace required.

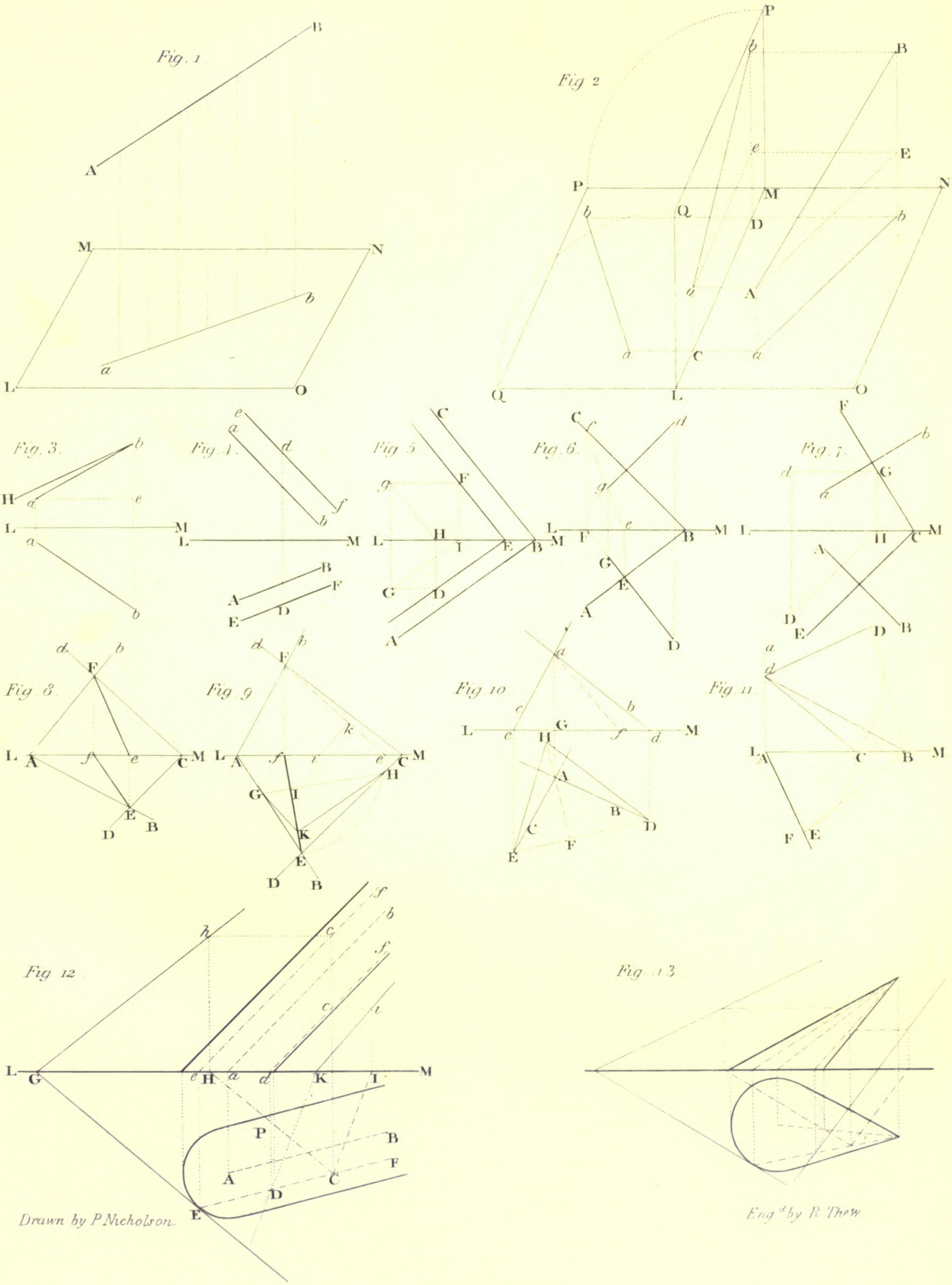
"*Second Question.*—From an imaginary point of a conic surface, of which the horizontal projection is given, to draw a tangent plane to such surface.

"The solution of this question differs only from the preceding, in having the generating right line, instead of being always parallel to itself, passing constantly from the apex whose two projections are given. We think it unnecessary to enlarge in this place, and leave the reader to examine for himself, with the assistance of *Figure* 13, should he stand in need of such aid.

"*Third Question.*—From an imaginary point of a surface revolving upon a vertical axis, and given in the horizontal projection, to draw a plane tangent to such surface.

"*Solution.—Figure* 14. Let A be the given horizontal projection of the axis, *a a'* its vertical projection, B C D E F the given generating curve, considered in a plane drawn from the axis, and G the given horizontal projection of the point of contact.

"If from the point of contact, and from the axis, a vertical plane be conceived, whose projection would be the indefinite horizontal line A G, such plane must cut the revolving surface in a curve, which will become the generator, passing through the point of contact: if from the point G, a vertical line be conceived, it will meet the generating curve, and consequently the surface, in one or several points, which will become so



Drawn by P. Nicholson.

Eng^d by R. Thew.

many points of contact, of which G will be the common horizontal projection. All these imaginary points of contact will be found in the plane of the generator, by carrying A G upon L M, from a to e, and drawing through the point e a line parallel to $a\ a'$; all the points, E, C, in which this line cuts the curve B C D E F, will be the intersections of the generating curve with the vertical line drawn through the point G, and will indicate the altitudes of as many points of contact above the horizontal plane. To obtain the vertical projections of these points of contact, draw through all the points, E, C, indefinite horizontal lines, which will contain such projections; and as they are also contained in the line perpendicular to L M, drawn from the point G, the intersections, $g\ g'$, of this line with the horizontal lines, will be the projections of the several points of contact.

"Now, if from each point of contact, a section be conceived, made by a horizontal plane, such section, which may be considered as a second generator, will be the circumference of a circle, whose centre will be in the axis, and of which the tangent, which must be perpendicular to the extremity of the radius, will also be perpendicular to the vertical plane drawn through A G, in which the radius is found: therefore the tangent plane which must pass through this tangent, will be also perpendicular to the same vertical plane, and will have, upon the horizontal plane, its trace perpendicular to A G. We only want, therefore, the trace of each of the tangent planes, to enable us to discover its distance from the point A: now, if through the points E, C, we draw to the first generator the tangents E I, C H, produced till they meet L M in the points I, H, the lines a I, a H, will be equal to those distances; therefore, if these lines be transferred from A to i, and from A to h, and if through the points i and h, the perpendiculars i Q, h P, be drawn to A G, and produced till they meet the line L M, we shall have, on the horizontal plane, the traces of all the tangent planes.

"To find on the vertical plane, the traces of the same planes, we must suppose for each point of contact, and in the correspondent tangent plane, a horizontal line produced to the vertical plane of projection; this line, which is the tangent to the circle, will determine, on this plane, which belongs to the trace. Now, for all the points of contact, these lines have the same horizontal projection, viz. the line G K drawn from the point G, perpendicularly to A G, and terminating in the right line L M. If, therefore, from the point K, an indefinite perpendicular, K $k\ k'$, be drawn upon L M, it will contain all the points of coincidence of the horizontal lines with the vertical plane of projection. But as these points of coincidence will also be found on the respective horizontal lines drawn through the points E, C; the intersections k. k', of such horizontal lines with the vertical line K, k', will be each a point of the trace of one of the tangent planes. Thus the line Q k will be on the vertical plane, the trace of one of the tangent planes; the line P k' will be that of another; and so of the rest, were there a greater number.

"We shall confine ourselves for the present, to the three preceding examples, because they are sufficient for all the surfaces, whose generation we have defined. In the course of this work, we shall have occasion to investigate the generations of tribes of surfaces, infinitely more numerous: and as they present themselves, we shall apply the same method to the determination of their tangent planes, and of their normals. At present we are about to propound a question, to the solution of which the consideration of the tangent plane may be appropriately and usefully applied.

"*Fourth Question.—Figure* 15. Two right lines being given, by their horizontal projections, A B, C D, and by their vertical projections, $a\ b$, $c\ d$; to construct the projections, P N, $p\ n$, of their shortest distance; that is to say, of the line that is at one and the same time perpendicular to both; and to find the quantity of this distance.

"*Solution.*—From the first of the two given right lines, conceive a plane parallel to the second; which is always possible, because if from any point whatever of the first, a line be drawn parallel to the second, and if this third line be conceived to move parallel to itself along the first, it will generate the plane spoken of. Imagine, also, a cylindric surface, with a circular base, having the second given right line for its axis, and the distance required for its radius; this surface will be touched by the plane in a line parallel to the axis, and will cut the first right line in a point. If from this point, a perpendicular to the plane be drawn, it will be the line required; for it will pass, in fact, through a point of the first given right line, and will be perpendicular to it, as it would to a plane passing along this right line; it will also intersect the second right line perpendicularly, because it will be a radius of the cylinder, of which such second line is the axis.

"It remains, then, only to construct, successively, all the parts of this solution.

"(1.) To construct the traces of the plane drawn through the first right line parallel to the second, we must first find the point, A, wherein this first line meets the horizontal plane, and which will be a point of the horizontal trace. To effect this, produce the vertical projection $b\ a$ till it cut the line L M in the point a, draw a A perpendicular to L M, and its intersection with the horizontal projection A B will determine the point A. Through the point in which the first right line cuts the vertical plane, whose projections are B b, conceive a right line parallel to the second given right line, and construct its projections by drawing, indefinitely, B E parallel to C D, and $b\ e$ parallel to $c\ d$. In like manner, construct the point, E, of coincidence of this parallel with the horizontal plane, by drawing e E perpendicular to L M; and the point E will be a second point of the horizontal trace of the plane. Then, if the right line A E be drawn, and produced till it cut, in the point F, the line L M, it will give the horizontal trace; and it is evident, that if through the points F and b, the right line F b be drawn, we shall have the trace on the vertical plane.

"(2.) To construct the line of contact of the plane with the cylindric surface; from any point of the second right line, which is the axis of the cylinder (as from the point C, for example, in which it meets the horizontal plane) drop a normal, that is, a perpendicular upon the tangent plane: and the foot of such normal will be a point of a line of contact.

"To find this foot, according the method already laid down in *Figure* 6, first construct the indefinite projections of the normal, by drawing through the point C, the line H G perpendicular to the trace A E, and through the point c, the line c K, perpendicular to the trace F b; then having produced H G till it meet A E in the point G, and L M in H, project the point G in g, and the point H in h, on the trace F b; draw the line $g\ h$, whose intersection with c K will determine the vertical projection, i, of the foot of the normal; and we shall have, on G H, the horizontal projection of the same point by letting I i fall perpendicularly on L M. The projections, i, I, of the foot of the normal being found, draw I N through the point I, parallel to C D, and $i\ n$, parallel to $c\ d$, and we shall have the projections of the line of contact of the plane with the cylindric surface. Lastly, the points N, n, in which these projections meet those of the first given right line, will be the projections of the point of such line, through which the common perpendicular required will pass.

"(3.) Having ascertained the projections, N, n, of one of the points of the required common perpendicular, it will be sufficient to obtain the projection of the perpendicular itself, to draw through the points N, n, the right lines N P, $n\,p$, perpendicular to the respective traces A E, F b; and the parts N P and $n\,p$ of these perpendiculars, comprised between the projections of the two given right lines, will be the projections of the required shortest distance.

"(4.) In conclusion, if the size of this shortest distance be desired to be known, it may be constructed by the process of *Figure* 3.

"The consideration of a cylindric surface touched by a plane, was not essential to the solution of the preceding question. After having supposed a plane parallel to the two given right lines, we might through each of these lines have drawn to such plane, a perpendicular plane; and the intersection of these two planes would have been the direction of the required shortest distance. We content ourselves with announcing this second method, and advise the reader to seek its construction by way of exercise.

"In the several questions which we have resolved relative to planes tangent to curved surfaces, we have always supposed the point, through which the tangent plane should be drawn, to be taken on the surface, and to be itself the point of contact: this condition alone sufficed to determine the position of the plane. But it is different when the point through which the plane should pass is taken out of the surface.

"In order to determine the situation of a plane, it must satisfy three several conditions, each equivalent to that of passing through a given point. Now, in general, the property of being tangent to a given curved surface, when the point of contact is not indicated, is only equivalent to one of these conditions: if, therefore, we propose to determine the position of a plane by conditions of this nature, we shall generally have occasion for three. For instance: suppose three curved surfaces to be given, and that a plane be tangent to one of them, in any point whatever; we can conceive that such plane would move around the surface, without ceasing to touch it: it would do so in every direction; only the point of contact would shift its situation on the surface, in proportion as the tangent plane changed its position; and the direction of the point of contact would be similar to that of the motion of the plane. Suppose this movement to be made in a certain direction till the plane meet the second surface, and touch it in a given point: then the plane would be tangent to the two first surfaces at once, and its position would not yet be fixed. Indeed, the plane may be supposed to turn about the two surfaces, without ceasing to touch them both. It will no longer, however, be free to move in every direction, as before, but will be confined to one only. In proportion as the plane changes its position, the two points of contact will move each upon the surface to which it belongs; so that if a right line be conceived as passing through those points, their movements will be in the same direction with respect to such line, when the plane touches the two surfaces on the same side, and they will be in a contrary direction, when it touches one surface on one side, and the other on the contrary side. Lastly, imagine this motion, which is the only one that can now take place, to be continued till the plane touch the third surface in a certain point; then its position will become fixed, and it can no longer move without ceasing to be tangent to one of the three surfaces.

"Hence we may perceive, that to determine the position of a plane by means of indeterminate contacts with given curved surfaces, we shall generally require three such surfaces. Thus, were it proposed to draw a tangent line to a given curved surface, this condition would be equivalent to only one of the three to which the plane is capable of answering: we might, again, take two others, at pleasure, and for example, make the plane pass through two given points, or, which is the same thing, along a given right line. Were it essential that the plane should be tangent to two surfaces at once, two conditions would be fulfilled; there would remain but one to be disposed of, and the plane could only be brought to pass through one given point.—Lastly, when the plane touches three given surfaces at once, there remains no longer any condition to be disposed of; its position is determined.

"The preceding observations relate to curved surfaces generally; yet we must except from them, whatever regards cylindric, conic, and developable surfaces; in which the contact with the plane is not reduced to a single point, but extends along the whole length of an indefinite line, which loses itself in the generator, in one of its positions. The property of a plane touching one only of these surfaces, would be equivalent to two conditions, since it would subject it to pass along a right line; and there would only remain one condition to be disposed of, viz., to make it pass through a given point. It were in vain, therefore, to propose to draw a plane, that should be at one time tangent to two of these surfaces, much less to three of them, unless there were some peculiar circumstances which should render these conditions compatible.

"It may not be altogether useless, before we proceed farther, to illustrate by a few examples, the necessity there is for drawing planes tangent to curved surfaces through points taken from the outside of them. The first of these examples is selected from the construction of fortifications.

"In treating of the general principles of fortification it is taken for granted, first, that, in every direction, the ground by which the place is surrounded, at least within the reach of cannon-shot, is flat, and free from every eminence that might be converted to advantage by a besieging army. This hypothesis being settled, the draught of the place is next determined, with its half-moons, covered ways, and advanced works; the bearings of the various parts of the fortifications upon each other are then marked out, so that they may all contribute, in the most efficacious manner, to their mutual and reciprocal defence. But, in order to apply these principles to cases where the surrounding country presents some height, of which besiegers might take advantage, and from which it is requisite that the fortification should be made to defile, a new consideration presents itself. If there be only a single eminence, two points should be fixed upon in the place, through which might be conceived a plane tangent to the height, from which it is desirable to defile: this tangent plane is denominated *the defiling plane;* and all the parts of the fortification must receive the same relief above such plane, as they would have had above the horizontal plane, had the country been quite level: by this means, they all acquire, relatively upon each other, and collectively upon the neighbouring height, a command equal to what they would otherwise have possessed over the flat country: and the fortification will possess the same advantages as in the first case. As to the choice of the two points, through which the defiling plane ought to pass, it must be conformable to the two following conditions: 1st, That the angle formed by the plane with the horizon, be the least possible, in order that, the platforms having less slope, the service of defence may be attended with fewer impediments; 2dly, That the relief of the fortification above the natural ground, be likewise as little as possible, that its construction may require less labour, and be attended with less expense.

"Should there be two heights in the environs of the place, from which the fortification should defile, the defiling plane must be tangent to the surfaces of both, at the same time: and to determine its position, there is but one disposable condition; and it is to be disposed of, by choosing in the place, a point, through which the plane may pass, as nearly conformable as possible to the conditions prescribed in the first case.

"The second example we shall take, is from painting.

"The surfaces of bodies, especially when polished, present brilliant points, whose lustre may be compared to that of the luminous body by which they are enlightened. The brightness of these points is greater, and their extent more confined, in proportion as the surfaces are more polished. When the surfaces are unpolished, the brilliant points have much less lustre, and occupy a greater portion of the surface.

"In every surface, the position of the bright point is determined by the following condition; that the incidental ray of light, and the reflected ray, directed to the eye of the spectator, be in the same plane, perpendicular to the plane tangent in this point, and make equal angles with it; for the shining point of the surface acts as a mirror, and reflects upon the eye a portion of the image of the luminous object. The determination of this point demands the utmost precision: for be the design never so correct, or the apparent contours traced with mathematical nicety, the least mistake committed in fixing the position of the brilliant point would be productive of the most palpable errors in the appearance of the shapes. We will give a single, but very striking case in proof.

"The surface of the ball of the eye is polished, and covered with a thin moisture, which renders the gloss more perfect. When we look upon an open eye, we see a bright point upon its surface, of great lustre, but of very limited extent, whose position depends upon the situation of the observer and the direction of the illuminating object. Were the surface of the eye perfectly spherical, it might turn on its vertical axis without in the least affecting the position of the brilliant point: but the surface being lengthened in the direction of the axis of vision, the position of the point is changed every time that the eye moves upon its vertical axis. Long experience having made us familiar with this change, our judgment, as to the direction of the eye, is considerably biassed by it. By the difference of position in the bright points upon the balls of the two eyes of a person, we chiefly judge whether he squint, or not; whether he look towards us; and when he does not, to which side his attention is directed.

"We do not pretend to infer from this example, that it is indispensable, in a picture, that the position of the brilliant point upon the ball of the eye be geometrically defined; our intention is merely to demonstrate how trifling errors as to this position may produce considerable distortion in the apparent form of the object, though in other respects the tracing of its apparent outline may remain the same.

"We now proceed to the determination of planes tangent to curved surfaces, drawn through points taken on the outside of them.

"The surface of the sphere is one of the most simple that can fall under our consideration; it has common generations with a great number of different surfaces; we may, for example, class it among revolving surfaces, and say nothing particular relative to it. But its regularity is productive of remarkable results, some of which are curious from their novelty, and with them, in the first instance, we are now about to be occupied, not so much on their own account, as to acquire, by the observation of the three dimensions, a habit, of which we shall stand in need, for more general and useful subjects.

"*First Question.*—Through a given right line to draw a tangent plane to the surface of a given sphere.

"*Solution.*—First method. *Figure* 16. Let A, *a*, be the two projections of the centre of the sphere; B C D, the projection of the great horizontal circle; E F, *e f*, the two indefinite projections of the given right line. Through the centre of the sphere, imagine a plane perpendicular to the right line, and construct, by the methods given under *Figure* 6, the projections G, *g*, of the point of coincidence of the right line with the plane.

"From this position, it is evident, that from the given right line two tangent planes may be drawn to the sphere, the first on one side, the second on the other, and, consequently, that the sphere will be placed between them: this indicates two different points of contact, whose projections we must now construct.

"If from the centre of the sphere, a perpendicular be conceived to fall upon both the tangent planes, they will each be bounded, at the point of contact with the surface of the sphere, by the corresponding planes; and will both be in the plane perpendicular to the given right line: therefore the two points of contact will be in the section of the sphere by the perpendicular plane; a section which must be the circumference of one of the great circles of the sphere, and to which the two sections made in the tangent planes by the same plane will be tangent.

"If in the perpendicular plane, and through the centre of the sphere, an horizontal line be imagined, whose vertical projection may be obtained by drawing the horizontal line *a h*, and its other projection by letting the perpendicular A H fall upon E F; and if the perpendicular plane be conceived to turn upon this horizontal line, like a hinge, till it become horizontal itself; it is evident that its section with the surface of the sphere would be lost in the circumference B C D, that the two points of contact would then be upon this circumference, and that were the point J constructed, in which, by this movement, the perpendicular plane would meet the given right line; the tangents J C, J D, drawn to the circle B C D, would determine these two points of contact to the position in which they then appear. It is easy to construct the point J, or, which is tantamount, to find its distance from the point H; for the horizontal projection of this distance is G H, and the difference of the vertical heights of its extremities is $g\ g'$; therefore by transferring the distance G H upon the horizontal line *a h*, from *g* to *h*, the hypothenuse *h g* will be the amount of this distance; and by transferring *g h* upon E F, from H to J, and drawing the two tangents J C, J D, the two points of contact, C, D, will be determined to the position they assumed, whilst the perpendicular plane was laid upon the horizontal one.

"Now, to find their projections in the position which they ought naturally to have, we must suppose the perpendicular plane to be restored to its original position, by turning it back upon the horizontal line, or hinge, A H, and it will carry with it the point J, the two tangents J C, J D, produced till they cut A H in the points K K′, and the chord C D, which will likewise cut A H, in the point N. In this movement, it is evident, that the points K, K′, N, which are upon the hinge, will be fixed, and that the two points of contact C, D, will describe arcs of circles, which will be in planes perpendicular to the hinge, and whose horizontal projections will be obtained by dropping from the points C D, the indefinite perpendiculars

C P, D Q, upon A H. The horizontal projections of the two points of contact will therefore be found upon the two right lines C P, D Q. But in the retrograde movement of the perpendicular plane, the two tangents J C K′, J K D do not cease to pass through the respective points of contact; and when this plane is returned to its primitive position, the point J is projected anew in G, and the two tangents are projected according to the right lines G K′, G K. The two latter, therefore, must each contain one of the points of contact; and, in fine, the intersections of these two right lines with the respective lines C P, D Q, will determine the horizontal projections, R, S, of the two points of contact, which are found in the same line with the point N.

"To obtain the vertical projections of the same points, first, draw the indefinite perpendiculars R *r*, S *s*, upon L M; then by projecting the points K K′, to *k*, *k′*, and drawing the lines *g k*, *g k′*, from the point *g*, we shall have the vertical projections of two similar tangents. These lines, therefore, will contain the projections of the respective points of contact; and the points, *r*, *s*, of their intersection with the vertical lines R *r*, S *s*, will be the projections required.

"The horizontal and vertical projections of the two points of contact being found, to construct, upon the horizontal plane the traces of the two tangent planes, lines parallel to the given right line must be conceived to pass through each of the points of contact. These lines will be in the respective tangent planes, and their horizontal and vertical projections will be obtained by drawing R U, S V, parallel to E F, and *r u*, *s v*, parallel to *e f*. On the horizontal plane, construct the trace, T, of the given right line, and the traces, U, V, of the two last lines; and the lines T U, T V, will be the traces of the two tangent planes.

"Instead of supposing fresh lines to pass through the points of contact, we may find the traces of the two tangents G R, G S, which will answer the same purpose. As to the traces of two similar planes with the vertical plane, they may be obtained by the method already so often alluded to.

"This solution may be rendered much more elegant by making the two planes of projection pass through the centre of the sphere itself. By this mode the two projections of the sphere would be mingled in the same circle, and the productions of the right lines would not be so long. We have only separated the two projections for the sake of perspicuity in the exposition: for it is easy to give to the construction all the conciseness of which it is susceptible.

"Second Method.—*Figure* 17. Let A, *a*, be the two projections of the centre of the sphere; A B, or *b*, its radius; B C D, the projection of its great horizontal circle; and E F, *e f*, the projections of the given right line. Conceive the plane of the great horizontal circle produced till it cut the given right line in a certain point, and we shall have the vertical projection of the plane, by drawing the indefinite horizontal line *b a g* through the point *a*; the point *g*, where this horizontal line cuts *e f*, will be the vertical projection of the point of coincidence of the plane with the given right line; and we shall have the horizontal projection, G, of this point by projecting *g* upon E F.

"This done, take the same point for an apex, and conceive a conic surface covering the sphere, all whose generating lines touch it in their respective points; now, we shall have the projections of the two horizontal generators of such conic surface, by drawing from the point G, the two lines G C, G D, tangent to the circle B C D, and which will touch it in the two points C, D, as may be easily determined. The conic surface will touch that of the sphere, whose line C D will be the diameter, whose plane will be perpendicular to the axis of the cone, and consequently vertical, and whose horizontal projection will be the line C D.

"If from the given right line two tangent planes to the conic surface be conceived, each of them will touch it, according to one of the generating lines, which will be at the same time on the conic surface and on the plane; and since such generating line also touches the surface of the sphere in one of its points on the circumference of the circle projected in C D, it follows, that this point is at once on the conic surface, on the plane which touches it, on the surface of the sphere, and on the circumference of the circle projected in C D, and that it is a point of contact common to all these objects. Hence we may conclude, 1st, That the two planes tangent to the conic surface, are also tangent to the surface of the sphere; 2dly, That their points of contact with the sphere, being in the circumference of the circle projected in C D, must be themselves projected on some part of this right line; 3dly, That the right line passing through the two points of contact, being comprised in the plane of the same circle, must also be projected indefinitely upon C D.

"We next proceed to an operation, for the plane of a large circle parallel to that of the vertical projection, similar to that which we have just finished for the great horizontal circle. The horizontal projection of such plane will be the right line B A H, indefinitely parallel to L M; the point wherein it meets the given right line will be horizontally projected to the intersection H, of the two right lines E F, B A H; and its vertical projection will be obtained by projecting the point H upon *e f*, in *h*. Conceive a new conic surface, whose apex shall be in this point of coincidence, and which, like the former, shall cover the sphere; and we shall have the vertical projections of the two extreme generating lines of such surface, by drawing from the point *h*, to the circle *b* K I, the tangents *h* K, *h* I, which shall touch it in such points, K I, as we may determine. This second conic surface will touch that of the sphere, in the circumference of a new circle, of which K I will be the diameter, and of which the plane, perpendicular to that of the vertical projection, will, consequently, be projected indefinitely upon K I. The circumference of this circle will likewise pass through the two points of contact of the sphere with the tangent planes required; whence the vertical projections of those two points of contact will be somewhere upon K I; and the right line by which these two points are united, will also be projected upon the same line K I.

"Thus the right line drawn through the two points of contact, is projected horizontally upon C D, and vertically upon K I; it meets the plane of the great horizontal circle in a point, whose vertical projection is at the intersection, *n*, of K I with *b a g*, and whose horizontal projection may be obtained by projecting the point *n* upon C D.

"This done, suppose the vertical plane of the circle, projected in C D, to turn upon its horizontal diameter, as upon a swivel, so as to become horizontal, and that it draw with it, in its movement, the two points of contact, through which its circumference passes, and the right line by which those two points are united. Construct this circle, in its new position, by describing upon C D, as a diameter, the circle C P D Q; and if the position assumed by the line uniting the two points of contact be constructed, it will cut the circumference C P D Q in two points, which will determine them upon this circumference considered in its horizontal position.

"The point, N, of the line of the two contacts, being upon the swivel C D, does not change its position by the movement: this line must, therefore, pass through such point when it has become horizontal. Besides, the point in which it meets the plane of the great circle, parallel to the vertical projection (a point whose horizontal projection is in the coincidence, O, of the two lines C D, D A H, and whose vertical projection *t*, is found by projecting the point O upon K I) describes in its movement upon the swivel C D, a quarter of a circle perpendicular to C D, whose radius is the vertical line *o t;* if, then, a line be drawn through the point O, perpendicular to C D, and if upon such perpendicular *o t* be transferred, from O to T, the point T will be one of those of the line of contact, when it becomes horizontal. Therefore, if a line be drawn through the points N and T, its two points of coincidence, P, Q, with the circumference C P D Q, will be the two points of contact considered in the vertical plane, when laid down.

"To obtain the horizontal projections of the same two points in their natural positions, imagine the circle C D P Q to be returned to its original station, by turning on the same swivel C D. In this movement, the two points P, Q, will describe quarter-circles in the vertical planes perpendicular to C D, whose horizontal projections will be the perpendiculars P Q, R S, dropping upon C D. The horizontal projections of the two points of contact will then be respectively upon the lines P Q and R S; and as we have seen that they must likewise be upon C D, they must, consequently, be upon the two points of coincidence R and S.

"The vertical projections, *r*, *s*, of the same two points may be obtained, by projecting the points R and S upon K I; or, which amounts to the same, by transferring upon the vertical lines R *r*, S *s*, beginning from the horizontal line *b a g*, *r' r*, equal to P R, and *s' s*, equal to Q S.

"The horizontal and vertical projections of the two points of contact being constructed, the traces of the two tangent planes may be determined according to the method of the first solution.

"This second solution may be rendered much more concise, by making the planes of projection pass through the centre of the sphere; which would reduce the two projections to one figure.

"These latter considerations lead us to the discovery of some remarkable properties of the circle, of the sphere, of conic sections, and of curved surfaces of the second degree.

"It has been seen, that the two conic surfaces bounded by a sphere, would each touch it in the circumference of a circle, and that their circumferences would both pass through the two points of contact of the sphere with the tangent planes. This property is not peculiar to the two conic surfaces that we have considered, but applies to all such as have their apex in the given right line, and are circumscribed by the sphere. If, therefore, we suppose a prime conic surface, which, having its apex upon the given right line, is bounded by the sphere; and if this surface be supposed to move so as that its apex may run along the right line without ceasing to be contained within, and tangent to the sphere; it will in any of its positions touch the sphere in the circumference of a circle: all which circumferences will pass through the same two points in which the sphere comes in contact with the two tangent planes; and the planes of these circles will intersect each other upon one right line, which is that of the two contacts. If now the plane be conceived as drawn from the given right line, and from the centre of the sphere, it will pass through the axes of all the conic surfaces, will be perpendicular to the planes of all the circles of contact, consequently to the right line that is their common intersection, and cut all these planes in right lines that will pass through one point.

"By reciprocity, a sphere and a right line being given, if a number of planes, taken at pleasure, be conceived as passing along the right line, which shall cut the sphere, each in the direction of a circle; and if, for each of such circles, a right conic surface be conceived, of which it shall be the base, and which shall be confined within the sphere, the apices of all such conic surfaces will be another identical right line.

"By merely considering what happens in drawing the plane from the given right line, and from the centre of the sphere, we are led to the two following propositions, which are immediate corollaries of what has preceded.

"*Figures* 18 and 19.—Given in a plane, a circle, whose centre is A, and any right line whatever, as B C; if, after having drawn from a point, as D, of the right line, two tangents to the circle, and the lines E F connecting the points of contact, the point D be supposed to move along the right line B C, drawing with it the two tangents, without ceasing to touch the circle; the two points will shift their position, as well as the line E F, by which they are united, but the latter will always pass through the same point, N, upon the perpendicular, A G, dropped from the centre of the circle upon the right line B C.

"And, reciprocally, if, through a point, as N, taken in the plane of a circle, a number of lines, as E F, be drawn at pleasure, each cutting the circumference of the circle in two points; and if through these two points two tangents to the circle, E D, F D, be drawn, to meet in a point, as D, all the other points of intersection, found in the same manner, will be upon the same right line, B C, perpendicular to A N.

"It is not because all the points of the circumference are equally distant from the centre, that the circle possesses the property just described; but because it is a curve of the second order, and has all its conic sections of the same quality.

"*Figure* 20.—For example, let A E B F be a conic section of any kind, and C D any given right line upon its plane: suppose the curve to turn upon one of its axes, A B, to generate a surface of revolution, and imagine the two tangent planes to this surface drawn from the right line C D; the two planes will each have their particular point of contact. Now take for an apex, any point whatever, as H, of the right line C D, and conceive the conic surface contained within, and tangent to the revolving surface, and it will touch the latter in a curve that must necessarily pass through the same two points of contact as the tangent planes. This curve will be plain; its plane, which will be perpendicular to that of the given conic section, will be projected upon the latter, according to the line E F; and this line will pass through the points of contact of the tangents with the conic section, drawn from the point H. Now, suppose the apex, H, of the conic surface to move along the right line C D, without ceasing to be contained within, and tangent to the revolving surface; in any of its positions, its curve of contact will possess the same properties of passing through the two points of contact with the tangent planes, of being plain, and of having its plane perpendicular to the conic section. The planes, therefore, of all the curves of contact will touch the ends of the line that unites the two points of contact, which is itself perpendicular to the plane of the conic section, and hence the projections of all the planes will be right lines that must all touch the ends of the projection, N, of the line, by which the two points of contact are joined.

"This proposition is only a particular case of another more general one, that takes place in the three dimensions, and which we shall be content with announcing in this place.

"Any curved surface whatever, of the second degree, and a conic surface contained within, and touching it, whose apex is a point chosen at pleasure, being given in space; if the conic surface move without ceasing to be contained within, and to touch the curved surface, but so as that its apex be kept in a right line, the plane of the curve of contact of the two surfaces will always pass upon one right line (which will be determined by the contacts of the surface of the second degree with the two tangent planes that pass along the line of the apices); and if the conic surface move so as that its apex be always in the same plane, the plane of the curve of contact will always pass upon the same point.

"*Second Question.*—From a given point, to draw a plane tangent to the surface of two given spheres.

"*Solution.—Figure* 21.—Let A, *a*, be the two projections of the centre of the first sphere; B, *b*, those of the second; and C, *c*, those of the given point. After having drawn the indefinite lines A B, *a b*, which are projections of the line that would pass through the two centres, and having constructed the projections G E F, *g e f*, H I K, *h i k*, of the great circles of the two spheres parallel to the planes of projection, conceive a conic surface containing the two spheres within it, and touching them both at the same time; the apex of this surface will be in the line which passes through the two centres. Then draw to the two circles G E F, H I K, the two common tangents E H, F K, meeting in the point D, of the right line A B; this point will be the horizontal projection of the apex of the cone, whose vertical projection, also, will be obtained by projecting the point D to *d*, on the production of *a b*. Lastly, draw the projections C D, *c d* of the right line passing through the apex of the cone and the given point. Now, if from this latter line two tangent planes be conceived to the conic surface, they will each touch it in one of its generating lines, and consequently will both be tangent, at the same time, to the two spheres. The question is therefore reduced to drawing two planes tangent to the surface of one of the spheres, from the right line that passes through the apex of the cone and the given point; which may be done as in the preceding question, and the two planes will also be tangent to the second sphere.

"It must here be remarked, that the same two spheres may be supposed to be contained within two conic surfaces. The first conic surface will envelope them both on the outside, and will have its apex on the outside of one of the spheres, with respect to the other, and the tangent planes to it will touch the two spheres on the same sides. The second conic surface will also envelope both spheres, but will have its apex between the two centres. The horizontal projection, D′, of this apex will be found by drawing to the circles E F G, H I K, the two interior tangents, which intersect each other in a point of the line A B; and its vertical projection by projecting the points D′ to *d*′, upon *a b*. The two tangent planes, drawn to this conic surface will also each touch the two spheres; but they will touch the first on one side, and the second on the other. Thus, four different planes may answer this question: for two of them, the two spheres are on the same side of the plane; and for the two others, they are on different sides.

"*Third Question.*—To draw a plane tangent at the same time to three spheres of given dimensions and positions.

"*Solution.*—Imagine the plane tangent at the same time to the three spheres; suppose, also, a conic surface containing the two first of those spheres, and touching them both; and the tangent plane will touch such conic surface in the whole length of one of its generating lines, and pass through the apex of the cone. If a second conic surface be supposed, containing the first and third spheres, the same tangent plane will also touch it along the length of one of its generating lines, and will consequently pass through its apex. Lastly, if a third conic surface be conceived, enclosing and touching the second and third spheres, the tangent plane will still touch it along one of its generating lines, and pass through its apex. Thus the apices of the three conic surfaces will be in the tangent plane; but they will also be in the plane which, passing through the centre of the sphere, contains the three axes: they will therefore be in two different planes at the same time; consequently, they will be in a right line. Hence it follows, that if the horizontal and vertical projections be constructed, as laid down in the preceding question, of which two will be sufficient, the projection of a line found upon the tangent plane may be made to pass through them. The question is therefore reduced to the drawing from a given right line, a tangent plane to that of the three spheres sought for, which may be done by the preceding methods, and this plane will be tangent to the two others.

"It must be observed, that, as we may always imagine, for any two spheres, two conic surfaces which envelope and touch them both, the first having its apex on the outside of one of the centres, with respect to the other, and the second having its apex between the two, it is evident, that in the preceding question there will be six conic surfaces, of which three will be on the outside of the three spheres, taken two by two, and three will have their apices between the spheres. The apices of these six cones will be distributed, three and three, upon four right lines, along each of which may be drawn two planes tangent at the same time to the three spheres. Thus eight different planes are sufficient for this question: two of which touch the three spheres on the same side relatively; and the other six are so disposed as to touch two of the spheres on one side, and the third on the other. These considerations lead to the following proposition:

"*Figure* 22.—Three circles whatever being given in position and magnitude on a plane, if, considering them two at a time, exterior tangents be drawn to them, produced till they intersect each other, the three points of intersection, D, E, F, so obtained, will be in a right line.

"Here, if we imagine the three spheres, of which these circles are the great circles, and a plane that touches them all three exteriorly, such plane will also touch the three conic surfaces contained within the spheres, considered two by two, and pass through their three apices, D, E, F; but these three apices are likewise upon the plane of the three centres; therefore they are on two different planes, and consequently in a right line.

"If to the same circles, considered two by two, interior tangents be drawn, intersecting each other, the three new points of intersection, G, H, I, will be, two by two, in a right line with the three first; so that the six points D, E, F, G, H, I, will be the intersections of the four right lines.

"This question is only a particular case of the following, which applies to all the three dimensions.

"The size and position of any four spheres being given in space, if the six conic surfaces circumscribed exteriorly by them, considered two by two, be conceived, the apices of the six cones will be in the same plane, and at the intersections of the four right lines; and if the other six conic sections, circumscribed interiorly by them, viz., that have their apices between the centres of the two spheres, be conceived, the apices of the six latter cones will be, taken three by three, in the same plane with three of the former.

"*Fourth Question.*—From an arbitrary point, to draw a tangent plane to a given cylindric surface.

"*Solution.—Figure* 23.—Let E I F K be the trace of the cylindric surface on the horizontal plane; a trace that we

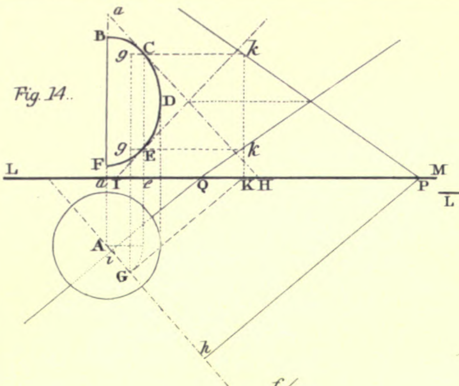


Fig. 14.

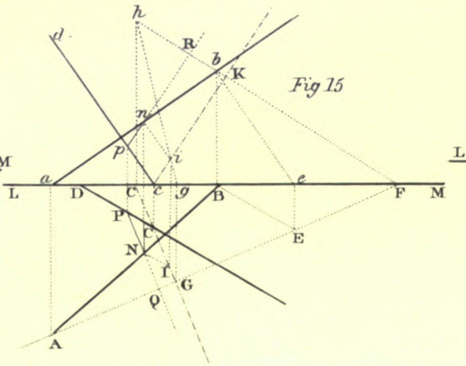


Fig. 15

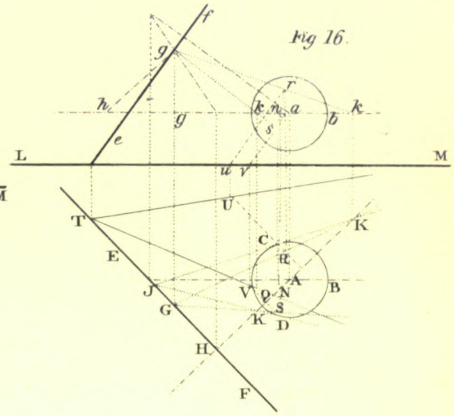


Fig. 16.

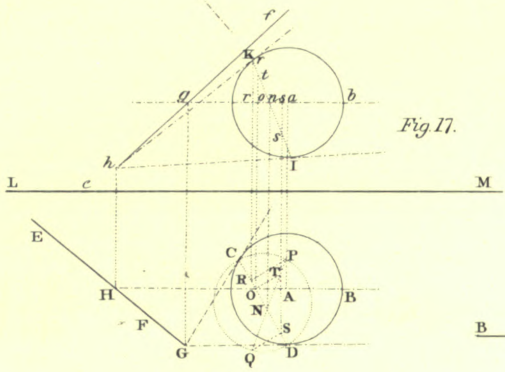


Fig. 17.

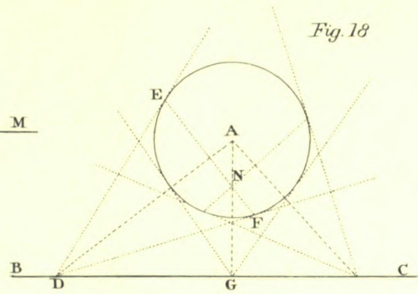


Fig. 18

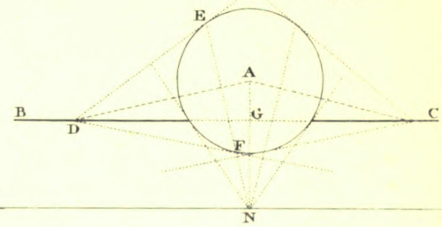


Fig. 19.

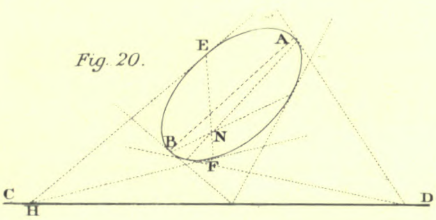


Fig. 20.

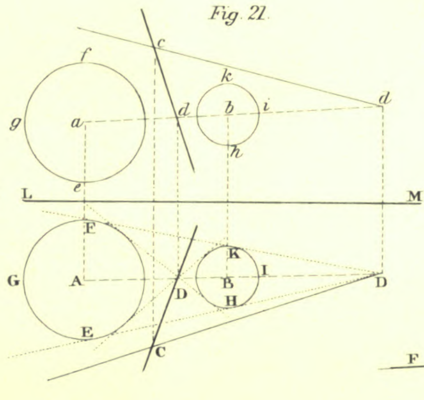


Fig. 21.

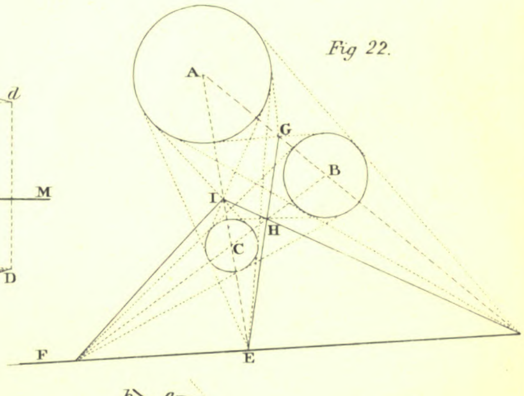


Fig. 22.

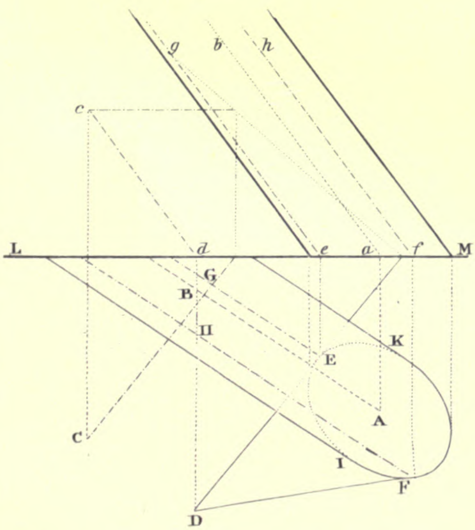


Fig. 23.

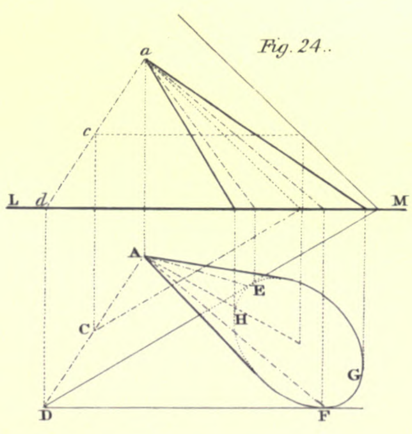


Fig. 24.

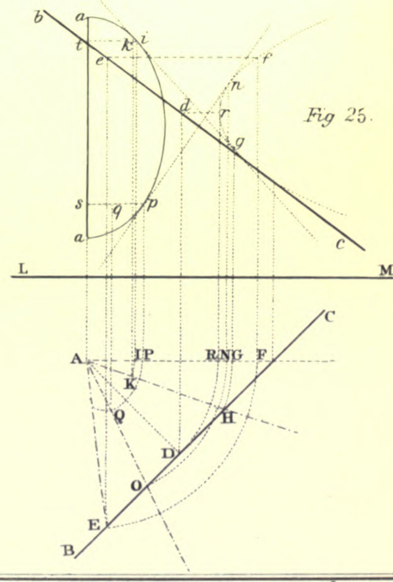


Fig. 25.

Drawn by M. A. Nicholson. Eng.d by R. Thew.

suppose to be given. Let A B, *a b*, be the two given projections of the right line, to which the generating line should always be parallel; and C, *c*, those of the given point. Conceive from this point a parallel to the generating line, it will be in the tangent plane required, and the points where it cuts the planes of projection will be upon the traces of the tangent plane. Then if from the point C, C D be drawn parallel to A B, and from the point *c*, *c d* parallel to *a b*, we shall have the two projections of this right line; then, having produced *c d* till it meet L M in the point *d*, if the point *d* be projected to D, upon C D, the point D will be the coincidence of this right line with the horizontal plane, and consequently a point of the trace of the tangent plane. Now, the horizontal trace of the tangent plane ought to be tangent to the curve E I F K, therefore, if from the point D we draw to such curve all the tangents possible, as D E, D F, &c. we shall have the horizontal traces of all the tangent planes that can possibly pass through the given point. By drawing from the points of contact E, F, &c. to A B, the indefinite parallels E G. F H, &c. we shall obtain the horizontal projections of the generating lines, wherein the different planes touch the cylindric surface. Lastly, we shall have the vertical projections *e g*, *f h*, &c. of these generating lines, or lines of contact, by projecting the points E. F, &c. upon the vertical plane, to *e*, *f*, &c. and by drawing from these latter points indefinite lines parallel to *a b*. As to the traces of the tangent plane upon the vertical plane, they will be found in the working of *Figure* 12.

"*Fifth Question.*—From an arbitrary point, to draw a plane tangent to a given conic surface.

"The solution of this question differing but little from that of the preceding one, we shall only refer to the *Figure* 24, where the curve E G F H, is the given trace of the conic surface; A, *a*, are the given projections of the apex; and C, *c*, those of the given point, through which the tangent plane must pass.

"*Sixth Question.*—From a given line, to draw a tangent plane to a given revolving surface.

"*Solution.—Figure* 25. Suppose the axis of the revolving surface to be perpendicular to one of the two planes of projection (which will not weaken the general application of the solution, because we always retain the power of disposing of the position of these planes so as to make them conform to this rule); let A be the given horizontal projection of the axis of the surface; *a a'*, its vertical projection; *a p i a'*, the generating curve of the surface; and B C, *b c*, the two given projections of the line along which the tangent plane should pass. From the point A drop the perpendicular A D upon B C, and it will be the horizontal projection of the shortest distance between the axis and the given right line; and project the point D to *d*, upon *b c*.

"Now, suppose the tangent plane to be drawn, and the given right line to turn about the axis of revolution, without shifting its distance from it, or its inclination upon the horizontal plane, drawing with it the tangent plane, so that the latter may still touch the surface; in consequence of such movement, it is evident, that the point of contact of the surface with the plane will change its position; but since the tangent plane uniformly preserves the same inclination, the point of contact will not change its altitude above the surface, and it will move in the circumference of a horizontal circle, whose centre will be in the axis. The given right line, also, will generate by its movement a second revolving surface around the same axis, to which the tangent plane will itself be tangent in every position.

"If we suppose a plane through the axis, and through the point of contact of the tangent plane with the first surface, it will cut the generating line in a point wherein the same tangent plane will come in contact with the second; for besides the generating line, along which it passes in this point, it also passes along the tangent of the horizontal circle to the same point, since it likewise passes along the tangent of the horizontal circle to the point of contact with the first surface, and therefore, from the known property of revolving surfaces, these two tangents are parallel.

"As we wish to resolve the question by means of the second revolving surface, it becomes necessary to construct the curve according to which it would be cut by a plane drawn from the axis: here we will suppose such plane to be parallel to the vertical plane of projection, and consequently projected on the horizontal plane in a right line, A F, parallel to L M.

"Take upon the given right line, any point whatever, whose projections are E, *e*, and seek for the point wherein it would meet the plane of the section in its movement. Here the point will describe around the axis of revolution, the arc of a horizontal circle, whose horizontal projection will be obtained, by describing from the point A, as a centre, and at the interval A E, the arc E F, till it meet the right line A F, somewhere in a point, as F; the vertical projection of the same arc may be had by drawing from the point *e*, the indefinite horizontal line *e f*. The point F, then will be the horizontal projection of the coincidence of the describing point with the plane of the section; therefore, by projecting the point F to *f*, upon *e f*, the point *f* will be the vertical projection of this coincidence, and consequently a point of the section. By repeating the same operation for as many other points as may be wanted, taken on the given right line, we shall have so many points, *g*, *f*, *r*, *n*, through which the curve required must pass.

"Next imagine the given right line, and the tangent plane, by their simultaneous rotation about the axis, to have arrived at a position wherein the tangent plane would be perpendicular to the vertical plane of projection. Here the projection on this plane would be a right line, tangent at the same time to both the curves *a' i p a*, *g r n f*; and if all the common tangents, as *g i*, *n p*, be drawn to these two curves, we shall obtain the projections of all the tangent planes required by the question, considered in the position they have assumed, when in the course of the rotation they have successively become perpendicular to the vertical plane. The points of contact, *i*, *p*, of these tangents with the generating line of the first surface will determine the height of those of each surface with all the tangent planes: therefore, if from these points the indefinite horizontal lines *i t*, *p s*, be drawn, they will contain the vertical projections of the points of contact of the surface with the planes: and if from the point A, as a centre, and with the radii respectively equal to *i t*, *p s*, the arcs of a circle, I K, P Q, be drawn, such arcs will contain the horizontal projections of the same points. To complete the discovery, it only remains to determine upon what meridians of the revolving surface they ought to be found, to which end the points of contact, *g*, *n*, will be subservient.

"For this purpose, project the points *g*, *n*, upon A G, to O, N; from the point A, as a centre, with the intervals successively equal to A O and A N, describe the arcs G H. N O, till they intersect the right line B C in the points H, O; these arcs will express the quantity of the rotation, which for each tangent plane, the right line passing through its contacts with the two surfaces has been obliged to make, in order to transport itself into the vertical plane parallel to that of projection. We have, therefore, the horizontal projections of the same right lines, considered in their natural positions, by drawing from the point A the lines A H, A O; and the points, K, Q, where the latter lines intersect the correspondent arcs I K, P Q, will be the horizontal projections of the points of contact of the first surface with the tangent planes drawn along the given right line.

"The vertical projections of the same points will be obtained by projecting the points K, Q, to k, q, on the respective horizontal lines $i\ t$, $p\ s$.

"The horizontal and vertical projections of the points of contact being determined, the traces of all the tangent planes may be constructed by methods similar to those already described.

"This mode may be easily generalized and applied to any surfaces generated by curves of determinate forms, and mutable as to their situation in space."

Of the Intersections of curved surfaces.

"When the generations of two curved surfaces are positively determined and understood; when the course of all the points of space through which they pass is no longer arbitrary for either; when for each of these points, one of its two projections being taken at pleasure, the other may be always constructed; if these two surfaces have any points in space common to them both, the positions of all such common points is absolutely determined; it depends on the form of the two curved surfaces and their respective positions; and is of such a nature as to be always capable of being deduced from the definition of the generations of the surfaces, of which it is a necessary consequence.

"The course of all the points common to two determinate curved surfaces, forms in general a certain curved line in space, which, in very particular cases, may be found upon a certain plane, having but a single curvature; which, in instances infinitely more peculiar, may become a right line, without any curve; and lastly, in cases still more rare, may resolve itself into a mere point; but which, in the general, is what is denominated *a curve of double curvature*, because it ordinarily partakes of the curvatures of two curved surfaces, upon each of which it is found at the same time, and forms their common intersection.

"There exists between the operations of analyses and the methods of descriptive geometry, a correspondence, of which it is here necessary to give an idea.

"In algebra, when a problem is put into equations, and we have as many equations as unknown quantities, we can always obtain the same number of equations, in each of which there enters but one of the unknown quantities; whence we gain a knowledge of the value of each of them. The operation by which this is performed, is called *elimination*, and consists in expelling, by means of one of the equations, one of the unknown numbers from all the other equations; so that by thus successively expelling all the different unknown numbers, a final equation is obtained, containing only one, whose value it ought to produce.

"The object of elimination in algebra bears a close analogy to those operations in descriptive geometry, by which the intersections of curved surfaces are determined.

"For example: suppose that in considering a point in space, and representing, by x, y, z, the distances from this point to three rectangular planes between them, a relation be established between these three distances, and that it be expressed by an equation, wherein the three quantities x, y, z, and fixed quantities enter. By virtue of this relation, the position of the point would not be determined; for the quantities x, y, z, may change their value, and consequently the point may vary in its position, without destroying the relation expressed by the equation; and the curved surface which passes through all the positions that the point may thus occupy, without abating the relation established between the three co-ordinates, is that to which the equation belongs.

"Thus, suppose a sphere, whose radius is expressed by A, have its centre in the point of intersection common to the three rectangular planes; and that in considering a certain point on the surface of the sphere, perpendiculars be supposed to fall from such point upon the three planes, and to be represented by the letters x, y, z; it is evident that the radius of the sphere, directed to the point under consideration, will be the diagonal of a rectangular parallelopiped, whose three arêtes will be x, y, z; that its square will be equal to the sum of the four squares of the four arêtes; and that we shall thus have the equation $x^2 + y^2 + z^2 = A^2$. Now, should the point change its position on the surface of the sphere, its distances, x, y, z, as to the three rectangular planes, would vary also; but its distances as to the centre would remain unaltered, and the sum of the squares of its three co-ordinates, which is always equal to the square of the radius, would still retain its first value: we should therefore have the relation between the co-ordinates of this point expressed by the equation $x^2 + y^2 + z^2 = A^2$. This equation, which answers for all the points of the surface of the sphere, and for them only, is that of the surface itself. All curved surfaces have, thus, each its equation; and though it be not always easy to express it in such simple quantities as the distances x, y, x, it is always possible to obtain it in more complex quantities, such as the inclinations of tangent planes, or the radii of curvatures: but it is sufficient for our present purpose to have conveyed our meaning by one example.

"If now, having, in x, y, z, the equations of two different curved surfaces, and supposing that for the points of the two surfaces the distances be taken to the same rectangular planes, we eliminate one of the three quantities x, y, z, the latter, for example, from the two equations; we establish first, by the similarity of these two equations, that which does not belong indiscriminately to all the points of the first surface, nor to all those of the second, with which we are occupied, but only to those of their intersection, for which each of the two equations ought to serve, because they are upon the two surfaces at the same time. Secondly, the equation in x, y, which results from the elimination of z, expresses the existing relation between the two distances for all the points of intersection, whatever may be the distance z, which has disappeared, and about which there is no longer any question in the equation; it is therefore the equation of the projection of the intersection of the two surfaces upon the plane perpendicular to z.

"Hence we discover that in algebra, the design of elimination among many equations with three unknown qualities, is to determine, upon the three planes to which all space is referred, the projections of the intersections of surfaces to which the equations appertain.

"The similitude between the operations of analysis and the methods of descriptive geometry, are not confined to the instance just given, but prevails in every situation. In working generating lines of any description in space, whatever movements be given to points, curved lines, or surfaces, they may always be governed by analytical operations; and the new objects which they originate, are expressed by the very results of such operations: on the other hand, there is no operation of analysis in three dimensions, but what is the expression of a movement operated in space, and ruled by it. To obtain the most advantageous acquaintance with the mathematics, the student should early accustom himself to perceive the existing analogy between the operations of analysis and those of geometry: on the one hand, he should be able to write down all the movements that he can conceive in space, in one analytical method; and on the other, to perpetuate upon his memory, the object moving in space, of which each of the analytical operations is the expression.

" We now return to our subject, viz., the mode of determining the projections of the intersections of curved surfaces.

" To present the exposition of this method in a clearer light, we shall not at first disclose it with all the elegance of which it is susceptible, but proceed towards it by degrees. And here it may be premised, that the exposition will be general, and applicable to any two surfaces whatever; and that though the letters used refer to the *Figure* 26, which shows the particular case of two conic surfaces, with circular bases and vertical axes, the reader should keep in mind, that the surfaces under consideration may be, each one in particular, any other than conic surfaces.

" *First general problem.*—The generating lines of two curved surfaces being known, and all the given lines which fix such generators being determined on the plane of projections; to construct the projections of the curve of double curvature, according to which the two surfaces intersect each other.

" *Solution.—Figure* 26. Conceive a series of indefinite planes, conveniently disposed in space; such planes, for example, may be all horizontal, as in fact we shall suppose them in the first instance. Here the vertical projection of each of them will be an indefinite horizontal right line; and as we are not restrained from drawing them at arbitrary distances, we shall suppose in the vertical projection as many horizontal lines, *e e′*, *e e′*, *e e′*, &c. as we please, and that the series of these lines is the vertical projection of the series of planes at first conceived. This done, work successively, for each of such planes, and relatively to the line *e e′*, which is its projection, the operation we are about to lay down for the one among them, that is projected in E E′.

" The plane E E′ will intersect the first surface in a certain curve, which will be easily constructed, when we are acquainted with the generation of the surface; it being the course of the points in which the plane E E′ is intersected by the generating line in all its positions. This curve being plain and horizontal, will have its horizontal projection equal, similar to itself, and placed in the same manner; it is therefore possible to construct such projection, and here we shall suppose it to be the curve F O H I K.

" The same plane, E E′, will likewise cut the second surface in another plain horizontal curve, whose horizontal projection may also be constructed, as by the curve F O O.

" It may happen, that the two curves, wherein the same plane, E E′, intersects the two surfaces, may intersect each other, or they may not: if they do not intersect each other, however much produced, it proves that, at the height of the plane E E′, the two surfaces have no common point; but if these curves do intersect each other, they will do so in a certain number of points common to the two surfaces, which are consequently so many of the points of intersection required: and according as the intersecting points of the two curves are upon the first or second of them, so are they upon the first or second of the surfaces proposed; therefore, if they be upon the two curves at once, they are also upon the two surfaces.

" As the horizontal projections of the points wherein the two curves intersect each other, should be found both on the projection of the first, and on that of the second; the points F, G . . . . of the coincidence of the two curves F O H I K, and F O Q, will be horizontal projections of as many points of the required intersection of the two curved surfaces. To obtain the vertical projections of the same points, observe that they are all comprised in the horizontal plane E E′, and that their projections must fall upon the line E E′. Therefore, by projecting the points, F, O . . . . upon E E′, to *f, g*. . . we shall have their vertical projections.

" By pursuing the same operation for all the other horizontal lines *e e′*, *e e′*, we shall obtain for each of them, in the horizontal projection, a series of new points, F, O. . . . ., &c., and in the vertical projection, another new series *f, g* . . . . &c. Then if the branch of a curve be passed through all the points F . . ., another branch through all the points G. . . . ., and so of the rest, the concourse of all these branches which may possibly meet one in another, will be the horizontal projection of the two surfaces; in like manner, if through all the points *f* . . . . a branch of a curve be passed, through all the points *g* . . . . another branch, and so of the others, the concourse of all these branches, which may likewise possibly meet one in another, will be the vertical projection of the intersection required.

" This method is general, even supposing a system of planes to be chosen which intersect a series of horizontal planes. But we shall see, presently, that in certain cases, the choice of the system of intersecting planes is not indifferent, that it may sometimes be so made as to be productive of systems more easy and more elegant; and that it may even be more advantageous, instead of a system of planes, to adopt a series of curved surfaces, which vary from each other only in one of their dimensions.

" To construct the intersection of two revolving surfaces, whose axes are vertical, the most advantageous system of planes, is a series of horizontal planes; for each of such planes intersects the two surfaces in the circumferences of circles whose centres are upon the respective axes, whose radii are equal to the ordinates of the generating curves, taken at the height of the intersecting plane, and whose horizontal projections are circles of known size and position. Here all the points of the horizontal projection of the two surfaces are found by the intersections of the arcs of a circle; and we are aware, that if all the revolving surfaces had their axes relatively parallel, but not vertical, it would be necessary to change the planes of projection, and so to choose them as that one of them should be perpendicular to the axes.

" Were it required to construct the intersection of two conic surfaces, with whatever bases, whose traces on the horizontal plane were given or constructed, the system of horizontal planes would demand operations too tedious for the example: for each of the horizontal planes would intersect the two surfaces in curves, which, though very nearly resembling the traces of the respective surfaces, would not be equal to them; they must be constructed by points, each by itself; whereas, if after having drawn a right line through the given apices of the two cones, the system of planes passing along such right line be adopted, each of the planes will cut the two conic surfaces in four right lines; and these right lines, which will be in the same plane, will cut each other, independently of the apices, in four points upon the intersection of the two surfaces. In this case, each of the points of the horizontal projection of the intersection will be constructed by the intersection of two right lines.

" For two cylindric surfaces, of whatever bases, whose generating lines are diversely inclined, the system of horizontal planes would not be the most eligible that might be adopted. They would, indeed, each cut the two surfaces in curves similar and equal to their respective traces; but the curves that did not correspond vertically to the traces would have for their projections, curves, that would be distant from the traces themselves, and which it would be necessary to construct from points. But were choice to be made of the system of planes parallel at the same time to the generating lines of the two surfaces, each of such planes would cut the two surfaces in right lines, and these lines would cut each other in points appertaining to the intersection of the two surfaces. By this means, the points of the horizontal projection would be constructed by the intersections of right lines. Indeed, this is but a necessary consequence of what has been said relative to the case of two conic surfaces.

"For two revolving surfaces, having their axes in the same plane, but not parallel to each other, the system of spherical surfaces having their common centre in the point of coincidence of the two axes, would be preferable to that of planes; for each of the spherical surfaces would cut the two revolving surfaces in the circumferences of two circles, having their centres upon the respective axes, and their planes perpendicular to the plane drawn along the two axes: the intersecting points of these two circumferences, which would be at the same time on the spherical surface and upon the two revolving surfaces, would belong to the intersection required. Thus the points of the projection of the intersection would be constructed by the coincidence of the circles with the right lines; in which case the most advantageous position for the two planes of projection is to have one perpendicular to one of the axes, and the other parallel to both.

"These few observations, with respect to such curved surfaces as most frequently meet together, will suffice to show how the general method should be employed, and how, by a knowledge of the generation of curved surfaces, that species of sections may be adopted which will yield the most ready constructions.

"When the respective form and positions of two curved surfaces are defined, not only is the curve of their intersection in space determined, but also all the affections of these curves immediately follow. Thus, for example, in each of their points the direction of their tangent is determined: it is the same as to their normal plane, viz., of the plane that cuts the curve in a right angle, and which is, consequently, perpendicular to the tangent at the point of intersection. As we shall have frequent occasion to consider planes normal to curves of double curvature, we shall not here enter into any detail as to their determination; for as they are always perpendicular to tangents, it is enough to have given the mode of constructing projections of tangents to the intersections of curved surfaces.

"*Second general Problem.*—From a point taken at pleasure upon the intersection of two curved surfaces, to draw a tangent to such intersection.

"*Solution.* The point chosen upon the intersection of two curved surfaces, is at the same time upon both such surfaces. If then, from this point, as considered on the first surface, a tangent plane be drawn to such surface, it will touch the intersection in the point in question. So, likewise, if from the same point, as considered on the second surface, a tangent plane be drawn to such surface, the plane will touch the intersection in the point under consideration. The two planes, then, will touch the intersection in the same point, which will also be one of their common points, and consequently one of those of the right line in which they intersect each other: therefore, the intersection of the two tangent planes will be the tangent required.

"From this problem arises the following observation, which is of great utility in descriptive geometry.

"The projection of the tangent of a curve of double curvature is itself tangent to the projection of a curve; and its point of contact is the projection of that of the curve of double curvature.

"Thus, if from all the points of the curve of double curvature, perpendiculars be supposed to fall upon one of the planes of projection, as upon the horizontal plane, for example, all such perpendiculars will be upon a vertical cylindric surface, which will be cut by the horizontal plane in the very projection of the curve. In like manner, if, from all the points of the tangent to the curve of double curvature, vertical lines be supposed to drop, they will be in a vertical plane, intersected by the horizontal plane in the projection of the tangent. Now, the cylindric surface and the vertical plane evidently touch each other in the whole extent of the vertical line dropped from the point of contact, and which is common to them both: the intersections, therefore, of the cylindric surface, and of the plane along the horizontal plane, touch each other in a point that will be the intersection of the line of contact of the cylindric surface and the vertical plane. Consequently, the projections of a curve of double curvature and of one of its tangents will touch each other in a point that is the projection of the point of contact of the curve.

"We shall now proceed to apply what has been said to some particular cases; and to begin with simple considerations, we shall first suppose one of two surfaces to be a plane, whose intersection we would determine.

"*First Question.*—To construct the intersection of a given cylindric surface with a plane of a given position.

"The position of planes of projections being arbitrary, we will first suppose, what is always possible, that these two planes have been so chosen as to have one perpendicular to the generating line of the surface, and the other perpendicular to the cutting plane; for in this supposition the construction is much more easy; and then to give to students a habit of making projections, we will suppose the two planes of projection in any other manner.

"*Solution.* First case, in which the generating line of the surface is supposed to be perpendicular to one of the planes of projection, as to the horizontal plane, for example, and the cutting plane perpendicular to the other.

"*Figure* 27.—Let A be the horizontal projection of the right line, to which the generating line of the cylindric surface should always be parallel; $a\ a''$ its vertical projection; B C D E, the given trace of the cylindric surface, which being the horizontal projection of the indefinite surface, is consequently that of the curve of intersection; let $f\,g$ be the given vertical projection of the cutting plane, which will also be that of the intersection required; and F G the horizontal trace of the same plane. It is evident, that if we draw to the curve B C D E, and perpendicular to L M, the indefinite tangents E e'', C c'', the right lines $e\,e''$, $c\,c''$, will be the vertical projections of the generating line, in its extreme positions; and that the points e', c', in which they intersect the projection, $f\,g$, of the cutting plane, will terminate upon $f\,g$, the vertical projection of the required intersection.

"Now, if from a point taken arbitrarily upon the intersection (a point whose horizontal projection will be a point, H, taken at pleasure on the curve B C D E, and whose vertical projection may be had by projecting the point H in i', upon $f\,g$) we would draw to this intersection, it is also evident that such tangent should be comprised in the cutting plane, and that its vertical projection would be the right line $f\,g$; also, that it would be comprised in the vertical tangent plane to the cylindric surface, and that its horizontal projection, which will be the same with that of the tangent plane, would be the right line F H N, tangent in H to the given curve B C D E. Thus all is determined as to the intersection required.

"Now, should it be required to construct this intersection such as it exists in its plane, and from one of its points, taken at pleasure, to draw a tangent to it: if the vertical plane of projection be at too great a distance from the curve B C D E, we may suppose another vertical plane, parallel to it, passing through the interior of the curve B C D E, and whose horizontal projection should be the right line E C, parallel to L M. This vertical plane will intersect the cutting plane in a right line parallel to its projection *f g*, and upon which, as upon a hinge, we will suppose the cutting plane to turn, to become vertical, and to present in full front the curve required. Then, from as many points, H, as may be thought convenient, taken arbitrarily upon B C D E, suppose vertical planes perpendicular to the vertical plane of projection, whose horizontal and vertical projections will both appear at the same time, in drawing through all the points H, the right lines H J K *i i'* perpendicular to L M. Each of these planes will intersect the cutting plane in a horizontal line, perpendicular to the hinge, whose vertical projection will be the point of coincidence, *i'*, of two right lines *f g*, *i i'*. In each plane this horizontal line will meet the hinge in a point, whose horizontal projection will be the intersection, J, of the two right lines E C, H J K, *i i'*; and will also meet the curve required in points, whose horizontal projections will be the intersections H, K, of the right line H J *i i'* with the curve B C D E. In a word, this right line and all its parts will be equal to their horizontal projections. Now, when the cutting plane turns upon the hinge, to become vertical, all these right lines, which were at first horizontal, remain perpendicular to the hinge, and do not vary in size. Therefore, if through all the points *i'*, we draw indefinite perpendiculars, *h k*, to *f g*, and if upon these perpendiculars J H be transferred from *i'* to *h*, and J K from *i'* to *h*, we shall have as many points, *h*, *k*, as we wish for, through which the required curve, *e' k c' h*, may be drawn.

"The curve being constructed in its plane, if it be required, from one of its points, *h*, taken arbitrarily, to draw a tangent to it, we may obtain the vertical projection of such point, by dropping from the point *h*, upon *f g*, the perpendicular *h i'*; and its horizontal projection, by projecting *i'* in H upon the curve B C D E; we shall have the horizontal projection of the tangent required, by drawing the right line F N tangent in H to the curve B C D E; and it will be sufficient to bring into the plane of the curve any point whatever of the tangent; as that, for example, which is projected on the point N taken arbitrarily, and whose vertical projection is upon *f g* in *a'*. Now, in making our deductions upon this point, as upon every other of the cutting plane, it cannot but be obvious, that if through the point *a'*, we draw to *f g* the perpendicular *a' n* and that if upon this right line we transfer from *a'* to *n* the distance N A from the point N to the right line E C, the point *n* will be the second of the tangent. Therefore by drawing the line *h n* we shall have the tangent required.

"Whatever curve be given to B C D E, we see that the intersection *e' k c' h* possesses the property of having for either of its points the sub-tangent *a' n* equal to the sub-tangent A N of the first. This property, which is very well known in the circle and ellipsis, when those two curves have a common axis, arises, with respect to them only, from their being the intersections of one cylindric surface through two different planes.

"Lastly, it may occur, that we shall want to trace upon the development of the cylindric surface, the effect of the section made by the cutting plane. For this purpose, after having developed the curve B C D E, with all its divisions, upon a right line R Q; if indefinite perpendiculars be drawn through all the divisions of R Q, we shall have, upon the development of the surface, the traces of the different positions of the generating line, and we shall then only have to transfer upon these perpendiculars the parts of the corresponding generating lines, comprised between the perpendicular section B C D E, and the section made by the cutting plane. Now, these parts of generating lines are equal to their vertical projections, and these projections are all terminated, on one hand, by the right line L M, and on the other by *f g*. If then the point H, for example, fall in S, upon the line R Q, by transferring *i i'* upon the perpendicular passing through the point S, from S to T, the point T will be, upon the developed surface, that where the generating line, which passes through the point H, is intersected by the cutting plane. The curve X T Y Z, which passes through all the determinate points in the same manner, will be the curve required.

"It is obvious, that were the tangent produced from the point H till it meet the horizontal trace, G F, of the cutting plane, somewhere in a point, F; and that if H F were transferred upon R Q, from S to U, the right line T U would be tangent to the curve; for when the cylindric surface is developed, its elements do not alter their inclination with respect to the horizontal plane.

"*Second Case*, wherein the cylindric surface and the cutting plane are supposed to be in any manner whatever with respect to the two planes of projections.

"*Solution.—Figure* 28. Let A A' and *a a'* be the two projections of the right line, to which the generating line should be parallel; C E D F, the given trace of the cylindric surface; and H G, *h b*, the traces of the cutting plane.

"Conceive a series of planes parallel to the generating line of the cylindric surface, and also perpendicular to one of the planes of projection, as the horizontal plane, for example: each of such planes would be projected upon a right line, O K E, parallel to A A', cutting the surface in right lines that would be so many positions of the generating line, and would meet the horizontal plane in the points of intersection, E, F, of the line O K E with the curve C E D F. By projecting, therefore, the points E, F, upon L M, in *e*, *f*, and drawing through these latter, to the right line *a a'*, the parallels *e e'*, *f f'*, the vertical projections of the intersections of the surface with each of the planes parallel to the generating line will be obtained.

"The same planes will likewise intersect the cutting plane in right lines, parallel to each other, all whose horizontal traces will be upon the different points, O, of the line O H, and whose vertical projections will be also parallel to each other. To obtain these projections, we must first find the direction of one of them, of that, for example, which corresponds to the vertical plane drawn from A A'. With this view, produce A A' till it meet, on one hand, the trace of the cutting plane in a point N, and on the other, the right line L M, in a point B, and by projecting the point B in *b* on *h b*, the two points N and *b* will be, upon the two planes of projection, the traces of the intersection of the cutting plane with the vertical one. By projecting the point N in *n* upon L M, and drawing the line *n b*, it will give the vertical projection of this intersection. By projecting on L M all the points, O, in which the trace O H is cut by the projections of the vertical planes, which will give a series of points *o*, and drawing from the latter the parallels *o i k*, to *n b*, the vertical projections of the intersections of the cutting plane, through the whole series of the vertical planes, will be obtained. Lastly, the points of coincidence, *i*, *k*, of each right line *o i k* with the projections *e e'*, *f f'*, of the sections made in the cylindric surface by the corresponding vertical plane, will be the vertical projection of the intersection required; and the curve that would pass through all the points, *i*, *k*, thus determined, would be that projection. By projecting the points *i*, *k*, in J, K, on the projection, O K E, on the corresponding vertical plane, we shall have the horizontal projection of the same points, and the curve, K J P, that would pass through all the points so determined, would be the horizontal projection of the intersection.

"In seeking the tangents of these two projections to the points J, *i*, it must be recollected that such tangents are projections of the tangent to the intersection. Now, the latter tangent being at the same time in the cutting plane and in the tangent plane to the cylindric surface, it must have its horizontal trace in the intersection of the horizontal traces of the two planes: the trace of the tangent plane is also the tangent in F to the curve C E D F. Therefore, by drawing this tangent, and having produced it till it meet the trace of the cutting plane in a point G, drawing the right line G J, we shall have the latter line touching, at the point J, the horizontal projection of the intersection. And by projecting the point G upon L M in *g*, and drawing the right line *g i*, we shall obtain the tangent, in *i*, of the vertical projection of the same curve.

"Should it be required to construct the curve of the intersection as it is in the plane, suppose the cutting plane to turn upon its horizontal trace H G, as upon a hinge, and applying itself to the horizontal plane. In this movement, each of the points of the section, that, by way of example, which is projected in J, will describe an arc of a circle, whose plane will be vertical, perpendicular to H O, and whose indefinite projection will be obtained by drawing through the point J a right line, R J S, perpendicular to H G; consequently, when the plane is laid down, the point of the section will fall somewhere upon a point of this right line. To discover the distance of such point from the hinge: as the horizontal projection of this distance is J R, and the difference of the heights of its extremities is the vertical line *i s*; if J R be measured upon L M, from *s* to *r*, the hypothenuse *r i* will be such distance. Then by measuring *r i* upon R J, from R to S, the point S will be one of the points of the intersection considered, with its plane laid down upon the horizontal plane, and the curve S T U V, drawn through all the points S constructed alike, will be the intersection itself.

"To obtain the tangent of this curve to the point S, it is sufficient to observe, that in the movement of the cutting plane, the tangent does not cease to pass through the point G of the hinge; therefore, by drawing the right line S G, we shall have the tangent required.

"*Second Question.*—To construct the intersection of a conic surface, of any given base, by a plane given in position.

"*Solution.*—Here we may suppose, what is always possible, the vertical plane of projection to be placed perpendicular to the cutting plane.

"*Figure* 29.—Let A, *a'*, be the projections of the apex of the cone, or of the centre of the conic surface; B C D E the trace of such surface on the horizontal plane; *f g* the vertical projection of the cutting plane; and O *f* its horizontal trace. Suppose from the apex of the cone a series of planes, perpendicular to the vertical plane of projection; the vertical projections of such planes will be the right lines *a' c*, drawn from the projection of the apex: and their horizontal traces will be the right lines *c* C, perpendicular to L M, which will cut the trace of the conic surface somewhere in the points C, C' . . . These planes will cut the surface in right lines, whose vertical projections will be the lines *a' c* . . . ., and whose horizontal projections will be obtained by drawing from the point A, the lines C A, C' A . . . ; the same planes will likewise intersect the cutting plane in lines perpendicular to the vertical plane. The projections of such lines will be the points, *h* . . ., of coincidence of *f g*, with the lines *a' c* . . . ; and their horizontal projections will be obtained by dropping, from the points *h* . . . ., upon L M, the indefinite perpendiculars *h* H . . . . This done, the lines *h* H . . . . will cut the corresponding lines C A, C' A . . ., in points, H, H' . . . ., which will be the horizontal projections of so many of the points of intersection required; and the curve, P H Q H', that would pass through all the points thus constructed, will be the projection of the intersection.

"To draw a tangent to this curve, from a point H, fixed upon at pleausre, it is only requisite to find upon the horizontal plane the trace of the tangent of the intersection in a point corresponding to H. This trace must be upon that of the cutting plane, and consequently on O *f*; it must also be upon that of the plane touching the conic surface in the right line, whose projection is A H: and if A H be produced till it meet the curve B C D E somewhere in a point C, the tangent, C F, of this curve, in the point C, will be the horizontal trace of the tangent plane. The point, F, of coincidence of the two traces *f* G, C F, will therefore be upon the tangent in the point, H, of the curve P H Q H'.

"Should it be required to construct the intersection considered in its plane, we may indefinitely suppose either that the cutting plane turns upon O *f*, as upon a hinge, in order to apply itself to the horizontal plane, and so construct the curve in the position it will thus assume; or that it turns upon its vertical projection *f g*, to apply itself to the vertical plane; the latter is the hypothesis we shall here adopt.

"All the horizontal lines in which the series of planes drawn from the apex has intersected the cutting plane, and which are perpendicular to *f g*, do not change their size in the movement of the cutting plane, nor do they cease to be perpendicular to *f g*: if then indefinite perpendiculars be drawn through all the points *h*, to *f g*; and if upon them the corresponding horizontal lines K H, K H', be measured and applied from *h*, to N and N', the points N, N', will be those of the section; and the curve R N S N', drawn through all the points thus constructed, will be the intersection considered in its plane.

"From all that has been said, it appears evident, that, to draw to this curve a tangent in a point, N, taken arbitrarily upon it, the perpendicular N *h* must be dropped from the point N upon *f g*; that the right line *a' h* must be produced till it meet L M in the point *c*; that this point must be projected in C, or the curve B C D E; that the tangent must be drawn to such curve in C, cutting the trace G *f* somewhere in a point F; and that F *f* must be carried perpendicularly to *f g*, from *f* in O. The right line O N will be the tangent required.

"As to the mode of constructing the development of the conic surface, of whatever base, and of tracing thereon the effect of the intersection with the cutting plane, we shall proceed to describe it, after having spoken of the intersection of the conic surface with that of a sphere having its centre in the apex.

"To construct the intersection of two conic surfaces with circular bases, whose axes are parallel to each other.

"*Solution.*—*Figure* 26. As it would be superfluous here to repeat what has already been said in treating of the general method, of which this figure was a type; we shall only observe, that in the case now before us, as well as in that of two revolving surfaces, of whatever description, the sections made in the two surfaces by the horizontal planes, are circles; but we shall enter upon some details relative to tangents, of which we have not yet had occasion to speak.

"To discover the tangent to the point D (*Figure* 26) of the horizontal projection of the intersection, we must recollect that it is the projection the tangent of the intersection of the two surfaces, in the point of corresponding to D, and that to determine it, it is only necessary to find the point S, which is, upon the horizontal plane, the trace of the tangent of the intersection. This latter tangent is in the two planes which touch the conic surfaces in the point of intersection; therefore, by finding the horizontal traces R *r*, Q *q*, of these two tangent planes, they will by their coincidence, determine the point S. But the plane tangent to the first surface touches it in a line that passes through its apex, whose horizontal projection may be obtained by drawing the indefinite right line A D. And if A D be produced till it meet the horizontal circular trace of the surface, T Q U V, in a point, Q, such point will be a point of the line of contact between the surface and the plane; consequently, the horizontal trace of the plane will be tangent in Q to the circle T Q U V: let this tangent therefore be drawn, as Q *q*. In like manner, by producing the radius B D till it meet in R the circular horizontal trace, R X Y Z, of the second surface, and drawing to this circle the tangent in R, the line R *r* will be the horizontal trace of the plane tangent to the second surface. And if from the point S, of the intersection of the two tangents Q *q*, R *r*, the right line S D be drawn, it will give the tangent, in the point D, of the horizontal projection of the intersection.

"With respect to the tangent to the corresponding point *d*, of the vertical projection, it is obvious that it may be obtained by projecting the point S in *s*, and by drawing the line *s d*, which will be the tangent required.

"It may happen to be necessary to construct upon the development of one of the conic surfaces, perhaps, even upon that of each of them, the effect of their mutual intersection; as, for example, if we were obliged to fabricate the cones of flexible substances, such as metal plates: in this case we must operate for such cone in the manner we are going to prescribe for the first.

"Before we proceed, let it be observed, that when a conic surface is developed so as to become a plane, the right lines that are upon it, change neither their form nor size, because each of them is successively the hinge upon which the development acts; so that all the points of the surface remain always at the same distance from the apex. And when, as in this case, the conic surface is direct and circular, all the points of the circular horizontal trace are at equal distances from the apex; they must, therefore, be also at an equal distance from the apex upon the development, and consequently upon the arc of a circle, whose radius is equal to the uniform distance of the apex from the circular trace. And if, after having taken an arbitrary point to represent the apex on the development, the arc of an indefinite circle, whose radius is equal to *a* C, be described, having such point for its centre, it will also be indefinitely the development of the horizontal trace of the surface. Then, by measuring the arc of the circle T Q on the arc just described, beginning from the point T of the trace from which it is designed to begin the development, the position of the point Q upon the development will be determined; and the indefinite right line drawn from this point to the centre of the development, will be the position occupied by the right line of the surface projected in A Q, and upon which the point D *d*, of the section referred to, will be found. To construct this point, it only remains to discover its distance from the apex, and to measure it upon the indefinite right line, beginning from the centre of the development. In order to this, draw the horizontal line *d k*, from the point *d* in the vertical projection, till it cut the side *a* C of the cone, in a point *k*, and the line *a k* will be the distance sought for. By constructing, in like manner, all the other parts of the intersection, successively, and passing a curve through them, the intersection of the two surfaces described upon the development of the first surface will be found. Proceed in the same manner for the second surface.

"*Fourth Question.*—To construct the intersection of two conic surfaces, of whatever basis.

"*Solution.—Figure* 30. Let A, *a*, be the projections of the apex of the first surface; C G D G′, its given trace upon the horizontal plane; B *b*, the projections of the apex of the second surface; and E H F H′, its trace on the horizontal plane. Suppose a right line passing through the two apices, whose projections are the indefinite lines A B, *a b*, and whose trace, I, may be easily constructed upon the horizontal plane. Along this line conceive a series of planes, each cutting the two conic surfaces in the system of several right lines; and such of these right lines as shall be in the same plane will determine, by their intersections, so many points of the intersection of the two surfaces. The horizontal traces of all the planes of this series will necessarily pass from the point I; and since the position of these planes is besides arbitrary, their traces may likewise be taken arbitrarily, by drawing from the point I, a number of lines, I K, at pleasure, by each of which the following operation may be worked for either of them.

"The trace, K I, of each of the planes of the series will cut the horizontal trace of the first conic surface in points, G G′, which will also be the horizontal traces of the right lines, according to which the plane cuts the conic surface: thus A G, A G′, will be the indefinite horizontal projections of these lines, and their vertical projections will be obtained by projecting G, G′, in *g*, *g′*, and drawing the indefinite lines *a g*, *a g′*. So likewise, the trace, K I, of the same plane of the series will cut the horizontal trace of the second conic surface in points, H, H′, from which if B H, B H′, be drawn indefinitely, the horizontal projections of the lines will be obtained, according to which the same plane of the series will cut the second surface; and their vertical projections may be had, by projecting H, H′, in *h*, *h′*, and drawing the indefinite lines *b h*, *b h′*.

"This done, for the same plane, whose trace is K I, we shall have on the horizontal projection a certain number of lines, A G, A G,′ B H, B H′; and the points, P, Q, R, S, in which those belonging to one of the surfaces, meet those belonging to the other, will be the horizontal projections of so many points of the intersections of both surfaces. Thus, by working successively, in the same manner, upon the other lines K I, we shall find new series of points, P, Q, R, S; and by afterwards passing through all the points P, a first branch of a curve, through all the points Q, a second, through all the points R, a third, &c., we shall have the horizontal projection of the intersection required.

"In like manner, for the same plane, whose trace is K I, we shall have upon the vertical projection a certain number of lines *a g*, *a g′*, *b h*, *b h′*, whose points of intersection will be the vertical projections of as many points of the intersection.

"Here let it be remarked, that it is not necessary to construct the two projections independently of each other, and that having constructed a single point of one of them, it may be projected in the other upon one of the lines that ought to contain it: hence we acquire means of verifying the operation, and of avoiding, in certain cases, the intersections of lines which cut each other in angles too oblique.

"To find the tangents to the horizontal projection, that, for example, which touches it in the point P, we must construct the horizontal trace, T, of the tangent of the intersection in the point corresponding to P. This tangent is the intersection of the two planes which touch the conic surfaces in that point; its trace, therefore, will be in the coincidence of the horizontal traces with such two tangent planes. And as A G′ P is the projection of the line of contact of the plane which touches the first surface, the trace of such first plane will be the tangent to the curve C G D G′, in the point G′: let then G′ T V be that tangent. So likewise B H′ P is the horizontal projection of the line of contact of the plane that touches the second surface; and as the horizontal trace of the second tangent plane will be the tangent, in the point H′, of the curve E H F H′, let H′ T U be such tangent. The two tangents G′ V. H′ U, will intersect each other in a point, T, from which if the line T P be drawn, we shall have the tangent in the point P, as required.

"By proceeding in like manner with the other points Q, R, S, we shall find, first, that the tangent in Q must pass through the point of coincidence of the tangents in G′ and H; secondly, that the tangent in R must pass through the coincidence of those in H and G; and, thirdly, that the tangent in S must pass through the coincidence of those in G and H′.

"Tangents of the vertical projection are attended with no difficulty, when those of the horizontal projection are once determined; for by projecting the horizontal traces of the tangents of the intersection, we have the points through which they must pass.

"*Fifth Question.*—To construct the intersection of a conic surface of any base, with that of a sphere.

"We shall here suppose the two surfaces to be concentric, that is to say, the apex of the cone placed in the centre of the sphere, because we shall have occasion for such a disposition in the following question.

"*Solution.—Figure* 31. Let A, *a*, be the projections of the common centre of the two surfaces; B C D E, the given horizontal trace of the conic surface; *a m*, the radius of the sphere; and the circle, *l f′ g′ m*, the vertical projection of the sphere. Suppose from the centre common to the two surfaces, a series of planes, which may likewise be conceived to be all perpendicular to one of the two planes of projection: in the *Figure* 31, we have supposed them to be vertical. Each of such planes will cut the conic surface in a system of right lines, and the surface of the sphere in the circumference of one of its great circles; and for each plane, the coincidence of these lines with the circumference of the circle will determine the points of the intersection required: draw, therefore, from the point A as many indefinite right lines, C A E, as you please, and they will be the horizontal projections of so many vertical planes in the series, and, at the same time, those of the lines according to which these planes cut the two surfaces. Each right line C A E, will intersect the horizontal trace B C D E of the conic surface in points, C, E, that will be the horizontal traces of the sections made in this surface by the corresponding plane; and if, after having projected the points C, E, upon L M, in *c*, *e*, the lines *a c*, *a e*, be drawn, they will give the vertical projections of the same sections.

"It now remains to discover the points of intersection of these sections with those of the sphere, upon the same plane.

"For this purpose, having drawn through the point A, the right line G A F, parallel to L M, suppose the vertical plane drawn through C E, to turn about the vertical line raised from the point A, and projected in *a′ a*, as upon a hinge, till it become parallel to the vertical plane of projection, and that it also draw with it the sections it has made in the two surfaces. In this movement, the points C, E, will describe around the point A, as a centre, the arcs of circles C G, E F, and will fall in, in O, F; by projecting the latter points upon L M, in *g*, *f*, the right lines *a g*, *a f*, will be the vertical projections of the sections made in the conic surface, considered in the new position they have assumed in consequence of the movement of the plane. The section made in the surface of the sphere, considered also in its new position, will have the circumference *l f′ g′ m* as a vertical projection. The points, therefore, of coincidence, *g′ f*, of this circumference with the lines *a g*, *a f*, will be the projections of the points of intersection required, considered also in the new position of the plane.

"Now, to obtain the projections of the same points, in their natural position, the vertical plane must be supposed to be returned to its original situation. In this movement, all its points, and consequently those of the intersection contained in it, will describe the arcs of horizontal circles around the vertical line raised from the point A as an axis, whose vertical projections will be horizontal lines. Then by drawing through the points *f′ g′*, the horizontal lines *f′ h*, *g′ i*, they will contain the vertical projections of the points of intersection: but these projections must also be upon the respective right lines *a c*, *a e*, and will be found in the points of coincidence, *i h*, of the latter, with the horizontal lines *g′ i*, *f′ h*. Thus the curve *k h n i*, drawn through all the points constructed in the same manner for any other line, besides C E, will be the vertical projection of the intersection required.

"By projecting the points, *i*, *h*, upon C E, in J, H, we shall have the horizontal projections of the same points of the intersection; and the curve K H N J drawn through all the points, J H, constructed in the same manner for any line besides C E, will be the horizontal projection of the intersection.

"To find the tangent to the point J of the horizontal projection, the horizontal trace P of the tangent to the corresponding point of the intersection must be constructed. This trace must be in the coincidence of the traces of the planes tangent to the two surfaces, in the point of the intersection corresponding to the point J. Here it is obvious, that by drawing C P through the point C, tangent to the curve B C E D, we shall have the trace of the plane tangent to the conic surface. And for that of the plane tangent to the surface of the sphere, the operation is similar to what has been described in the cases of revolving surfaces, *viz.* by drawing *g′ o* through the point *g′*, tangent to the circle *l f′ g′ m*, produced to the right line L M, in *o*, afterwards measuring *a′ o* upon C E, from A to O, and drawing the line O P, through the point O, perpendicular to C E. The two traces C P. O P, then will cross each other in a point, P, through which, if J P be drawn, it will be the tangent to the point J.

"Hence we see that the tangent to the point *i* of the vertical projections of the intersection will be obtained by projecting the point P upon L M in *p*, and afterwards drawing the right line *i p*, which is the tangent required.

"If the sphere and the conic surface were not concentric, it would be necessary to conceive a right line passing through their two centres, and to choose a series of cutting planes that should pass through such line. Each of these planes would cut the conic surface in right lines, and that of the sphere in one of its great circles, as in the preceding instance; which would give an equally simple construction: but then it would be advantageous to place the vertical plane of projection parallel to the right line drawn through the two centres, in order that, in the movement given to each cutting plane to render it parallel to the vertical plane of projection, the two centres may remain motionless, so as not to change their projections; by this means the constructions are simplified.

"*Sixth Question.*—To construct the development of a conic surface, of any base, and to represent upon the surface so developed, a section, whose two projections are given.

" *Solution.*—Suppose the surface of a sphere, whose radius is taken at pleasure, whose centre is placed in the apex of the cone, and construct, as in the preceding question, the projections of the intersections of the two surfaces. This done, it will appear evident, that all the points of the spherical intersection being at the same distance from the apex, they must likewise, upon the surface developed, be at an equal distance from the apex, and consequently upon an arc of a circle described from the apex as a centre, with a radius equal to that of the sphere.

" Thus, supposing the point R (*Figure* 33) to be the apex of the surface developed, if from this point, as a centre, with a radius equal to *a m* (*Figure* 31) the arc, S T U, of an indefinite circle be described, it is upon this arc that all the points of the spherical intersection will fall, so that the points of such arc will be respectively equal to the corresponding points of the spherical intersection. It therefore now remains, (after having taken at pleasure a point by way of origin, as, for example, the one projected in N, *n* (*Figure* 31), and a point S (*Figure* 33) to correspond with it on the surface developed) to develop the different arcs of the spherical intersection, and to measure them successively upon the arc of the circle S T U, from S. in certain points T. To do which, the spherical surface being of double curvature, it must be successively deprived of its two curvatures, without, however, altering its size, in the following manner.

" The spherical intersection being projected on the horizontal plane in N J K H, (*Figure* 31) it may be considered as traced upon the surface of a vertical cylinder, whose base would be N J K H: this surface may then be developed as directed in *Figure* 27, and the spherical intersection may be described upon it by developing the arc N J (*Figure* 31) in N′ J′ (*Figure* 32), and carrying the vertical line *i′ i* (*Figure* 31) perpendicularly to N′ N′ (*Figure* 32) from J′ J″. The curve N″ J″ K″ N″, passing through all the points, J″, thus determined, will be the spherical intersection, freed from its horizontal curvature, without having changed its length. The tangent to the point J″ of this curve will be obtained by carrying J P (*Figure* 31) measuring it upon N′ N′ (*Figure* 32) from J to P′, and drawing the right line J″ P′.

" Now, we shall develop the curve N″ J″ K″ H″ N″, in order to fold it on the arc S T U (*Figure* 33): for example, measure the arc N″ J″ from S to T, and the point T will be on the conic surface developed, the point in which that of the spherical intersection will apply, whose projections are J, *i* (*Figure* 31.) Therefore by drawing the right line R T we shall have upon the development of the surface, the generating line, whose horizontal projection is A C (*Figure* 31). Lastly, should any point be found upon this generating line, that should be brought upon the surface developed, it will be only requisite to take the distance (*Figure* 31) of such point from the apex of the conic surface, and to carry it (*Figure* 33) upon R T, from R to V; and the point V will be upon the surface developed, the one required.

" *Seventh Question.*—To construct the intersection of two cylindric surfaces, of any bases.

" *Solution.*—In making the research in which this question originates, if we have no other intersections to consider than that of the two cylindric surfaces, (and especially when these surfaces have circular bases) it will be found expedient so to choose the planes of projection, as that one among them may be parallel to the generating lines of the two cylinders: by which means the intersection will be constructed without the aid of any other curves than those given. But when we are obliged also to keep in view the intersections of these surfaces with others, there is no longer any advantage to be derived from a change of the planes of projection; it will even prove more easy to represent the objects by referring them all to the same planes. We shall therefore suppose the generating lines of the two surfaces to be placed indifferently as to the planes of projection.

" Under this idea, let T F U F′, X G V G′ (*Figure* 34) be the given horizontal traces of the two cylindric surfaces; A B, *a b* the given projections of the right line, to which the generating line of the first is parallel; C D, *c d*, those of the line to which the generating line of the second is parallel. Suppose a series of planes parallel to the two generating lines: such planes will intersect the two surfaces in right lines; and the coincidences of the sections made in the first surface with those made in the second, will determine the points of the intersection required.

" Thus, after having constructed, as in *Figure* 15, the horizontal trace, A E, of a plane drawn along the first given right line, parallel to the second, draw as many parallel right lines, F G′, to this trace as you please, and consider such parallels as traces of the planes of the series. Each line, F G′, will cut the trace of the first surface in such points as F, F′, and that of the second in such as G, G′, through which draw to the respective projections of the generating lines, the parallels F H, F′ H′ . . . . . G J, G′ J′; and the intersecting points, P, Q, R, S, of these lines, will be the horizontal projections of so many points of the intersection of the two surfaces. By working in a similar manner on the remainder of the lines F G′, we shall obtain a succession of systems of points P, Q, R, S, and the curve that will pass through all the points so found, will be the horizontal projection of the intersection.

" To obtain the vertical projection, project upon L M the points F, F′ . . . . . G, G′ . . . . . in *f, f* . . . . . *g, g′* . . . . . and draw through these latter points, to the projections of the respective generating lines, the parallels *f′ h, f′ h* . . . . *g i, g′ i′* . . . . and their coincidence will determine the vertical projections, *p, q, r, s*, of the points of intersection. And by thus proceeding with all the other lines F G′, we shall obtain new points *p, q, r, s*, and the curve that would pass through such points will be the vertical projection of the intersection.

" In order to obtain the tangents of these curves to the points P, *p*, construct the horizontal trace, F′ Y, of the plane tangent in this point to the first cylindric surface; then the trace, G′ Y, of the plane tangent in the same point to the second surface; and the right line drawn from the point P to the point Y of the coincidence of these traces, will be the tangent in P. Lastly, project Y upon L M in *y*, and draw the right line *p y*, and it will give the tangent to the point *p* of the vertical projection.

" *Eighth Question.*—To construct the intersection of two revolving surfaces, whose axes are in the same plane.

" *Solution.*—Dispose the planes of projection in such a manner, that one among them shall be perpendicular to the axis of one of the surfaces, and the other parallel to the two axes. Then let A, *Figure* 35, be the horizontal projection of the axis of the first surface; *a a′* its vertical projection; and *c d e* the given generating line of such surface. Let A B, parallel to L M, be the horizontal projection of the axis of the second surface; *a′ b* its vertical projection, so as that A, *a′* be the projections of the point of coincidence of the two axes; *f g h* the given generator of the second surface. Conceive a series of spherical surfaces, whose common centre would be in the point of concourse of the two axes; and for each of such surfaces construct the projection *i k n o p q* of the great circle parallel to the vertical plane of paojection; which projections, being arcs of circles described from the central point *a′*, with radii taken arbitrarily, will cut the two generating lines in the points *k p*.

"We shall now find each spherical surface cutting the first surface in the circumference of a circle whose plane is perpendicular to the axis $a\ a'$, and whose vertical projection may be obtained by drawing the horizontal line $k\ o$, and its horizontal projection, by describing from the central point A, with a diameter equal to $k\ o$, the circumference of a circle K R O R′. In like manner, every spherical surface of the series will cut the second revolving surface in the circumference of a circle whose plane will be perpendicular to the vertical plane of projection, and whose vertical projection may be obtained by drawing through the point p a line, $p\ n$, perpendicular to $a'\ b$.

"Should the points r, in which the two right lines $k\ o$, $p\ n$, intersect each other, be nearer to the two respective axes than are the points $k\ p$, it is evident that the two circumferences of circles would intersect each other in two points, of which r would be the common vertical projection; and a curve drawn through all the points r, constructed in a similar way, would be the vertical projection of the intersection of the two surfaces. By projecting the point r upon the circumference of the circle N R O R′. in R, R′. we shall have the horizontal projection of the two points of the coincidence of the circumferences of circles found upon the same sphere; and the curve drawn through all the points R, R′, constructed in like manner, will be the horizontal projection of the intersection required.

"These examples may suffice for conveying an idea of the method to be adopted in constructing the intersections of surfaces, and drawing tangents to them; more especially if the student be careful to make his constructions with scrupulous exactness, if he employ large dimensions, and, as much as possible, trace the curves in all their extent.

"In the foregoing pages, we have supposed the curves of double curvature as being each determined by two curved surfaces, of which it is the intersection; and, indeed, such is the point of view wherein they most commonly present themselves in descriptive geometry; and, under this consideration we have shown that it is always possible to draw tangents to them. But, although a curved surface may be defined by means of the form and movement of its generator; it may nevertheless happen, that a curve may be given, by the law of motion, from a generating point; in which case, if the practitioner do not choose to have recourse to analysis. he may adopt the method of Roberval. This method, invented by him before Descartes had applied geometry to algebra, is implicitly comprised in the processes of differential calculi, and is therefore not noticed in the elements of the mathematics; a summary exposition of it in this place, will be sufficient; those who are curious to see numerous applications of this method may consult the *Memoirs of the Academy of Sciences* (French) anterior to the year 1699, wherein the works of Roberval have been collected.

"When, pursuant to the law of its motion. a generating point is constantly impelled towards one particular point in space, the line it describes by virtue of such law is a right line; but if, in the whole course of its movement, it be at the same time impelled towards two points, it will in general describe a curve, though in particular cases it may describe a right line. The tangent to such curve may be obtained by drawing through the point of the curve two right lines, following the two different directions of the motion of the generating point; by measuring upon these directions, in an appropriate manner, parts proportional to the swiftness of two respective motions of the point; by completing the parallelogram, and drawing the diagonal, which will be the tangent required: for this diagonal will be in the direction of the movement of the describing point to the point of the curve under consideration.

"The following is an example.

"*Figure* 36.—A thread, A M B, being fastened by its extremities to two fixed points, A, B; if, by means of a point, M, this thread be stretched out, and the point moved, so as still to keep the thread in a state of tension, it will describe the curve D C M, being an ellipsis, whose foci are the fixed points A, B. From the generation of this curve, it is easy to draw a tangent to it, by Roberval's method. For instance; as the length of the thread is not altered, the radius A M, in every instant of its motion, is lengthened in the same proportion that the radius B M is shortened. The swiftness, therefore, of the describing point in the direction A M, is equal to its motion in the direction M Q. Therefore, by measuring on M B, and on the prolongation of A M, the equal right lines M Q, M P, and by completing the parallelogram M P R Q, the diagonal, M R, of this parallelogram will be the direction of the generating point in M, and consequently the tangent to the same point of the curve. Hence we may clearly perceive, that in the ellipsis, the tangent divides the angle B M P, formed by one of the vector radii, and by the prolongation of the other, in two equal parts; that, the angles A M S, B M R are equal to each other; and that the curve possesses the property of reflecting upon one of its foci the rays of light emanating from the other.

"The method of Roberval in the case of three dimensions, may be readily understood, and applied to the construction of tangents to curves of double curvature. Thus, if a generating point move in space, so as to be constantly impelled towards three different points, the line it will traverse, though in some particular cases it may be a right line, will in general describe a curve of double curvature. The tangent to such curve may be obtained in any point whatever, by drawing right lines from the given point, in the three directions of the movement of the generating point; by measuring upon such lines, in an appropriate direction, parts proportional to the swiftness of the three respective motions of this point; by completing the parallelopiped, and drawing the diagonal of the parallelopiped, which will be the tangent to the curve in the point taken.

"We shall now apply this method to a case analogous to that of the ellipsis. The *Figure* 37, to which we refer, represents the object in perspective and not in projection.

"Three fixed points, A, B, C, being given in space, let a thread, A M B, be fastened by its two extremities to the points A, B; let a second thread, A M C, independent in its size of that of the other, be attached by its extremities to the points A, C; let a generating point, holding both threads, be moved so as to keep them in a state of tension, and it will describe a curve of double curvature. In order to draw a tangent to this curve in the point M, we must observe that the length of the first thread, A M B, being uniform throughout its movement, the part A M is lengthened out precisely in proportion as the part M B is shortened, and that the swiftness of the generating point in the direction A M is equal to that of its movement in the direction M B. So, likewise, the length of the second thread, A M C, being unaltered, the swiftness of the generating point in the direction M C is equal to that of its motion in the direction A M. Therefore, by measuring upon the prolongation of A M, and on the right lines M B, M C, the equal parts M P, M Q, M R, and completing the parallelopiped M P U S V Q R T, we shall obtain in the diagonal, M S, of this parallelopiped, the tangent required.

"The method of Roberval being founded on the principle of compound motion, we may readily conceive that in cases more complex than these, which we have chosen as examples, we may avail ourselves of the known methods to find the resultance of forces impelled towards a point, whose size and directions are ascertained.

"*Application of the method of constructing the intersections of curved surfaces to the solution of various questions.*

"In *Figure* 26, we have defined the mode of constructing the projections of the intersection of two curved surfaces, definite in their form and position; which we have done in the abstract, that is, without attending to the nature of the questions whose solutions would require such operations. The exposition of this method, even in this abstract manner, will be found sufficient for most of the arts; for instance, in masonry and carpentry, the curved surfaces there considered, and the construction of whose intersections may be required, generally form the principal object of attention, and present themselves naturally. But as descriptive geometry will one day become a principal part of the national education, its methods being no less necessary to artists than reading, writing, and arithmetic; we conceive it must prove useful to point out, by a few examples, how it may furnish the analysis for the solution of a great number of questions, which, at first sight, seem not to admit of being treated in this manner. We shall begin with such examples as require only the intersections of planes, and then proceed to those in which the intersections of curved surfaces are necessary.

"The first question that forcibly occurs to those who are learning the elements of ordinary geometry, is the finding of the centre of a circle whose circumference passes through three arbitrary points on the plane. The determination of this centre by the intersection of two right lines, upon each of which it is necessarily found, surprises the pupil as well by its generality, as because it yields a mode of execution. Were all geometry treated in the same manner, which it may be, it would suit a much greater number of geniuses, would be cultivated and practised by a far more numerous class of men, the ordinary instruction of the nation would be more advanced, and the science itself carried to a greater extent.

"In the three dimensions, there exists a question analogous to the one just quoted, with which we shall begin.

"*First Question.*—To find the centre and radius of a sphere, whose surface passes through four points, given arbitrarily in space.

"*Solution.*—The four points being given by their horizontal and vertical projections, conceive right lines drawn from one of them to each of the others; and trace the horizontal and vertical projections of such lines. Then, in considering the first of these right lines, it will appear evident, that as the required centre must be at equal distances from the two extremities, it will be on the plane perpendicular to such right line, and drawn through its middle. Therefore by dividing the projections of the line into equal parts, which will give the projections of its middle, and by constructing the traces of the plane drawn through the point perpendicular to the line, as has been before described, we shall obtain the traces of a plane upon which the centre required will be found. Next, in considering the two other right lines, and working successively for each of them, a like operation, we shall obtain the traces of three several planes, upon each of which the centre sought for will be found. Now, as the centre must be upon both the first and second of these planes, it can be nowhere but in the line of their intersection, therefore, by constructing the projections of this intersection, we shall have upon each plane of projection, a line containing that of the centre. For the same reason, if the projections of the intersection of the first and third planes be constructed, we shall have on each plane of projection another line containing the projection of the centre. Hence we have upon each plane of projection two right lines, whose intersection will determine the projection of the required centre of the sphere.

"By using the intersection of the second and third planes, we shall obtain a third right line, that passes through the centre, and whose projections also pass through those required, which furnishes a means of verification.

"As to the radius, it is evident, that a right line drawn through the projection of the centre and that of one of the given points, will be its projection; whence we may obtain both the horizontal and vertical projections of the radius, and consequently its size.

"When the position of the planes of projection can be chosen at pleasure, the preceding method may be considerably simplified. Thus, suppose the plane that we have considered as horizontal (*Figure* 38) to pass through three given points, so as that of the given projections A, B, C, D, of the four points, the three first may be blended with their respective points; then, having drawn the three right lines, A B, A C, A D, suppose the vertical plane to be parallel to A D, that is to say, that the right lines L M and A D are parallel to each other; the vertical projections of the three first points will be upon L M, in such points as *a*, *b*, *c*, and that of the fourth will be given somewhere in a point, *d*, of the right line D *d*, perpendicular to L M. This done, the line drawn from the point A to B, being horizontal, any plane perpendicular to it will be vertical, having for its horizontal projection a line perpendicular to A B. It is the same with respect to the right line drawn from A to C. Therefore, by drawing through the middle of A B, the indefinite perpendicular E *e*, we shall have the horizontal projection of a vertical plane, that passes through the centre of the sphere; consequently, the horizontal projection of the centre will be somewhere on the line E *e*. So, likewise, by drawing through the middle of A C, the indefinite perpendicular F *f* we shall have the projection of a second vertical plane, that passes through the centre of the sphere, and the horizontal projection of this centre will be in some point of the right line F *f*: therefore, the point G, of the intersection of the two lines E *e*, F *f*, will be the horizontal projection of the centre of the sphere, and its vertical projection will consequently be upon the indefinite right line of projection G *g g'*.

"The line drawn from the point A to the fourth point being parallel to its vertical projection *a d*, any plane perpendicular to it, will also be perpendicular to the vertical plane of projection, and will have its vertical projection in a right line perpendicular to *a d*. Hence by drawing through the middle of *a d*, the indefinite perpendicular H *h*, we shall obtain the projection of a third plane, that passes through the centre of the sphere; therefore the vertical projection of the centre being at the same time upon *g g'* and H *h*, must be in the point K, of the intersection of these two lines.

"Lastly, by drawing the two right lines A G, *a* K, we shall evidently have the two projections of the same radius of the sphere; therefore, by measuring A G upon L M, from *g* to J, we shall have, in the right line J K, the size of the radius required.

"*Second Question.*—To inscribe a sphere in a given triangular pyramid; that is to say, to find the position of the centre of the sphere and the size of its radius.

"*Solution.*—As the surface of the inscribed sphere must touch the four faces of the pyramid, it is evident that a plane passing through the centre of the sphere and through each of six arêtes, would divide the angle formed by the two faces that pass through the same arête, into two equal parts. If, then, three of the six arêtes be chosen, which do not all pass through the same apex of a solid angle, and if through each of these arêtes a plane be made to pass, dividing in two equal parts the angle formed by the two corresponding faces, we shall obtain three planes, upon each of which the centre of the sphere required will be found, whose position will be determined by their common intersection.

"In order to simplify the construction, we shall suppose the planes of projections to be so chosen as that the one which we consider as horizontal may be the same with one of the faces of the pyramid.

"*Figure* 39.—*Plate* 4. With this view, let A, B, C, D, be the given horizontal projections of the apices of four solid angles of the pyramid, and *a*, *b*, *c*, *d'*, their vertical projections; conceive through the apex of the pyramid, planes perpendicular to the three sides of the base; such planes will be vertical, and their horizontal projections will be the right lines D E, D F, D G, falling perpendicularly from the point D on the sides A C, C B. B A, of the base. Each of these planes will cut the base of the pyramid and the face that passes through the arête in two right lines, comprehending between them an angle equal to that which the face forms with the base. Then, by measuring on L M the right lines D E, D F, D O, beginning from the vertical line D *d d'*, from *d* to *e*, *f*, *g*, and drawing from the apex *d'*, the right lines *d' e*, *d*, *f*, *d' g*, the latter will form with L M angles equal to those formed by the corresponding faces of the pyramid with the base; and if each of these three angles be divided into two equal parts by the right lines *e e'*, *f f'*, *g g'*, the angles formed by these last lines with L M, will be equal to those formed by the base with the faces of a second pyramid, having the same base with the given pyramid, and whose apex will be in the centre of the sphere required.

"To find the apex of this second pyramid, let it be cut by a horizontal plane, drawn at an arbitrary height, whose vertical projection may be obtained by drawing any horizontal line whatever, as *p n*. This line will cut *e e'*, *f f'*, *g g'*, in the points *h'*, *i'*, *k'*, from which let the vertical lines *h' h*, *i' i*, *k' k*, fall upon L M; and by measuring the three distances *h e*, *i f*, *k g*, on the respective perpendiculars, from E to H, from F to J, and from G to K, we shall have in H, J, K, the horizontal projections of points taken in the three faces of the second pyramid, and which will be found upon the arbitrary horizontal plane. Then by drawing through the points H, J, K, to the respective sides of the base, parallel lines, as P N, N O, O P, they will be the projections of the sections of the three faces of the second pyramid, upon the same horizontal plane; they will also intersect each other in points, as N, O, P, which will be projections of as many points of the three arêtes of the second pyramid; and by drawing from these points to the apices of the respective angles of the base, indefinite right lines, as A P, B O, C N, such line will be the projections of the arêtes; lastly, the single point Q, wherein they all three meet, will be the horizontal projection of the apex of the second pyramid, and consequently of the centre of the sphere required.

"To obtain the vertical projection of this centre, draw, first, the indefinite right line of projection Q *q q'*, on which it will be found; then project the three points, N, O, P, on the horizontal line *n*, *p*, in *n*, *o*, *p*; draw through the projections, *a*, *b*, *c*, of the apices of the respective angles of the base, the right lines *a p*, *b o*, *c n*, and they will be the vertical projections of the three arêtes; and the single point, *q'*, wherein the three last lines cut each other, and which will be at the same time on the right line Q *q q'*, which will be vertical projection of the centre of the sphere.

"Lastly, the vertical line *q q'* will be evidently equal to the radius of the inscribed sphere, and the points Q, *q*, will be the projections of the point of contact of the surface of the sphere with the plane of the base.

"We have shown by what considerations we are enabled to determine the position of a point, after having ascertained its distances from three points of known position; we shall now proceed to the actual construction of this question.

"*Third Question.*—To construct the projection of a point, whose distances from three other points given in space is known.

"*Solution.*—*Figure* 40. Let the planes of projection be so chosen as that the one considered as horizontal may pass along the three given points, and let the other be perpendicular to the right line by which two of the points are joined. Then let A, B, C, represent the three given points; and A', B', C', their given distances from the point required. Join two of the points by the right line A B, perpendicularly to which draw L M, and it will determine the position of the vertical plane of the projection. Take the points A, B, C, as centres, and describe with radii equal to the respective distances A', B', C', three arcs of circles, which may cut each other by two's, in the points D, E, F, J, P, Q; through the intersecting points of these arcs taken by two's, draw the lines D E, F J, P Q, and they will be the horizontal projections of the circumferences of circles wherein the three spheres intersect each other; and the single point N, wherein these three lines meet, will evidently be the horizontal projection of the point required.

"In order to obtain the vertical projection of the same point, draw the indefinite line of projection N *n n'*; then, observing that the circle projected in D E is parallel to the vertical plane, and that its projection on this plane must be a circle of equal radius, project the line A B upon L M, in the point *r*, from which, as a centre, and with an interval equal to D R, or the half of D E, describe the circle *d n e n'*, and the circumference will cut the right line N *n n'*, in two points, *n n'*, which will be indifferently the vertical projection of the point required.

"According to the other circumstances of the question, we may determine whether the two points *n*, *n'*, ought to be both used; and in case of one only being necessary, which of them to prefer, and which to reject.

"*The reader may propose to himself the construction of the projections of a point whose distances from three lines given in space are known.*

"*Fourth Question.*—An engineer, when surveying a mountainous country, whether for the purpose of studying the form of the earth, or for making a draught for public works dependent on such form, is furnished with a topographical chart, whereon not only the projections of the different points of the earth are exactly laid down, but also the altitudes of all these points above a level surface, are indicated by figures placed on their sides respectively, commonly called *quotas:* he meets with a remarkable point, not placed on the chart, either in consequence of an omission, or because it has become remarkable since the chart was drawn. The engineer has no instrument of observation about him, except a graphometer, used for measuring angles, furnished with a plumb-line.

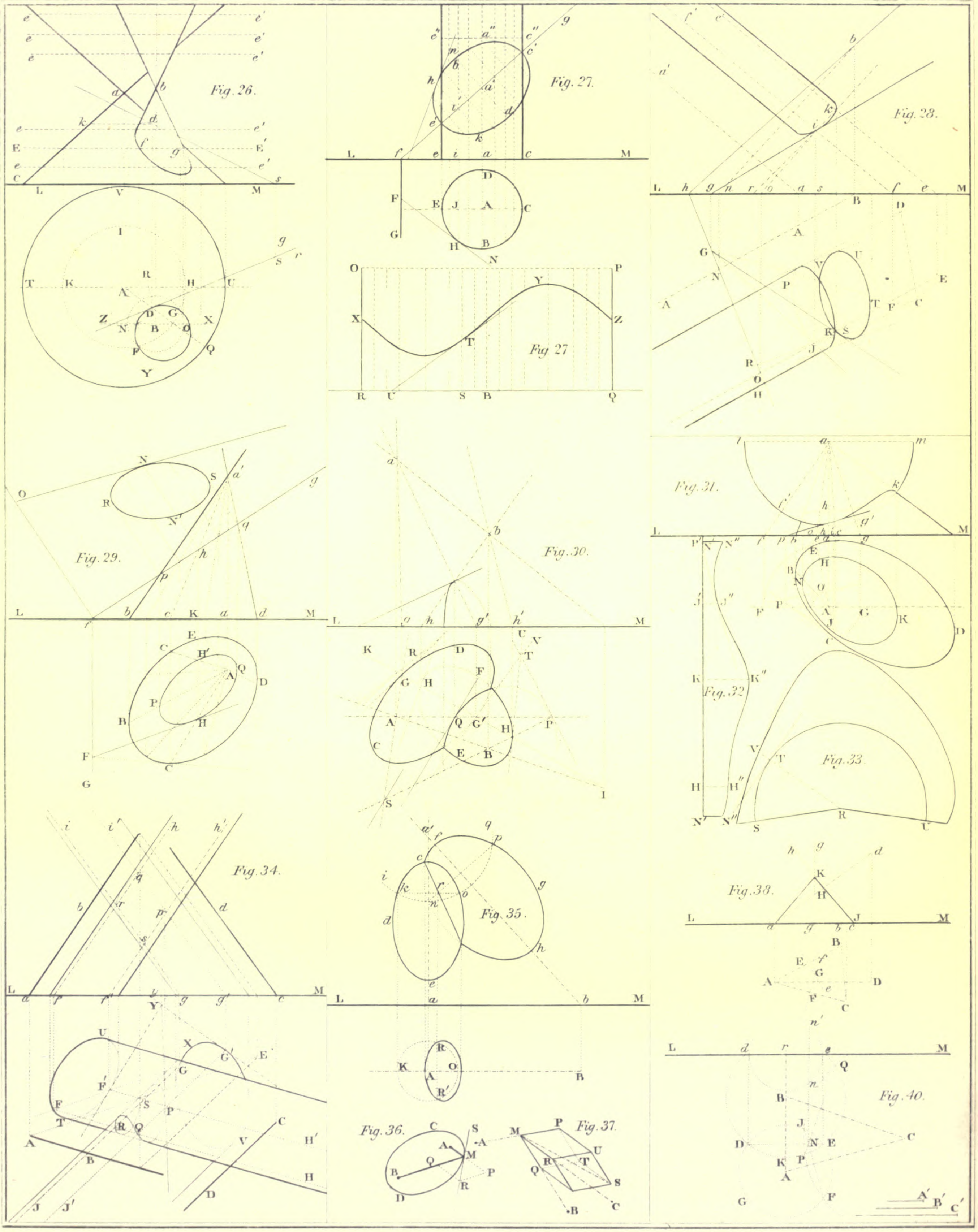
"Placed in such circumstances, he is required, without quitting the station, to construct on the chart the position of the point in question, and to find the suitable quota, *viz.* its height above the level surface.

"*Mode of Solution.*—Among the points correctly described on the chart, nearest to the one under consideration, let the engineer select three, of which two at least are not of the same altitude with that on which he stands; then let him observe the angles formed by the zenith with the visual rays directed to these three points, and by this single observation he may resolve the question.

"For instance: Let A, B, C, represent the three points observed, whose horizontal projections are on the chart, and whose vertical projections he may construct, by means of

DESCRIPTIVE GEOMETRY.

PLATE III



Drawn by M A Nicholson.

Engraved by R Thew.

their quotas. Knowing the angle formed by the zenith with the visual ray directed to the point A, he is also acquainted with the angle formed by the same ray with the vertical line raised above the point A: for, disregarding the convexity of the earth, which is here admissible, these two angles will be found to be alternate-internal, and consequently equal. Then by conceiving a conic surface, of a circular base, with its apex in the point A, its axis vertical, and forming with its axis and generating line an angle equal to the angle observed, which completely determines such surface, it will pass along the visual ray directed to the point A, and consequently along the point of the station: thus he will have a first curved surface determined, on which he may find the point required. By proceeding in a similar manner for the points B, C, as for the first, the point required will farther appear on two other conic surfaces, with circular bases, having their axes vertical, their apices in the points B, C, and each forming an angle with its axis and generating line equal to the angle formed by the zenith and the corresponding visual ray. The point sought for, therefore, will be at the same time upon three conic surfaces, of determinate forms and positions, and consequently in their common intersection. It remains then only to construct, according to the data of the question, the horizontal and vertical projections of the intersections of these three surfaces, taken by two's; the intersections of these projections will give the horizontal and vertical projections of the point required, and consequently its position on the chart, with its height above or below the points of observation, which will determine the quota.

"This solution will generally produce eight points in answer to the question; but the observer may readily distinguish among them that which coincides with the point of the station. He may at first sight ascertain whether the point of the station be above or below the plane that passes along the three points of observation. Suppose this point to be above the plane of the apices of the cones; he may then neglect such branches of the intersections of the conic surfaces as are below the plane, which will reduce the number of possible points to four. So, on the contrary, were the point of the station placed below the plane, the number of points would be equally reduced by omitting such branches as were above it. Then among these four points, if indeed so many exist, he will easily recognize that whose position, relatively to the three apices, is the same with that of the point of the station, relatively to the points of observation.

"*Construction.—Figure* 41. Let A, B, C, represent the horizontal projections of three points of observation taken on the chart; *a*, *b*, *c*, the vertical projections of such points, constructed by measuring on the vertical lines B *b*, C *c*, beginning from the horizontal line L M, passing through the point *a*, the difference of the quotas of the two other points; and let A′ B′ C′, represent the angles which the visual rays, directed to the respective points A, B, C, form with the zenith.

"Draw the indefinite vertical lines *a a′*, *b b′*, *c c′*, and they will be the vertical projections of the axes of the three cones; through the three points *a*, *b*, *c*, draw the right lines *a l*, *b m*, *c n*, and they will form with the vertical lines, angles respectively equal to the given angles A′, B′, C′; which right lines will be each the vertical projection of one of the two extreme sides of the corresponding conic surface.

"This done, draw in the vertical projection horizontal lines, *e e′* at pleasure, which may be considered as the projections of as many horizontal planes, and for each of them work the operation we are about to describe for the one indicated by E E′.

"This line will cut the projections of the axes of the three cones in points *f*, *g*, *h*, that are the vertical projections of the centres of the circles, according to which the corresponding horizontal plane cuts the three conic surfaces; it will also cut the extreme sides of the cones *a l*, *b m*, *c n*, in such points *f′*, *g′*, *h′*, that the distances *f′ f g g′ h h′*, will be the radii of these circles. From the points A, B, C, taken successively as centres, and with the radii respectively equal to *f f*, *g g′*, *h h′*, describe circles, whose circumferences will be the horizontal projections of the sections made in the three conic surfaces by the same plane E E′; these circumferences will intersect each other, two by two, in points D D′, K, K′, J, J′, that are the projections of as many points of the three intersections of the conic surfaces, considered by two's; and by projecting these points upon E E′, *d d′*, *k k′*, *i i′*, we shall obtain the vertical projections of the same points of the three intersections.

"By afterwards working in the same manner upon the other right lines *e e′* we shall obtain from each of them new points, D, D′, K, K′, J, J′, in the horizontal projection, and likewise *d*, *d′*, *k*, *k′*, *i*, *i′*, in the vertical one; then pass a curve, D P D′, through all the points D, D′ . . . . and it will be the horizontal projection of the intersection of the first conic surface with the second; pass another curve, K P K′, through all the points K, K′ . . . . and it will be the projection of the intersection of the second surface with the third: and by passing a third curve, J P J′, through all the points J, J′ . . . ., we shall have the projection of the intersection of the third surface with the first. All the points P . . . . wherein these three curves intersect each other, are the horizontal projections of as many points answering to the question.

"So, in the vertical projection, by passing a first curve through all the points *d*, *d′* . . . . a second through all the points *k*, *k′* . . . . and a third through all the points *i*, *i′* . . . . we shall have in such curves the vertical projections of the intersections of the three surfaces, taken in pairs; and all the points, *p* . . . . wherein such curves intersect each other, will be the vertical projections of all the points necessary to the solution of the question.

"The projections P, *p*, of an identical point will be in the same perpendicular to L M.

"Having discovered among the points P the one indicative of the point of the station, the observer will be in possession of the horizontal projection of such station, and, consequently, of its position on the chart; then by means of the altitude of the corresponding point *p* above the right line L M, he may obtain the elevation of the point of the station above that of the point of observation A., and that will give him the appropriate quota.

"In this solution we have constructed the projections of the three intersections of the surfaces; but two would have been sufficient. Yet we would always advise the adoption of this practice, because the projections of the two curves of double curvature may intersect each other in points not correspondent to those of intersection; and also, because in order to recognize the projections of the points of intersection, it is necessary to follow the branches of the two curves that are upon the same face of one of the surfaces; which requires a laborious degree of attention, seldom, if ever, necessary in constructing the three curves: the points wherein they all three cut each other, are true points of intersection.

"*Fifth Question.*—Under circumstances similar to the preceding, except that the instrument is not furnished with a plumb-line, so that the angles formed with the zenith cannot be measured, the engineer is required, without quitting the station, to determine on the chart the situation of the point where he is, and to find the quota belonging to it, viz. its elevation above the level surface to which all the points of the chart refer.

"*Mode of Solution.*—Having made choice of three points of land, whose situations are accurately marked on the chart, and of such kind as not to be in the same plane with the point of the station, let the engineer measure the three angles which he visual rays directed towards those three points form with each other; and by means of this simple observation he will be able to resolve the question.

"Thus, by letting A, B, C, represent the three points of observation, and supposing them to be joined by the right lines A B, B C, C A, the engineer will be in possession of the horizontal projections of such lines, traced on the chart; and by means of the quotas of the three points, he may obtain the differences of the altitudes of the extremities of the lines; he may, therefore, ascertain the size of each of them.

"This done, if any plane whatever, drawn through A B, a rectangular triangle, B A D (*Figure* 42) be conceived as constructed, with A B for its base, whose angle in B is the complement of the angle under which the side A B has been observed, the angle in D will be equal to the angle of observation, and the circumference of a circle described through the points A, B, D, will possess the property that if from any point whatever, E, of the arc A D B, two right lines be drawn to the points A, B, the angle, in E, which they include, will be equal to the angle of observation. If, then, the plane of the circle be conceived to turn upon A B, as on a hinge, the arc A D B will generate a revolving surface, all whose points will be endowed with the same property, viz. that if from any point of the surface two right lines be drawn to the points A, B, they will include an angle equal to the angle of observation. Now, it is evident that the points of such revolving surface alone possess this property; therefore the surface passes through the point of the station.

"By operating in a similar manner upon the two other lines B C, C A, two other revolving surfaces will be obtained, on each of which the point of the station will be found; this point will therefore be at the same time upon three different revolving surfaces, determined as to their form and position; consequently it must be a point of their common intersection. Thus, in the construction of the horizontal and vertical projections of the intersections of these three surfaces, taken in pairs, the points in which the three projections cut each other will be the projections of the point answering the question. The horizontal projection will be its position on the chart, and the vertical projection its elevation above or below the points of observation.

"Were this question to be treated by analysis, it would generally lead to an equation of the sixty-fourth degree; for each of the revolving surfaces has four distinct faces, two of which are generated by the arc A D B, and the other two by the arc A F B. As each of the faces of the first surface may be cut by all those of the second, sixteen branches may be the result in the curve of intersection; and as these may be again cut by the four faces of the third surface, they may produce sixty-four points of intersection in the three surfaces; though they would not all apply to the solution of the question. Thus, if from any point, as F, of the arc A F B, lines be drawn to the extremities of A B, the angle A F B, included by them, would not be equal to the angle of observation, but would be its supplement. The faces generated by the arc A F B, and the analogous faces in the other revolving surfaces, cannot therefore serve towards the solution of the question; and all the intersecting points belonging to any of these faces are foreign to the problem.

"In descriptive geometry, we may, and indeed should exclude the arc A F B, and those analogous to it, in the two other surfaces; each of which will then have but two faces, and the number of their possible points of intersection will be reduced to eight. Of these, four will be on one side of the plane passing through the three revolving axes, and four on the other. The observer, being always aware of the side on which he is placed relatively to this plane, will, of course, not construct the intersections of the opposite side, so that the number of points will in fact be reduced to four. Now, among these four points, if they all exist, he will readily know which is placed in respect to the points A, B, C, in a manner similar to that of the station relatively to the three points of the country that he has observed.

"*Construction.*—Select the position of the two planes of projection so as that the one taken as horizontal may pass through the three points observed, and that the other may be perpendicular to the right line drawn through two of those points. Let then A B C (*Figure* 42) represent the triangle formed by the points observed, considered in its plane, and A′, B′, C′, the three angles given by the observation. Draw perpendicularly to the sides A B, the right line L M, which will indicate the position of the vertical plane of projection; and construct, according to the directions already given, the generating arcs A E D B, B G C, C F A, of three revolving surfaces, whose sides, A B, B C, A C, are the axes. Then, taking the point A as a centre, describe arcs of circles, as E O F, at pleasure, and they will cut the generators, whose axes meet in A, in such points as E, F, from which, drop upon the respective axes, the indefinite perpendiculars E E′, F F′; these perpendiculars will intersect each other somewhere in a point, as H, which will be the horizontal projection of a point of intersection of the two surfaces, whose axes are A B, A C; and the curve, A H P, drawn through all the points H.... thus found, will be the horizontal projection of this intersection. Next, after projecting the axis A B in *a*, take the point *a* as a centre, and describe from it, with radii successively equal to the perpendiculars E E′, arcs of circles, as *e e′ h*, on each of which, by projecting the point H, to its corresponding point in *h*, we shall have the vertical projection of a point of the intersection of the two same revolving surfaces; and the curve, *a h p*, drawn through all the points, *h*.... so constructed, will be the vertical projection of this intersection.

"The same method may be pursued for the two surfaces revolving about the axes A B, B C; *viz.* taking the point of coincidence, B, of the two axes as a centre, describe arcs of circles, as D K G, at pleasure; which arcs will cut the two generators in points, as D, G, from which drop on the respective axes the indefinite perpendiculars D, D′, G G′; these perpendiculars will cut each other in a point, as J; and the curve, B J P, drawn through all the points J... will be the horizontal projection of the intersection of the first and third revolving surfaces. Taking the point *a* as a centre, with radii successively equal to the perpendiculars D D′, describe arcs of circles, as *d d′ i*, on which project in *i* the corresponding points J; and the curve, *a i p*, drawn through all the points *i*, will be the vertical projection of the same intersection.

"Here we shall find that all the points, P.... in which the two curves A H P, B J P, cut each other, are horizontal projections of so many points applicable to the question; and that all the points, *p*.... in which the curves *a h p*, *a i p*, intersect each other, are the vertical projections of the same points.

"The projections, thus found, will not give immediately the position of the point of station on the chart; nor its height, because the horizontal plane is not that of the chart; but it will be easy to find them on the true planes of projection.

"*Sixth Question.*—The general of an army meets that of an enemy, but not having a chart of the country, is at a loss how to form his plan of attack. But being in possession of

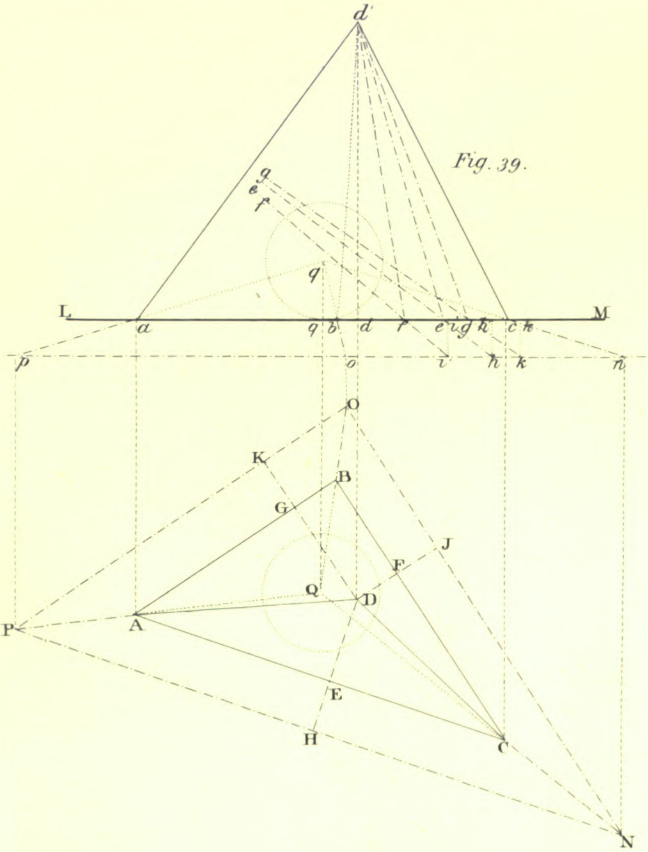


Fig. 39.

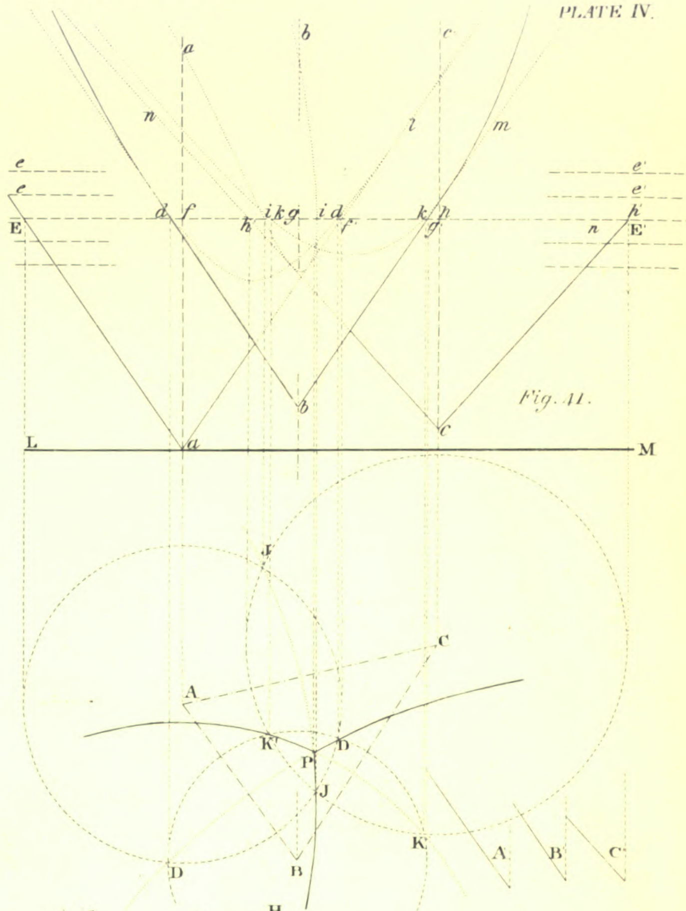


Fig. 41.

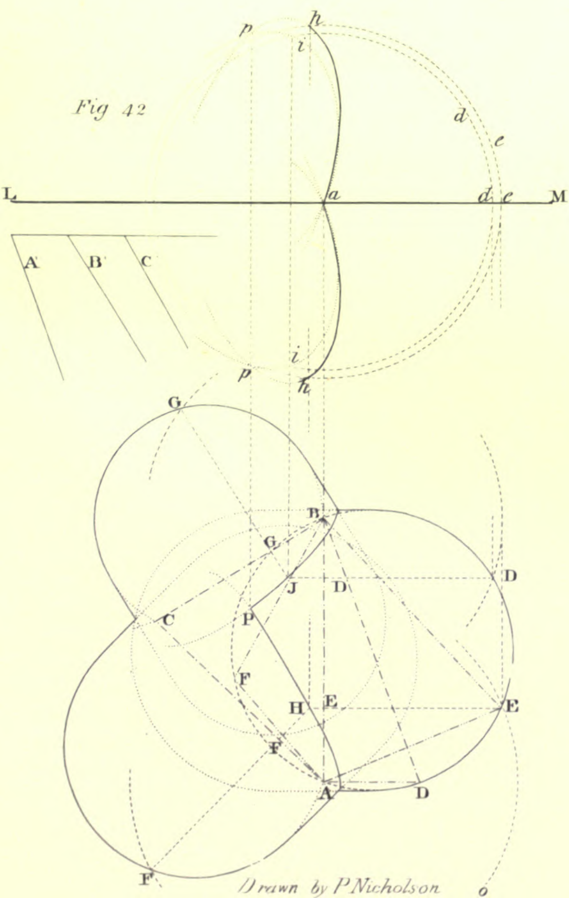


Fig. 42

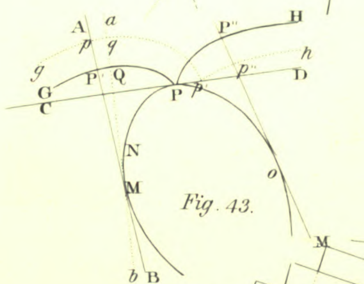


Fig. 43.

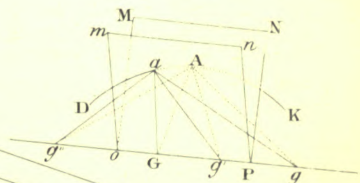


Fig. 44.

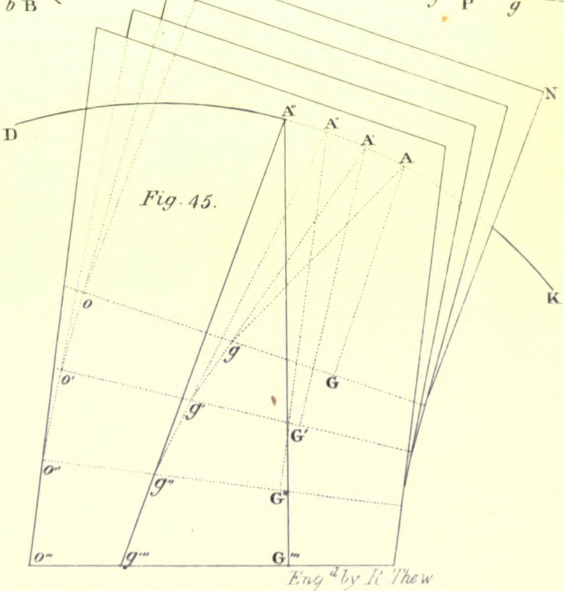


Fig. 45.

Drawn by P. Nicholson

Eng^d by R. Thew

a balloon, he dismisses an engineer in it, to make the necessary arrangements for constructing a chart, and to give as near an idea of the level of the country as possible. Fearing, however, that, should the balloon be suffered to change its station over the earth, the enemy might anticipate his design and frustrate it, he permits the engineer to raise himself to different altitudes in the atmosphere, if necessary, but not to alter his perpendicular station. The engineer is provided with an instrument for the measurement of angles, which is also furnished with a plumb-line: it is asked, how can the engineer fulfil the object of his general?

"*Solution.*—The engineer must take two stations in the same vertical line, whose difference he may ascertain by measuring the cord let out, to raise the balloon from one station to the other. In one of these, the lowest, for example, let him measure the angles made by the zenith with the visual rays directed towards the points whose position he wishes to determine on the chart; then, among these points, let him select one, which he will consider as the first, and which we shall denominate A; let him also measure successively the angles formed by the visual ray directed to the point A, and those directed towards all the other points. In the second station, let him measure the angles formed by the zenith with the visual rays directed to all the points of the country: and from these observations, he may construct the chart required.

"When we are acquainted with the angles formed by the zenith with the two visual rays directed from the two stations towards the same point, we know that such point is at once upon two determinate and known conic surfaces, with circular bases, having their axes in the same zenith, the distance of their apices equal to the difference of the altitudes of the two stations, and the angles formed by their generators with the common axis equal to the angles observed. Also, when we are acquainted with the angle formed by the visual ray directed from the first station to this point, and by that directed towards the point A, we know that the point considered must likewise be on a third conic surface, with a circular base, whose inclined axis is the visual ray directed from the first station towards the point A, having its apex in the first station, and forming an angle between its axis and generator equal to the angle observed. The point considered, therefore, will be found at the same time on conic surfaces with circular bases, of known form and position; consequently it must be the point of their common intersection; and by constructing the horizontal and vertical projections of the intersection, we shall obtain the position of the point on the chart, with its elevation above or below others.

"Without varying from these considerations, the construction may be rendered more simple, by some of the methods already prescribed: for with a knowledge of the angles formed at the first station by the visual ray directed towards the point A, and by the rays directed towards all the other points; and knowing the angles formed by the sides of these angles with the zenith, it is easy to reduce them to the horizon, viz. by constructing their horizontal projections. By selecting, therefore, on the chart, an arbitrary point, to represent the projection of the zenith of the balloon, and drawing an arbitrary right line through it, to represent the projection of the visual ray directed towards A; drawing also, through the same point, right lines, making with such projection of the ray, angles equal to those reduced to the horizon; it is evident that each of these lines must contain the horizontal projection of its correspondent point of country. It only remains, then, to find the distance of this point of the country from the zenith. For this purpose, take, in the vertical projection, and upon the projection of the zenith of the balloon, two points, which in parts of the scale are distant from each other equal to the measured distance of the two stations, and through these points draw right lines making with the zenith angles equal to those observed for an identical point of country; which lines will cross each other in a point whose distance from the zenith will be the distance required; and by measuring it on the corresponding ray, beginning from the projection of the balloon, we shall have on the chart, the position of the point of country. The same two right lines, in the vertical projection, will, by their intersection, determine the height of such point; therefore, by taking on the vertical projection, the heights of all the points of country above a common horizontal plane, we shall be able to determine the quotas suitable for all the points of the chart, and likewise the level of the country.

"This construction is so easy, that it does not require a figure.

"The right line drawn from the projection of the zenith of the balloon to that of the first point, A, observed, having been in the first instance traced upon the chart arbitrarily, it follows that the chart is not adjusted to the cardinal points, and, indeed, in the observations laid down, we find nothing by which to determine the objects observed towards them. But if an engineer observe on the earth, the angle made by the meridian with a visual ray directed from the foot of the zenith towards one of the points placed on the chart, and if he describe this angle upon its projection, he will have the direction of the meridian, and the chart will be adjusted to the cardinal points."

The great length to which our extracts from Monge's work have extended, will be, we trust, pardoned, in consideration of the value of those extracts; and of our desire to do the most ample justice to the learned and ingenious author. Though many works of a similar kind by eminent writers have since issued from the press, the *Geometrie Descriptive* of Monge still holds a most distinguished place; and will continue to be regarded as one of the best elementary books of modern times.

DESICCATION, (Latin, *desicco*, to dry), the act of making dry; it is the chemical operation of drying bodies, and is effected in different modes, according to the nature of the substance. The term, Desiccating Process, has been applied to a patented invention, (Davison and Symington's Patent), for seasoning or drying a great variety of substances. It is said to have been used with success in seasoning wood.

DESIGN, (*designo*, Latin; *dessein*, French), an original drawing of a building to be executed, comprehending the invention, composition, and arrangement of the whole. A design includes plans, elevations, and sections of the building intended to be carried into execution, besides other drawings of *details*, or *parts at large*. The number of these will, of course, depend either upon the nature of the building, that is, on its being more or less complex, or as it is intended to show it more or less fully. A small simple house will only require one plan and an elevation. A large edifice, with great variety of parts, will require plans of each story, elevations of the different fronts, a longitudinal and transverse section, and, in general, as many drawings as will be sufficient to explain all the parts All the minute parts, as bases, capitals, architraves, friezes, cornices, and other mouldings, are to be exhibited in their true geometrical proportion, at full size.

There is, perhaps, a certain prejudice against drawings of this kind, from an impression too generally entertained, that they are unintelligible except to the initiated. This feeling would be easily removed, were unprofessional persons to take the pains to examine a complete set of well-prepared architectural drawings. A very little explanation renders these drawings perfectly clear to any person of common capacity, however ignorant he may be of architecture.

To begin with the *plan*.—This may be described as the *map* of the building. By its means we distinguish most clearly the exact shape and extent of the structure as regards the space on which it stands; the thickness of the walls, the internal arrangement of all the rooms and passages; and the situation and width of doors, windows, fireplaces, staircases, &c. The raised and solid parts, such as walls, columns, piers, &c., are shaded; the voids and apertures, such as doors, windows, &c., are left white. For every story of a building there should be a separate plan, although it is not usual, in books of designs, to give more than those of the ground-floor, and the principal one above it.

Next to the plan we may describe the *Elevation*. This may be defined as a vertical plan; it shows the front, or one external face of the building, and gives the precise forms and measurements of every part, drawn to scale. It must be observed, that the particular in which an elevation differs from other drawings, and from the appearance of the objects themselves, is, that no distinction is made between curved horizontal lines and straight ones; so that, whether the part be a plane or a curved surface, can be understood only from the shadowing, unless there happens to be something that assists in denoting curvature of plan. Thus, the mouldings of the base of a column are all straight lines; consequently, without shadow to express rotundity, we could not determine whether they belonged to a flat or a round surface, unless the shaft be fluted, in which case the flutes will diminish in width, according to their distance from the centre.

Elevations have sometimes given to them something of a pictorial character, by colouring as well as by shadowing, and not unfrequently by the addition of sky and background. It would be better, perhaps, were such accompaniment restricted to what may be just sufficient to relieve the building, instead of being extended over the whole picture, and carefully worked up; because such additions to the usual plain architectural drawing are calculated to give a formal and stiff appearance to the drawing, offensive to good taste and simplicity. In modern architectural publications, especially foreign ones, *outline* elevations are now generally given; these are preferable to those which are shadowed, as they exhibit all the forms more distinctly, and admit of being measured with much greater exactness.

We next proceed to describe the *Section*. A section is the projection or geometrical representation of a building supposed to be cut by a vertical plane, for the purpose of exhibiting the interior, and describing the height, breadth, thickness, and manner of construction of the walls, &c. By the section we are made acquainted with a variety of particulars, in regard to which a plan cannot be made to afford any information. It shows us the thickness of the walls and floors, the heights of the rooms, the forms and profiles of ceilings, whether flat, coved, or arched, also the exact forms of domes and skylights. It shows the heights of the doors, how they are panelled and decorated, the form of the chimney-pieces, &c., and, in some instances, furniture and fittings-up are advantageously introduced, with a view to judge of effect. For detailed and filled-up sections, it is usual to employ outline with the walls and floors shaded, the former as more solid, being made darker than the latter. When, on the other hand, the elevations of the rooms themselves are shadowed, the thickness of the intersected walls, &c., are left white, in order to prevent confusion, and exhibit the profiles better.

Indispensable and interesting, however, as they are, sections are a far more conventional mode of drawing than elevations, because they represent a building as it never can be seen, except where the front of a house has been taken down for the purpose of rebuilding it, while the floors and partition-walls are left standing; in which case any one may obtain a good idea of the nature of a section, but of one seen in perspective.

Besides general sections showing the whole of a building from top to bottom, there are frequently partial ones, showing only the rooms on one floor, or even a single room, when it is desired to show any particular apartment on a larger scale than could conveniently be done any other way. Sometimes recourse is had to a plan of the room with each of its sides drawn around it, as if laid flat on the ground, by which means the whole of the apartment is described. Horizontal sections also are given, to show more accurately than can be done on a plan, the soffits of entablatures, the ceiling and its ornaments, the window recesses, and door-cases, and the capitals of columns and projection.

Besides the usual plans, elevations, and sections, there should also be detailed drawings, answering, in some respect, to what are termed *working drawings;* these give a more correct idea of the minutiæ and finishing of the subject than can be obtained from the general design only.

In a complete design, however, it is desirable to have perspective views both of the exterior and principal parts of the interior. These enable a person to comprehend the character and effect of the design as a whole, which, without such drawings, can be judged of only piecemeal. The perspective drawing of the exterior ought to exhibit the edifice from one of the most frequented points of view, and ought also to be so contrived as to make it impressive from every point whence it can be seen, and particularly from those positions in which the greatest part of the design is comprehended at one view.

In very large works, a model will be useful for preventing many mistakes that might otherwise arise, as all the parts can be easily seen by inspection; but when drawings only are used, from the number that are necessary to the performance of the work, a long examination and consideration are requisite; and after all, some of the most essential parts of the construction may be, and frequently are, overlooked.

For other particulars respecting designs, we refer to the articles Apartment, Break, Building, House.

DESIGNING, the art of delineating or drawing the appearance of natural objects by lines on a plane.

DESK, a part of a pulpit; as the clerk's or precentor's *desk;* also a kind of rostrum where the clergyman reads the printed service of the English Church.

DESTINA, Latin, a pillar or other support of a building, in which sense the term is used by Vitruvius; but when employed by ecclesiastical writers, it is usually applied by them to the aisle of a church, or to a small cell.

DETACHED COLUMN, the same as Insulated Column, which see.

DETAIL, (from the French, *détailler*) the delineation of all the parts of an edifice, so as to be sufficiently intelligible for the execution of the work. The detail is otherwise denominated *the working drawings.*

The expression *detail* is also used in other ways, as, when a moulding is exhibited in profile by abutting on a plane, it is said to *detail* on the plane. Details in the fine arts are minute and particular parts of a picture, statue, or building, as distinguished from the general conception, or larger parts of a composition.

DETERIORATION, (from the Latin, *deterior*) the act whereby a thing is rendered worse. This was the fate of architecture in passing from the Greeks to the Romans, and more particularly in the decline of the Roman empire.

DETERMINATE, a word applied in mathematics to those problems which have one answer only, or at least a certain and finite number of answers.

DETERMINING LINE, in conic sections, the intersection of a plane parallel to the cutting plane with the plane of the base of the cone. In the sections of a cone which produce the hyperbola, the determining line falls within the base of the cone; in parabolic sections, it forms a tangent to the base. In the elliptic section, it falls without; and when the section is a circle, the determining line will, in one case, never meet the plane of the base, as in this instance the cutting plane is parallel to the plane of the base.

DIACONICON, (from *διακονεω*, *I serve, I minister*) a place adjoining to the ancient churches, where the sacred vestments, vessels, relics, and ornaments of the altar, were preserved. This apartment was otherwise called *sacristy*. It was also denominated *ασπ ςικον*, and in Latin, *salutatorium*; because it was here that the bishop received and saluted strangers. Sometimes it was called *μητατωνιον*, or *μιτατωριον*, *mensa*, on account of the tables kept there.

DIAGONAL, (from the Greek, *διαγώνιος*) in geometry, a line drawn through any figure, from the vertex of one angle to that of another.

Every rectilinear figure may be divided into as many triangles, wanting two, as the figure has sides.

Every diagonal divides a parallelogram into two equal parts.

A most excellent theorem in elementary geometry, first demonstrated by Mr. Lagny, in the *Mémoires de l'Academie Royale des Sciences, an.* 1706, is, that the sum of the squares of the two diagonals of every parallelogram is equal to the sum of the squares of the four sides; and it is evident that the 47th proposition of Euclid may be derived as a mere corollary from this theorem. The demonstration is as follows: Let A B C D be an oblique parallelogram, of which B D is the greater diagonal, and A C the lesser. From the vertex, A, of the obtuse angle D A B, drop the perpendiculars A E and B F to C D; then the triangles A D E, B C F, are equal and similar; for A D is equal to B C, and the angles A D E and B C F are equal to each other; also the angles A E D, and B F C, are equal to each other; consequently D E is equal to C F. Now, by proposition xii. lib. ii. of Euclid, in the obtuse-angled triangle B D C, the square of the side B D is equal to the sum of the squares B C, C D, together with double the rectangle C F by C D; and by the 13th proposition of the same book, in the triangle D A C, the square of A C is equal to the sum of the squares of A D and C D, abating double the rectangle of C D by D E equal to C F; for C F is equal to D E: now, since

$$BD^2 = BC^2 + CD^2 + 2(CF \times CD)$$
$$\text{and } AC^2 = AD^2 + AB^2 - 2(CF \times CD)$$

$$\text{Therefore } BD^2 + AC^2 = BC^2 + CD^2 + AD^2 + AB^2$$

Then, if the parallelogram be right-angled, the diagonals are equal, and consequently each equal to the squares of the two sides containing other right angles opposite that diagonal.

Hence, if one of the diagonals and a side be known, the other diagonal will likewise be known.

Another proposition, of a similar nature to the above, was discovered by Ptolemy, viz., that the rectangles of any two diagonals of a quadrilateral figure inscribed in a circle, is equal to the sum of the two rectangles contained by the opposite sides.

In taking the dimensions of a building, in order to make a plan, it is by far the most accurate and expeditious method, to take the diagonals. In carpentry and joinery, no polygonal frame whatever can be rendered stationary or immovable about the angles, without diagonal pieces, as the strength consists in dividing the work into triangles. In geometry, a polygon cannot be constructed by the linear dimensions of its sides only, without the diagonals, as the area of the figure may be variable under the same number of sides, *ad infinitum*, from a certain position of the sides, in which they will contain the greatest possible area to any less area whatever.

The impulse given to a body, at the same instant, by two forces, in different directions, causes that body to move in the diagonal of a parallelogram, of which, each of the forces acting separately, would cause the body to describe a side, in the same time as the body moved conjointly by the two forces.

DIAGONAL BUTTRESS, a buttress placed at the angle of a building, chiefly used in churches of mediæval date, and employed to resist the thrusts of the ribs of the last severy of the vaulting. It answers the same purpose as two distinct buttresses set square with the two walls at their intersection, but with less material. Diagonal buttresses do not seem to have been employed to any extent previous to the fourteenth century, but are common in buildings of the Decorated style. Previously, two buttresses at right angles were employed.

DIAGONAL MOULDING, the same as ZIG-ZAG or DANCETTE.

DIAGONAL PAVING. *See* PAVEMENT.

DIAGONAL RIB, a rib or groin passing diagonally across a bay of vaulting from one angle to the opposite.

DIAGONAL SCALE, a compound scale, by which a subdivision may be made of any part of the smallest unit upon a straight line, by means of equidistant parallels crossing others of the same kind.

DIAGRAM, (from *διαγραφω*, *I describe*) in geometry, a scheme for the explanation or demonstration of a figure.

DIAL, (from the Latin, *dies*, day) an instrument serving to measure time by the shadow of the sun. Or more particularly, the surface of a body so graduated that a certain line parallel to the earth's axis will show the hour of the day, when the sun shines upon the surface of such body.

DIAMETER, (from *δια*, *through*, and *μετρειν*, *to measure*) a straight line passing through the centre of a circle, and terminated at each end by the circumference; the diameter is therefore a chord passing through the centre of the circle, and is consequently greater than any other chord in the same circle.

The diameter of a circle divides the circumference into two equal parts.

For other particulars, see the article CIRCLE.

DIAMETER OF A COLUMN, the thickness of the lowest part of the shaft at the bottom. In a colonnade, or range of columns, the intercolumns should always be proportioned to the diameter of the column.

DIAMETER OF A CONIC SECTION. *See* CONIC SECTION.

DIAMETER, *Conjugate*. *See* CONIC SECTION.

DIAMETER OF DIMINUTION, the diameter at the top of the shaft.

DIAMETER OF A SPHERE. *See* SPHERE.

DIAMETER, *Transverse*, the longest axis of an ellipsis.

DIAMETERS, *Conjugate*, of a circle, two diameters at right angles.

DIAMOND, an instrument for cutting glass.

DIAMOND, the small instrument used by glaziers for cutting glass, and formed by the setting of a fractured piece of diamond in a wooden handle. There are now in use two descriptions of pencil diamonds, the old one, and the new or patent pencil. The defect of the former is the difficulty experienced in placing it on the glass in, at once, the proper angle, so as to make it cut and not scratch. The patent pencil overcomes this difficulty, the diamond being fixed by the peculiar mode of its setting at the correct angle at which it will cut the glass. The diamond in these pencils is about the size of an ordinary pin's head, and is set in a nipple of brass or copper. They are differently fitted up, according to the quality of the material which they are to work upon.

DIAMOND FRET, a species of moulding consisting of fillets intersecting each other, so as to form diamonds or rhombuses.

DIAMOND, *Glass*. *See* GLASS.

DIAMOND, *Pavement*. *See* PAVEMENT.

DIANA, *Temple of*. *See* TEMPLE.

DIAPER, a panel or recessed surface enriched with carving in low relief, and frequently gilded and coloured; or a plain surface enriched with polychrome. Also a kind of linen-cloth wrought with figures in weaving.

DIAPERING, the decoration employed in the relief of any plain surface by the interweaving of fret-work, or covering the field with ornamental patterns. In some cases, it consists in the application of colour only, but in others of embossed or carved work, delicately chiselled, and also enriched with gilding and colour. Diaper-work is usually composed of small square panels, containing flowers in low relief, as in the spandrels of the choir arches, and in other parts of Westminster Abbey. There is a beautiful specimen of later date on a monument in the choir of Canterbury cathedral; the design is composed of a flower of six leaves in low relief, within a sexagonal compartment, the sides of which are formed by the sides of six spherical triangles, and are foliated within, and coloured azure and gules. Another specimen is to be seen in the Lady Chapel, Ely, at the back of the canopies of the ornamental arcade which surrounds the walls; others at Waltham Cross, and in many buildings erected during the reigns of Henry III. and Edward I. Diaperings of a rich and tasteful design were also employed in ecclesiastical hangings, vestments, &c. Some very beautiful designs may be seen in *Pugin's Glossary*.

DIASTYLE, (from *δια*, and *ςυλος*, *a pillar*) in classical architecture, that distance between columns equal to three diameters of the column; or the word is applied to the edifice itself, in which columns are applied at this interval.

DIATHYRA, the vestibule in front of the doors of a Greek house, answering to the prothyra of the Romans.

DIATONI, quoins or corner-stones bonding two walls together.

DIDORON, (from the Greek) a kind of brick used by the Greeks, being one foot long and half a foot broad.

DIE, of a pedestal, that part contained between the base and the cornice. *See* DYE.

DIFFERENTIAL, a term used to denote an infinitely small quantity. The differential method is applied to the doctrine of infinitesimals; it consists in descending from whole quantities to their infinitely small differences, and comparing them. Hence it is called the differential calculus or analysis of infinitesimals.

DIGGING is performed by the solid yard of 27 cubic feet.

In soft ground, where only cutting with the spade is necessary, a man will throw up a cubic yard in an hour, or 10 cubic yards in a day. But if hacking be necessary, an additional man will be required; and very strong gravel will require two. The rates of a cubic yard depending thus upon each circumstance, they will be in the ratio of the arithmetical numbers 1, 2, 3. If, therefore, the wages of a labourer be 2s. 6d. per day, the price of a yard will be 3d. for cutting only; 6d. for cutting and hacking; and 9d. when two hackers are necessary.

In sandy ground, when wheeling is requisite, three men will be required to remove 30 cubic yards a day, to the distance of 20 yards, two filling and one wheeling; but to remove the same quantity in a day, to any greater distance, an additional man will be required for every twenty yards.

To find the price of removing any number of cubic yards to any given distance:

Divide the distance in yards by 20, which gives the number of wheelers; add the two cutters to the quotient, and you will have the whole number employed; multiply the sum by the daily wages of a labourer, and the produce will be the price of 30 cubic yards.—Then,

As 30 cubic yards is to the whole number, so is the price of 30 cubic yards to the cost of the whole.

Example.—What will it cost to remove 2,750 cubic yards, to the distance of 120 yards, a man's wages being three shillings per day?

2,0)12,0

6 number of wheelers.
2 fillers.

8 men employed.
3 shillings per day.

24 price of 30 cubic yards.

$$30 : 2750 : : 24 : \frac{2750 \times 24}{30} = £110.$$

See farther under EXCAVATION.

DIGLYPH, (from the Greek, *διγλυφος*), a tablet with two engravings or channels.

DIKE, or DYKE, (from the Saxon, *dic*, a bank or mound), a work of stone, timber, or earth, supported by fascines, raised to oppose the entrance or passage of waters of the sea, a river, lake, or the like. These dykes usually consist of elevations of earth, strengthened with hurdles or stakes, stones, and other matters.

DILAPIDATION, (from the Latin), the state of a building suffered to fall into a ruinous condition by neglect. The term is usually restricted, in its legal sense, to the pulling down or destroying the houses or buildings belonging to an ecclesiastical benefice, or suffering them by neglect to fall into ruin or decay. In the experience of every-day life, there are few families who have not had occasion to feel how much of annoyance, inconvenience, and loss may be hidden under the word *dilapidations*.

In the "Builder" of January, 1849, there appeared an excellent letter on this subject, and as it is evidently written by one well acquainted with it, we consider its insertion here will be both interesting and useful:—

"This subject," says the writer, "is one that has never received proper consideration from the hands of a large class who are interested and affected by it—'tenants.' Men who are daily imposing upon themselves heavy responsibilities, the extent, or the peculiar obligations, and the ultimate result of which they are totally unacquainted with.

"Few persons on taking a lease think of raising objections to covenants which are, they are informed, of the usual character; or, if prudent enough to pledge themselves to an agreement of but three years, they fearlessly, and without hesitation, affix their signatures to a clause promising to 'uphold, maintain, and sustain,' &c., or that which really may turn out an impossibility; for some houses, so to speak, have the elements of destruction and disease upon them from their infancy. Bad brickwork, causing by its humidity damp walls, rots everything; unseasoned timber, that shrinks and twists in all directions, throwing floors out of their level, and making settlements from top to bottom, through which the doors and windows have to be constantly eased and rehung; faulty and imperfect drainage, which becomes constantly choked; the roof acting like a sieve; and this list of ills that modern houses are heir to, is no exaggeration; yet many a man, and he, too, who may be esteemed in his own business a prudent man, is induced, from a want of consideration, readily to promise to do and perform all needful and necessary repairs, or at least to leave the house in tenantable repair. It is not a little amusing to observe the tenant's surprise at the end of his tenancy, on receiving a notice of dilapidations. What! he exclaims, and leave the house 100 per cent. better than when I took it? This, and the various sums of money paid to jobbing tradesmen, all the accounts of whom he can enumerate by heart, constitute the anchor of hope to the poor tenant, when informed, in spite of all the benefits the house has derived from him during his tenancy, that still such and such are dilapidations, and as such he is answerable for their being reinstated. In the present age, remarkable for the number of scantily-constructed houses, with so nice and clean, yet deceitful, an exterior, invitingly waiting for tenants on lease or agreement, it cannot fail to be useful to consider the nature of the obligation that exists between landlord and tenant upon the hire of house-property; for as mistakes will happen in the best regulated families, so do the friendship and good understanding that may have existed between landlord and tenant suddenly cease with the termination of the lease. Covenants to repair, when once entered into, are irrevocable; it is, therefore, most important that each party should clearly understand what constitutes repairs or dilapidations; and as to all defects, whether they arise from accident, neglect, or decay, and by which party they are to be made good.

"A landlord, on making a claim from his tenant for dilapidations, must show that they are such as were stipulated for in the lease, as the obligation on the part of the tenant to make good, varies, in nearly every case, according to the different covenants of the lease, by which the tenants are bound by more or less stringent clauses, involving greater or less responsibilities.

"Mr. Gibbons, in an excellent treatise on this subject, defines dilapidations as the act or default of a person having to use a tenement to the injury of another having a right to the same tenement, or a tenant's obligation may be considered as depending on the old maxim—'You must not injure another's property, but use it as your own.'

"It is an imperative act of justice to himself for the future tenant to make a stipulation that, previous to the commencement of his tenancy, the premises shall be surveyed; so that, if then there can be considered anything unsound or defective on the premises, it may be made good before the agreement is concluded, otherwise the tenant will find that he must make good all, whatever was the state of repair when he took possession of the premises.

"*Houses held on lease.*—In the case of premises being let on lease, as tenant should not be compelled to supply and make good defects that may arise from time and use, because, as the tenant bargained for use, and gives to the owner an equivalent rent, the landlord has a claim only for a restoration of the tenement as injured by the tenant, but has no right to make a claim for the wear to be made good; but then, as the tenant agrees to keep the house in tenantable repair, he is bound to supply all occasional and accidental defects which may expose the premises to premature decay. Accidents happening during his tenancy, if not inevitable, must be made good by the tenant, for it is fair to presume, that had he adopted proper precautions, the accident might have been prevented; therefore, there exists an obligation not to suffer dilapidations, and it is evident that the tenant is equally bound not to do any act that will cause an injury to the tenement.

"*Voluntary waste* means an alteration in the tenement, it being held in law that a lessee cannot change the nature of the thing demised; the act of alteration exceeds the right to use, and infringes on the condition that the landlord shall receive back the premises in the same state and condition as when the lease was granted. It is, therefore, essential that a tenant contemplating an alteration or improvement should receive proper permission and authority from the landlord."

"*Permissive waste* consists of a neglect on the part of a tenant to supply the repairs required by time and use, and also a neglect to make good occasional and accidental dilapidations. Houses and outbuildings are the principal subject of dilapidations, but the law extends to trees, land, changing the course of industry, &c., but the chief subject is buildings. These, though subject to decay in the progress of time, are capable of having the defective or decayed parts made good, and are therefore subject to both permissive and voluntary waste.

"A tenant hiring premises on lease is bound to perform tenantable repairs, which may be divided into three heads,—the ornamental, which includes the trades of painter and paper-hanger; the substantial, which includes the trades of bricklayer and carpenter; the third includes all works which tend to preserve the fabric from decay—as, stopping out wind and weather, which includes the trades of the joiner, plasterer, and glazier.

"Dilapidations caused by accident are very serious upon a tenant, as not only is the accident considered as a dilapidation, but injuries arising therefrom, of which the following is an illustration from Mr. Gibbons:—'If a building be covered with weather-boarding, and such boarding decay from age, so long as it form an entire and complete covering, it is no dilapidation; but if, owing to any neglect, any of the internal woodwork become injured, that is a dilapidation. If the main timbers decay, they are not chargeable as a dilapidation, so long as they are an efficient support; but if they give way, the tenant is bound not only to replace the timbers, but all damage done by their fall. Accident, shown to be inevitable, such as resulting from tempests, does not fall upon the tenant, as in the case of a house being prostrated, the tenant need not rebuild, but if the roof be blown off, the tenant must replace it. A tenant, generally speaking, is *not* answerable for dilapidations resulting from natural decay, or the result of time, or fair ordinary wear and tear, but *is* answerable for all extraordinary decay. For instance, as to decay, caused by the premises being exposed to the weather, as if the roof be suffered to go in bad repair, the tenant must make good the rafters and other timbers, if they are injured.' Lord Chief Justice Tindal defined a tenant's obligation to repair thus:—'Where an old building is let, and the tenant enters into a covenant to repair, it is not meant that the old building is to be restored in a renewed form at the expiration of his tenancy, or that the premises shall be of greater value than it was at the commencement. What the natural operation of time flowing on effects, and all that the elements bring about in diminishing the value, which, so far as it results from time and nature, constitute a loss, falls upon the landlord. But then the tenant must be careful that the tenement do not suffer more than time and nature would effect. He is bound to keep the premises in nearly the same state of repair as when demised.'

"*An annual tenant's* obligation has been thus laid down by Lord Kenyon:—'A tenant from year to year is bound to commit no waste, and to make from time to time fair and tenantable repairs, such as windows and doors that be injured during the tenancy.' Lord Tenterden decided that 'an annual tenant was bound to keep the premises wind and water tight.'

"It seems but justice, that under any mode of letting or hiring of house property, a tenant should be bound to use all ordinary precautions to preserve the building from decay; therefore there exists an obligation to keep the outside and the roof sound, perfect, and water-tight; and if the internal woodwork decay sooner than it otherwise would do for want of paint, &c., the tenant is bound to restore it. Glass, if cracked or broken, becomes dilapidation, it being an outside covering.

"*A tenant with no agreement as to duration of his tenancy*, cannot be bound to perform any repairs, the nature of his tenancy being so weak that he cannot be expected to do any repairs, as his landlord might immediately determine his tenancy, and reap the advantage to be derived from the outlay: besides, if the house require any repairs being done, the landlord can enter, and take any necessary steps for its preservation; but not so with premises let for a definite time.—then, the landlord having granted the use for a certain period, has not a right to enter upon the premises until the expiration of the tenancy. A tenant under this mode of letting. is however bound neither to commit nor permit waste. This kind of tenancy may be considered rather as a 'deposit than as a letting on hire,' and the tenant's obligation may be defined as 'to use the house with care.'"

The above extract gives a very clear and concise description of the responsibilities undertaken by tenants under varied forms of tenancy. It is well worthy the attentive perusal of the young professional man, and indeed the whole subject of dilapidations is an important one, requiring his careful study. It is one on which he is very frequently called upon to advise; and he will scarcely be competent to do so unless well acquainted with the just claims of the landlord, and the fair obligations of the tenant. To give in a list of repairs required to be done, is simple enough in acting for the landlord, but the surveyor should be well assured, from a practical acquaintance with what really are dilapidations, to what extent he is justified in calling on the tenant to do them.

DIMENSION (from the Latin) a principal distance measured in a straight line on the surface of a body, in some particular direction, or through some certain point, by the help of which the body may be constructed or measured as to its superficial or solid contents.

The dimensions of rectangular figures and solids are taken along, or parallel to the straight lines which bound their surfaces; and consequently rectangles have two dimensions, viz. length and breadth, and rectangular prisms three dimensions, viz. length, breadth, and thickness. The dimension of a parallelogram are the length of one side, and the distance from that side to the opposite side of the same, so that the two dimensions of a parallelogram are at right angles to each other. The dimensions of any plane figure are the lengths of the sides and diagonals. The dimensions of a circle are its radius, diameter, or circumference, or all. The dimensions of a regular polygon are the length of one of its sides, and their number. The dimensions of any prism are the dimensions of one of its ends or bases, and the perpendicular or distance between the said ends or bases. The dimensions of a pyramid are the dimensions of its base, and the distance or perpendicular form the apex to the plane of the base. The dimensions of a sphere are its diameter or circumference. The dimensions of a spheroid are the fixed and revolving axes. The dimensions of an irregular surface or body are in a great measure arbitrary. The dimensions of an irregular surface are thus taken: Fix upon some principal line passing through the middle of the body in the direction of its greatest extension, as nearly as can be judged; then divide the length of this line into equal parts; through the points of division, draw perpendiculars, terminated by the boundary; then the length of the first line and of the perpendiculars are the dimensions. The dimensions of a definite body may be limited as to number, and the body may be accurately ascertained, either with regard to its construction or solidity; but an indefinite body can never be ascertained for either, whatever may be the number of its dimensions: greater accuracy, however, will be obtained, the greater the number of dimensions taken. The dimensions of an irregular plane figure or solid, ought to be taken in equidistant lines or planes.

The subjects to which dimensions are applied belong to geometry, mensuration, and the construction of solids. The method of squaring dimensions will be found under the articles Cross Multiplication, Decimals, and Duodecimals.

In writing the dimensions of a body, consisting of many different parts, in order to avoid mistakes, an eye-draught, or sketch of the body, should be made, and two angles, each with its apex fixed in the opposite extremities of the extension, with a number placed between them to denote the length of the line: thus, ⟨ - - - - - 36 ft. - - - - - ⟩ denotes 36 feet between the point of one angle and that of the other: the opening of each angle is always turned towards the centre of the line. By this method no mistake can occur, even though ever so many other dimensions cross one another, unless they come so close as to confuse. Simple rectangles, or rectangular prisms, are most frequently written down without any eye-draught, and the dimensions entered in the book with a cross between each, or the word by; thus, for a rectangle, 3 . . 9′×4 . . 8′, or 3 . . 9′ by 4 . . 8′; that is, 3 feet 9 inches by 4 feet 8 inches; the mark thus′, signifying that the figures below are inches, and consequently that the first is the place of feet. A solid is thus denoted, 5 . . 3′ × 4 . . 8′ × 12 . . 6′, or 5 . . 3′ by 4 . . 8′ by 12 . . 6′; that is, the end, or base, is 5 feet 3 inches by 4 feet 8 inches, and 12 feet 6 inches from end to end; or the solid is 12 feet 6 inches long, 5 feet 3 inches broad, and 4 feet 8 inches thick.

In finding the contents of artificers' works in buildings, the dimensions are placed one under the other, according to their denominations, and the surface or solid is known by the number of its dimensions; in order therefore to distinguish any set of dimensions from the next, whether above or below, a horizontal line must be drawn between them. *See* the article Brickwork.

Dimension Book, a book in which the measurement of the builder's work is entered, specimens of which are given under the head Brickwork.

DIMINISHED BAR, of a sash, one that is thinner on the inner edge, or the edge next to the apartment, than where it recedes close to the glass, in order to give it a lighter appearance.

Diminished Column, one whose upper diameter is less than the lower; as is to be seen in all the regular orders of architecture.

Diminishing Rule, a board cut with a concave edge, so as to ascertain the swell of a column. and try its curvature. For the method of forming a diminishing rule, *see* Column.

Diminishing Scale, a scale of gradation, used in finding the different points for drawing the spiral curve of the Ionic volute, by describing the arc of a circle through every three succeeding points, the extreme point of the last arc being one of the next three; each point through which the curve passes being so regulated as to be in a line drawn to the centre of the volute, and the lines at equal angles with each other. *See* Spiral and Volute.

DIMINUTION OF COLUMNS, the continued contraction of the diameter from the base to the top of the shaft.

Some modern authors make the diminution to commence from one-third of the height of the column; but if ancient methods are to have a preference, we shall find few examples to authorize this practice. In all the Grecian antiquities of Athens, or Ionia, the diminution commences invariably from the bottom of the shaft, immediately above the apophyge: and, according to the engravings from Stewart's drawings, the diminution is continued in a straight line, excepting in the Temple of Corinth, where the swell is shown. The diminution is rarely less than one-eighth, or greater than one-sixth, of the inferior diameter.

In Gothic architecture, neither swell nor diminution is used; all the horizontal sections being similar and equal.

In ancient examples, even of the same order, the diminution is very variable.

Other particular remarks will be found under Column.

DINING-ROOM, an apartment in a house, appropriated to the eating of dinners. The dining-room and drawing-room ought to have some relation to each other in point of size, as the company move from one to the other. In the smallest houses, the dining-room ought to be the largest, and nearly square upon a plan. In houses of a middle size, they are very frequently of the same magnitude, which may be 18 feet in breadth, 24 feet in length, and 13½ feet in height, or 3-4ths of the breadth. In larger houses, the length may be extended to 40 feet; and in very considerable edifices even to 50 feet: in the latter case the length may be double the breadth.

Dining-rooms are sometimes fitted up with a recess at one end for receiving the side-board; but if the apartment be very large, a recess at each end is necessary: these recesses may be either square, or in the form of a niche. *See* House, *and* Room.

DINOCRATES, an eminent architect, patronized by Alexander the Great; whose history is thus related by Vitruvius:—"At the time that Alexander was conquering the world, Dinocrates, the architect, confiding in his knowledge and genius, and being desirous of obtaining the royal commendation, left Macedon, and repaired to the army. He carried with him letters from his relations and friends in his own country, to the nobles of the first rank, that he might thereby more easily gain access. Being favourably received, he requested to be immediately presented to Alexander; they gave him many promises, but made delays, pretending to wait till a proper opportunity should offer. Dinocrates, therefore, suspecting that he was derided, sought the remedy from himself. He was very large of stature, had an agreeable countenance, and a dignity in his form and deportment. Trusting to these gifts of nature, he clothed himself in the habit of a host, anointed his body with oil, crowned his head with boughs of poplar, put a lion's skin over his left shoulder, and holding one of the claws in his right hand, approached the tribunal where the king was administering justice. The novelty of the appearance attracting the notice of the people, occasioned Alexander also to see him, who, wondering at the sight, commanded way to be given, that he might approach. Alexander then demanded who he was. Dinocrates replied, 'I am a Macedonian architect, who come to thee with ideas and designs, worthy of the greatness of thy fame; I have formed a design to cut Mount Athos into the statue of a man, in whose left hand shall be a large city, and in his right a bason, which shall receive all the rivers of the mountain, and again discharge them to the sea.' Alexander, delighted with the idea, immediately inquired, if the country adjacent would produce sufficient food for the sustenance of the inhabitants. When he understood that provision must be conveyed thither by sea, he replied: 'Dinocrates, I discern the excellence of thy design, and am pleased with it; but I consider, that whoever should establish a colony in such a place, would hereafter be justly blamed; for, as a new-born infant cannot be nourished, or gradually reared to the different stages of life, without the milk of the nurse; so neither can a city be peopled, nor can it thrive, without fertile land and plenty of provision; however, as I approve the design, though I disapprove the place, I will have thee attend me, that elsewhere I may employ thee.' From that time, Dinocrates remained with the king, and attended him into Egypt. There Alexander, observing a spot which had a haven formed secure by nature, an excellent place for an emporium, the adjacent country through all Egypt being fruitful, and having the accommodation of the river Nile, ordered him to build the city now called, from his name, Alexandria. Thus, by the means of a graceful countenance and dignity of person, Dinocrates became eminent."

Dinocrates was also employed to superintend the rebuilding of the temple of Diana, at Ephesus, when burnt by Erostratus, which he did with more magnificence than before. The last design which history ascribes to him, was that of erecting a temple to Arsinoë, queen of Ptolemy Philadelphus, at Alexandria, with a dome above it, which was to enclose a magnet, in order to keep suspended in the air an iron statue of that queen. Ptolemy approved the design, and gave orders for its execution; but both the king and the architect died before the project could be accomplished.

DIOPHANTINE PROBLEMS, in mathematics, certain questions relating to square and cube numbers, and right-angled triangles, &c., the nature of which was determined by Diophantus.

DIOPHANTUS, a celebrated mathematician of Alexandria, reputed to have been the inventor of algebra. The exact date of his birth is unknown; some authors asserting that he lived before Christ, and others after, in the reigns of Nero and the Antonines. His reputation was very high among the ancients, since they ranked him with Pythagoras and Euclid in mathematical learning.

Diophantus left behind him thirteen books of arithmetical questions, of which, however, only six are extant.

DIORAMA, a mode of painting and scenic exhibition invented a few years ago by two French artists, Daguerre and Bouton. The peculiar, and almost magical effect of the diorama arises, in a great degree, from the contrivance employed in exhibiting the painting, which is viewed through a large opening or proscenium. Within this proscenium the picture is placed at such a distance, that the light is thrown upon it, at a proper angle from the roof, which is glazed with ground glass, and cannot be seen by the spectators. While the light is thus concentrated on the picture, the spectators are left in comparative darkness, by which the effect is materially increased; and the illusion is rendered still more complete, by the skilful manner in which the transitions of light are managed. The light may be diminished or increased at pleasure, and that either gradually or suddenly, so as to represent the change from ordinary daylight to sunshine, from sunshine to cloudy weather, or to the obscurity of twilight, and also the difference of atmospheric tone attending them. By means of different folds or shutters attached to the glazed ceiling, transitions are produced in regard to light and atmospheric effects of the most pleasing character. The diorama is indeed a most perfect scenic representation of nature; by varied and ingenious contrivances, it is capable of displaying the greatest difference in its pictures. It is peculiarly adapted for moonlight subjects, and for exhibiting such "*accidents*" in landscapes as sudden gleams of sunshine and their disappearance. For showing architecture, particularly interiors, it is unrivalled, as powerful relief may be obtained without that exaggeration in the shadows which is almost inevitable in every other mode of painting. Although as yet only employed for purposes of public exhibition, the diorama might undoubtedly be made use of for the embellishment of such parts of a building as corridors and the like, where light can only be obtained from one extremity.

The Diorama in the Regent's Park, was erected for the exhibition of pictures with the effects we have been describing; and as one of the most interesting and remarkable of the "sights in London," deserves a passing notice.

The pictures exhibited are each about 72 feet long, and 42 feet wide, and are capable of being shifted and exchanged for others when required. They are placed at distances from the spectator proportioned to the angle at which he would view the object in nature; and by the united talents of the artist and the machinist, the illusion is rendered so perfect, and so true to nature, that the beholder is almost led to doubt that they are really the effect of art. Thus, in architectural subjects, as the interior of the cathedral, the whole is at one moment subdued by gloom, as by the overshadowing of some passing cloud. The "long-drawn aisle" and deep recesses are obscured, all seems about to be buried in darkness, when, in an instant, as though the interruption had passed away, and the bright light of day was permitted to shine through the windows in its full lustre, the Gothic architecture is illumined in the most beautiful manner, the shadows projected with force and truth, and the secondary lights produced beneath the groinings of the roof in all the delicate gradations of natural reflections. Landscape scenes undergo similar changes, and admirable effects are produced in the transitions from shade and darkness, to the brightness of light and sunshine.

The elevation of the building was designed by Mr. Nash; it is of the Ionic order, the basement embellished with columns and pilasters, &c., the centre of which is the approach to the theatre. The building consists of a vestibule and two lateral houses, facing a circular part of the edifice, which may be regarded as the audience-room of the theatre, and is occupied by boxes, and an open area for spectators. The sides of this circular part are painted and adorned with festooned draperies, and the top is covered with a transparent painting, divided into many compartments, and charged with medallion likenesses of several eminent artists. Over this semi-transparent ceiling, or inner roof, rises a conical roof, nearly half of which is glazed. The circular part consists of a wall, two-thirds of a circle, with two small doorways, and two large openings to the compartments of the scenic theatre. Immediately within this wall, but detached from it, is another wall, rising from the floor to the inner ceiling, and which, with the floor, revolves on a pivot beneath. A large square opening, like the proscenium of a theatre, allows the audience to view the pictures.

The Diorama was opened to the public in October, 1823, and has ever since continued to be visited as one of the most popular exhibitions in the metropolis.

DIPTERON, or Dipteros, (from the Greek), or Diptere, (from the French), in ancient architecture, a temple surrounded with a double row of columns, forming a sort of porticos, called *wings*, or *aisles*. Vitruvius informs us, that dipteral temples were octostyle; but this he must mean only in general; for they may be also decastyle. Indeed, they could not have been less than octostyle, as no room would have been left for the cell. The same author also observes, that Hermoginus made a very great improvement in the construction of dipteral temples, by taking away the interior range of columns, which occasioned confusion in the perspective appearance.

DIRECT RADIAL, a right line from the eye, perpendicular to the picture.

DIRECTING LINE, the line in which an original plane would cut the directing plane.

Directing Plane, a plane passing through the point of sight, or the eye, parallel to the picture.

Directing Point, that in which any original line produced cuts the directing plane.

DIRECTOR of an original Line, the straight line passing through the directing point and the eye of the spectator.

Director of the Eye, the intersection of the plane with the directing plane, perpendicular to the original plane and that of the picture, and hence also perpendicular to the directing and vanishing planes; since each of the two latter is parallel to each of the two former. The director of the eye is also sometimes called *the eye director.*

DIRECTRIX, or Dirigent, in geometry, a term expressing the line of motion along which a describent line, or surface, is carried in the genesis of any plane or solid.

Thus, if the line A B move parallel to itself, and along the line A C, so that the point A always keeps upon the line A C, it will form a parallelogram, A B C D, of which the side A B is the describent, and A C the dirigent. So, also, if the surface A B C D be supposed to be carried along the line C E in a position always parallel to itself, in its first situation, the solid A D E H will be formed, when the surface A D is the describent, and the line C E is the dirigent.

DIRETTA, the same as Gola, or Sima-Recta, which see.

DISCHARGE, (from the French), a term applied to a brick wall, or post, when trimmed up to a piece of timber overcharged in its bearing; in which case the wall or post is a discharge to that bearing.

Discharging Arches, rough brick or stone arches, built over the wooden lintels of apertures. These are scheme arches, being the segments of very large circles. Discharging arches are employed in the inside of external walls or in partition walls. The length of the chord of a discharging arch should exceed that of the wooden lintels beneath, so that when the wood begins to decay, the lintels may be taken out, and the arch will be sufficient to sustain the superincumbent part of the wall, as well as that the arch may be sustained by the walls, and not have any dependence upon the lintels. To make the arches resist with greater force, the lintels should not have more wall-hold than what may be found sufficient to sustain the superincumbent part while building: indeed, if walls be well built, upon firm ground, wooden lintels may be dispensed with.

Discharging Struts, the same as *auxiliary rafter*, or *principal braces:* the term is used by Batty Langley.

DISH-OUT, to form coves by any kind by means of ribs, or to form wooden vaults for plastering upon.

Dishing-out, any kind of coved work formed by wooden ribs, for plastering upon. The term is of the same import as *cradling.*

DISPLUVINATED CAVÆDIUM. *See* Cavædium.

DISPOSITION, (from *dispono*, to place), in architecture, the just placing of the several parts of a building, according to their use; as, disposition of apartments, disposition of columns, as eustyle, diastyle, pichnostyle, &c.

DISTANCE of the Eye, in perspective:—If a straight line be drawn from the eye, perpendicular to the plane of the picture, the intercepted part of such line is termed *the distance of the eye.*

Distance, *Point of.* *See* Point of Distance.

Distance of a vanishing Line, the length of a perpendicular, falling from the eye perpendicular to the vanishing line.

Distance, *Inaccessible.* *See* Trigonometry.

DISTEMPER, (from the French, *détremper*, to temper or dilute,) in painting, the working up of colours with something besides mere water or oil. If colours be prepared with water, the painting is called *liming;* and if with oil, it is called *painting in oil*, or simply *painting.*

If the colours be mixed with size, whites of eggs, or any such proper glutinous or unctuous substance, and not with oil, they then say it is done *in distemper;* as those of the admirable cartoons, formerly at Hampton Court, and as all ancient pictures are said to have been before the year 1410.

In distemper, the white colour or base generally used is the finest whiting, which is prepared in large quantities by various manufacturers. The colours most commonly mixed with it for producing the various tints are as follows:—Straw colour may be made with white and masticot, or Dutch pink; fine grays, with white and refiner's verditer; an inferior gray may be compounded with blue black or bone black, and damp blue or indigo; pea-greens, with French green, Olympian green; and fawn colour, with burnt sienna or burnt umber and white, and so of any intermediate tint. All the colours used in distemper, should either be ground very fine, or washed over so as to ensure the most minute division of their particles. In general, the size made of common glue is used with a proper quantity of water to render the colour liquid, but where the work will afford it, parchment-size will be found greatly superior.

It will not require less than two coats of any of the foregoing colours, in order to cover the plaster, and bear out with an uniform appearance. When old plastering has become discoloured with stains, and it be desired to have it painted in distemper, it is advisable to give the old plaster, when properly cleaned off and prepared, one coat at least of white-lead ground in oil, and used with spirits of turpentine, which will generally cover all old stains, and, when quite dry, will take the water-colours very kindly.

The best methods of compounding the colours with the vehicles, is to mix the size in water, then to levigate the colours in part of it, and afterwards to put each kind into a proper pot, adding as much more of the melted size as will bring it to a due consistence, and mixing the whole well together in a pot with a brush or wooden spatula. Warm water may be afterwards added, if necessary, for grinding the colours, or for working. The pots must be covered with bladders, and tied. This method of painting is chiefly confined to scenes and grosser works, where the effect depends more upon the perspective and opposition of the colours, than upon their brightness.

DISTRIBUTION, the dividing and disposing of the several parts of a building according to some plan, or to the rules of architecture. The proper distribution or arrangement of the various apartments in a large building is of great importance, and may be either good or bad, as they may be best suited to answer their use. That arrangement only can deserve the former appellation, in which every apartment seems placed in its very best position, with regard to architectural symmetry, elegance of appearance, and domestic convenience.

DISTYLE, (Greek, δυω-στυλος), a portico of two columns. It applies rather to a portico with two columns in antis, than to the mere two-columned porch.

DITRIGLYPH, an interval admitting two triglyphs over the intercolumn; that is, if in two adjoining columns a triglyph be placed with its middle over each, the ditriglyph will contain three metopes, or spaces, two half triglyphs, and two whole triglyphs.

DIVAN, among the Orientals, a council-chamber, or the saloon or hall in which a council is held: it is applied generally to denote a state apartment, or room in which company is received.

DIVERGING LINES, such as are continually increasing in their distance from each other.

DIVIDERS. *See* Mathematical Instruments.

DIVISION, *Harmonical.* *See* Harmonical Division.

Division of an Order. *See* Order.

DOCK, an artificial receptacle for shipping, generally formed by excavation, and enclosed by gates, which open for the ingress and egress of vessels; the sides are usually constructed of masonry.

Dock, a place artificially formed on the side of a harbour or bank of a river, for the reception of ships. Docks are of two kinds, wet docks and dry-docks. A wet-dock is an excavation or basin, of considerable extent, which vessels can enter to discharge or take in their cargoes, and in which they are always afloat; of this kind are the immense docks of London, Liverpool, and other places of great commerce. A dry-dock is used for inspecting and repairing ships, and is so contrived, that the water can be admitted or excluded at pleasure, so that a vessel can be floated in when the tide is up, and the water may run out with the fall of the tide; or, the gates of the dock being closed to prevent the egress of the water, it is pumped out by steam-power. Dockyards belonging to the government usually consist of dry-docks for repairing ships, and of *slips* on which new vessels are built; besides which they comprise storehouses, in which various kinds of naval stores are kept, and workshops in which different processes subsidiary to ship-building, are carried on.

DODECAGON, (δωδεκα, *twelve* and γωνια, *angle*), a regular polygon or figure, with twelve equal sides and angles.

If the radius of a circle O A D F, be so divided into two parts, that the rectangle under the whole and the one part shall be equal to the square of the other part; then this last part will be equal to the side C D of a regular decagon A B C D E F, &c., inscribed in the circle; and that line whose square is equal to the two squares of the whole, and of the same part, will be equal to the side, A C, of a regular pentagon inscribed in the same circle. For, draw the radii O A, O C, O D, O F; also draw A D, cutting O C in G, and let A H be perpendicular to O G. The triangle O D G, having the angle $COD\ (= \frac{1}{2} DOF = OAD) = ODA$, is isosceles: the triangle A O G, having $AGO\ (= GDO + DOG = 2\,DOC) = AOC$, is likewise isosceles; as is also the triangle C D G; because, CGD being $= AGO$, and $CDG\ (CDA) = FAD$, the triangles A O G and C D G are equiangular; consequently, C D, A O; C G, G O, being corresponding sides, we have $CG \times AO\ (CG \times CO) = CD \times GO = GO^2$, because $GO = GD = DC$, the side of the decagon, &c. Moreover, because $AG = AO$, HG will be $= HO$; and GC being the difference of the segments H O and H C, we have $AC^2 - AO^2 = CO \times GC = OG^2$; and consequently AC^2 (*i. e.* the square of the side of the pentagon) $= AO^2 + OG^2$.

Let $CO = a$, $GO = x$, then will $CG = a - x$; and by this proposition, $\overline{a - x} \times a = x^2$ and $x^2 + a x = a^2$; and resolving this quadratic equation, we shall have $x^2 + a x + \frac{1}{4} a^2 = a^2 + \frac{1}{4} a^2 = \frac{5}{4} a^2$; whence $x + \frac{1}{2} a = \sqrt{\frac{5}{4} a^2}$, and $x = \sqrt{\frac{5}{4} a^2} - \frac{1}{2} a$. Let the radius a be $= 1$, and G O, or the side of a regular decagon inscribed in the circle, is $= \sqrt{\frac{5}{4}} - \frac{1}{2}$. Hence it appears that the sine of 18^0 (or half the side of a decagon inscribed in the circle) is $= \frac{1}{2} \sqrt{\frac{5}{4}} - \frac{1}{4} = \frac{1}{2} \sqrt{1.25} - \frac{1}{4} = \frac{1.11803398}{2}$, &c. $- \frac{1}{4} = .55901699$, &c. $- .25 = .30901699$, &c.

If the side of a dodecagon be 1, its area will be equal to three times the tangent of $75^0 = 3 \times 2 + \sqrt{3} = 11.1961524$ nearly; and, the areas of plane figures being as the squares of their sides, 11.1961524 multiplied by the square of the side of any dodecagon, will give its area. Hutton's *Mensuration*, p. 114.

To inscribe a dodecagon in a given circle.—Carry the radius six times round the circumference, which will divide it into six equal parts, or form a hexagon, (See HEXAGON); then bisect each of those parts, which will divide the whole into 12 parts, for the dodecagon.

DODECAHEDRON, (from δωδεκα, *twelve*, and ἑδρα, *seat*,) one of the regular bodies comprehended under twelve equal sides, each of which is a pentagon; or, a dodecahedron may be conceived to consist of twelve quinquangular pyramids, whose vertices, or tops, meet in the centre of a sphere conceived to circumscribe the solid; consequently they have their bases and altitudes equal.

To find the solidity of the dodecahedron.—Find that of one of the pyramids, and multiply it by the number of bases, viz., 12; the product is the solidity of the whole body. Or its solidity is found by multiplying the base into one-third of its distance from the centre, twelve times; and to find this distance, take the distance of two parallel faces; the half is the height.

The diameter of the sphere being given, the side of the dodecahedron is found by this theorem; the square of the diameter of the sphere is equal to the rectangle under the aggregate of the sides of a dodecahedron and hexahedron inscribed in the same, and triple the side of the dodecahedron.

Thus, if the diameter of the sphere be 1, the side of the dodecahedron, inscribed, will be $(\sqrt{\frac{5}{3}} - \sqrt{\frac{1}{3}}) \div 2$; consequently, that is to this as 2 to $(\sqrt{\frac{5}{3}} - \sqrt{\frac{1}{3}})$ and the square of that, to the square of this, as six : $3 - \sqrt{5}$. Therefore the diameter of the sphere is incommensurable to the side of an inscribed dodecahedron, both in itself and in its power.

If the side, or linear edge, of a dodecahedron be s, its surface will be

$$15 s^2 \sqrt{1 + \frac{2}{3} \sqrt{5}} = 20.6457788 s^2: \text{ and its solidity}$$

$$\frac{5 s \sqrt{47 + 21 \sqrt{5}}}{40} = 7.66311896 s^3.$$

If the radius of the sphere that circumscribes a dodecahedron be r, then is

$$\text{its side or linear edge} = \frac{\sqrt{15} - \sqrt{3}}{3} r,$$

$$\text{its superficies} = 10 r^2 \sqrt{2 - \frac{2}{3}\sqrt{5}}, \text{ and}$$

$$\text{its solidity} \quad \frac{20 r^3}{8} \quad \frac{\sqrt{u + \sqrt{5}}}{30}$$

The sides of a dodecahedron inscribed in a sphere is equal to the greater part of the side of a cube inscribed in the same sphere, and cut according to extreme and mean proportion. If a line be so cut, and the lesser segment be taken for the side of a dodecahedron, the greater segment will be the side of a cube inscribed in the same sphere. The side of the cube is equal to the right line which subtends the angle of a pentagon, of the dodecahedron inscribed in the same sphere.

DODECASTYLE, an edifice having twelve columns in front.

DOG-LEGGED STAIRS, such as are solid between the upper flights; or those which have no well-hole; and the rail and balusters of both the progressive and retrogressive flight, fall in the same vertical plane. The steps are fixed to strings, newels, and carriages; and the ends of the steps of the inferior kind terminate only on the side of the string, without any housing.

No. 1. The plan.—*a* the seat of the newel; *g* the seat of the upper newel.

The dotted lines represent the faces of the risers, and the continued lines the nosings of the steps.

No. 2. The elevation.—A B the lower newel, the part B C being turned; G H the upper newel; D E, F G, the lower and upper string-boards, framed into the newel; K L a joist framed into the trimmer I; *k l*, *n o*, *q r*, *&c.*, the faces of the risers; *m n*, *p q*, *s t*, the heads, or cover-boards; *m*, *p*, *s*, *&c.*, nosings of the steps; M O, F Q, the upper and lower ramps.

To describe the ramps.—Suppose the upper one to be drawn; produce the horizontal part, H M, of the rail to P: draw M N perpendicular to P H, and produce the straight part, B O, to N: make N O equal to N M: draw O P at right angles to B N: from P, as a centre, describe the arc M O: and describe another concentric circle to meet the under side of the rail, and the sloping part B O; and the ramp will be completed.

R S, the story-rod; this is a necessary article in fixing the steps; for if a common measuring rule be used for this purpose, the workman will be very liable to err either in excess or defect, and thus render the stairs extremely faulty; which cannot be the case if the story-rod be applied to every riser, and if the successive risers be regulated thereby. When steps are put up without the use of the story-rod, the smallest error is liable to multiply.

In the construction of dog-legged staircases, the first thing is to take the dimensions of the stair and the height of the story, and lay down a plan and section upon a floor to the full size, representing all the newels and steps; then the situation of the carriages, pitching-pieces, long bearers, and cross bearers, will be ascertained, as also of the string-boards.

The quantity of room allowed for the stairs, and the situation of the apertures and passages, will determine whether there are to be quarter-paces, half-paces, one-quarter winders, or two-quarter winders. In order to give all the variety possible, we shall suppose the flight to consist of two-quarter winders.

The strings, rails, and newels, being framed together, they must be fixed with temporary supports; the string-board will show the situation of the pitching-pieces, which must be put up next in order, wedging one end firmly into the wall, and fixing the other to the string-board; this being done, pitch up the rough strings, and thus finish the carriage part of the flyers. In dog-legged staircases, the steps and risers are seldom glued up, except in cases of returned nosings; suppose them, therefore, to be of separate pieces; proceed to

Fig 1. No 2

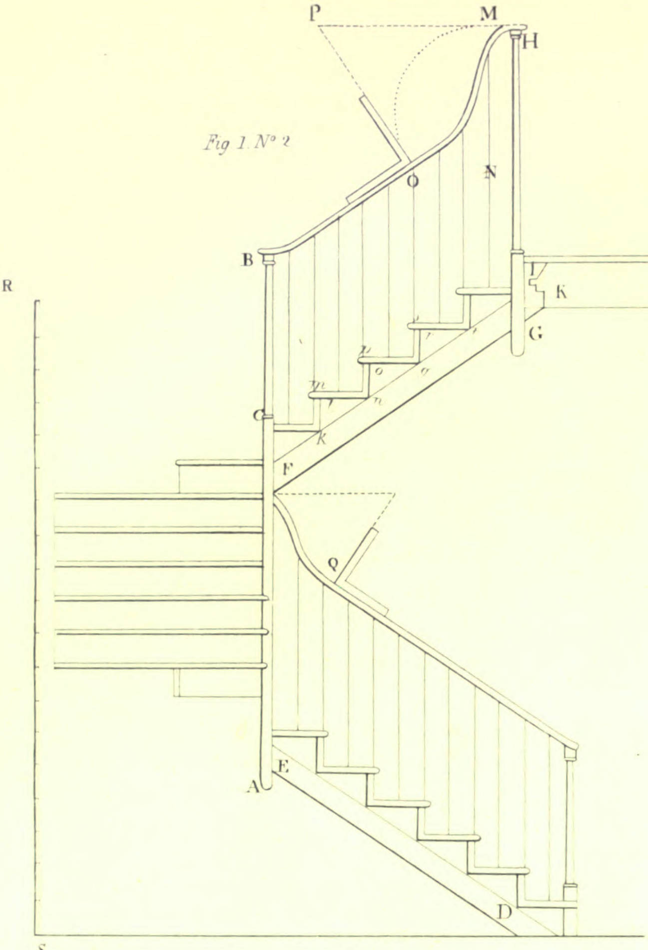


Fig 2.

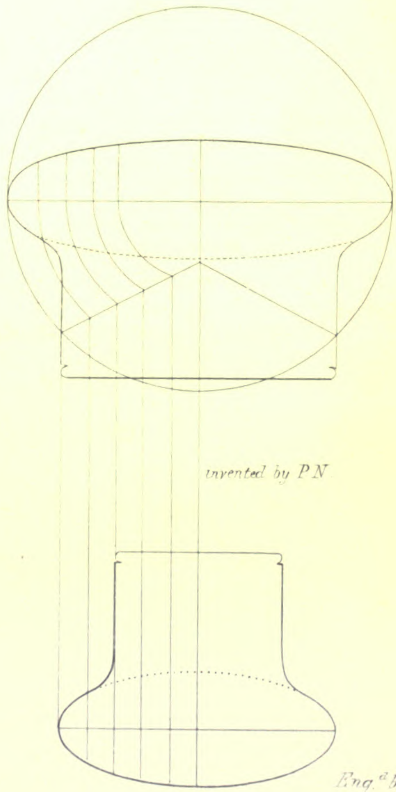
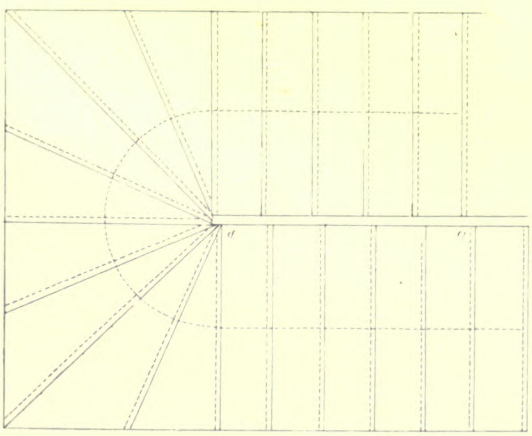


Fig 1. No 1.



Drawn by P. Nicholson.

Engd by R Tho

put up the steps: place the first riser in its situation, having fitted it down close to the floor; the top being brought to a level at its proper height, and the face in its right position, fix it with flat headed nails, driving them obliquely through the bottom part of the riser into the floor, and then nailing the end to the string-board; proceed then to cover the riser with the first tread, observing to notch out the farther bottom angle opposite the rough strings, so as to make it fit closely down to a level on the top side, while the under side beds firmly upon the rough strings at the back edge, and to the riser towards the front edge: nail down the tread to the rough strings, driving the nails from the seat, or place on which the next riser stands, through that edge of the riser into the rough strings, and then nailing the end to the string-board; begin with the second riser, having brought it to a breadth, and fitted it close to the top of the tread, so that the back edge of the tread below it may entirely lap over the back of the riser, while the front side is in its regular vertical position: nail the head of the riser, from the under side, taking care that the nails do not go through its face, and thereby spoil the beauty of the work.

Proceed in this manner, with tread and riser alternately, until the last parallel riser. The face of this riser must stand the whole projection of the nosing back from the face of the newel. Then fix the top of the first bearer, for the first winding tread, on a level with the top of the last parallel riser, so that the farther edge of this bearer may stand about an inch forward from the back of the next succeeding riser, for the purpose of nailing the treads to the risers upwards, as was done in the treads and risers of the flyers; and having fitted the end of this bearer against the back of the riser, and nailed or screwed them fast together, fix a cross-bearer, by letting it half its thickness into the adjacent sides of the top of the riser, and into the top of the long bearer, so as not to cut through the horizontal breadth of the long bearer, nor through the thickness of the riser, as this would weaken the one, and spoil the look of the other. Then fix the riser to the newel, driving a nail obliquely from the top edge of the former into the latter: then proceed to put down the first winding tread, fitting it close to the newel, in the bird's-mouth form. Proceed in this manner with all the succeeding risers and treads, always fixing in the bearers, previously to laying each successive tread, until the steps round the winding part are entirely completed. Then proceed with the upper retrogressive range of flyers as with those below. Fit the brackets into the backs of the risers and treads, so that their edges may join each other on the sides of the rough strings, to which they are fixed by nails, and thus the work is completed. Some workmen do not mind the close fitting of the riser; but it certainly makes the firmest work.

In the best kind of dog-legged stairs, the nosings are returned; sometimes the risers are mitred to the brackets, and sometimes mitred with quaker-strings: in the latter case, a hollow is mitred round the internal angle of the under side of the tread, and the face of the riser. Sometimes the string is framed into the newel, and notched to receive the ends of the steps; the other end having a corresponding notch-board, and the whole flight is put up like a step-ladder. In order to get the lower part for the turning, set the thickness of the capping on the return string-board, and where that falls on the newel below, is the place of the lower limit for the turning.

To find the section of the cap of the newel for the turner.— Draw a circle to its intended diameter: draw a straight line from the centre to any point without the circumference, and set half the breadth of the rail on each side of that line; through the point draw a line parallel to the middle straight line, and the extreme lines will contain the breadth of the rail: draw any radius of the circle, and set half the breadth of the rail from the centre towards the circumference; through the point where this breadth falls, draw a concentric circle; from the point where this circle cuts the middle line of the rail, draw two lines to the points where the breadth of the rail intersects the outer circle, and these lines will show the mitre. *See* HAND-RAILING and STAIRCASING.

DOGS, otherwise termed *andirons* or *endirons*, *creepers*, &c. iron standards used in the olden times to support the logs of wood when consumed for fuel. The distinction between the andirons and creepers consists in the former being of a larger size than the latter; the use of the andirons was to support the logs, and of the creepers to keep the brands off the hearth. ENDIRONS.

DOG-TOOTH, an ornament very prevalent in edifices of the Early English style, in which it forms a very marked feature. It consists of a pyramidal flower of four leaves, so disposed as to have the space between the two adjacent leaves in the centre of the sides of the pyramid; a series of such ornaments is very frequently seen inserted in a hollow moulding.

DOME, a term applied to a covering of the whole or part of a building. The Germans call it *Dom*, and the Italians *Duomo*, and apply the word to the principal church of a city, although the building may not have any spherical or polygonal dome. From this and other circumstances we may infer the term to be derived from the Latin *Domus*, house.

A dome is an arched or vaulted roof, springing from a polygonal, circular, or elliptic plan; presenting a convex surface on the outside, or a concavity within, so as that every horizonal section may be of a similar figure, and have a common vertical axis. According to the plan from which they spring, domes are either circular, elliptical, or polygonal; of these, the circular may be spherical spheroidal, ellipsoidal, hyperboloidal, paraboloidal, &c. The word dome is applied to the external part of the spherical or polygonal roof, and cupola to the internal part. Cupola is derived from the Italian *cupo*, deep, whence also our word cup. But cupola and dome are often used synonymously, although perhaps incorrectly. Such as rise higher than the radius of the base, are denominated *surmounted domes;* those that are of a less height than the radius, are called *diminished* or *surbased;* and such as have circular bases, are termed *cupolas*.

The remains of ancient domes are generally spherical in their form, or built of stone or *tufo*. Ruins of numerous ones still exist in the neighbourhood of Rome and Naples. They were frequently used among the Romans, after the accession of Augustus, in whose reign, the use of the arch, and consequently of domes, first became common. The arch, indeed, is of Grecian origin, though in all the ancient edifices of that country, we do not meet with a single instance of a built dome: that which covers the monument of Lysicrates, being only a single stone, can only be looked upon as a lintel: and the invention of this species of vault seems justly attributed to the Romans, or Etrurians.

Of the ruins of domes in and near Rome, the principal are the Pantheon, and the temples of Bacchus, Vesta, Romulus, Hercules, Cybele, Neptune, and Venus, and also some of the chambers of the Thermæ. The most magnificent dome of antiquity is that of the Pantheon, at Rome, built in the reign of Augustus, and supposed to be a chamber of the great baths of Agrippa. It is still entire, and consists of a hemispherical concavity, enriched with coffers, and terminating upwards in an aperture, called *the eye*. The exterior rises from several degrees, in a sloping direction, nearly tangent to the several internal quoins, and presenting to the spectator the truncated segment of a sphere, considerably less than a hemisphere. The diameter of the dome internally is 142 feet 8½ inches; the circular opening at the top in the centre 28 feet 6 inches in diameter; the height from the top of the attic 70 feet 8 inches. The interior of the dome is ornamented with five rows of square compartments, and as these converge towards the top, each row is considerably larger than that immediately above it. Each of the large squares contains four smaller ones sunk one within the other. It is supposed that these were decorated with plates of silver. The base of the dome externally consists of a large plinth with six smaller plinths or steps above it; and in the curve of the dome a flight of steps is formed which leads to the opening at the top of the dome. From the drawings of Serlio, it appears that similar flights of steps were formed at intervals all round the dome, but these are now covered with lead. The dome is constructed of bricks and rubble. The thickness at the base is about 17 feet; at the top of the highest step, 5 feet 1½ inches; and at the top of the dome, 4 feet 7 inches. The circular wall which supports the dome is 20 feet thick, but is divided by several large openings, and has discharging arches of brick. The dome of the Pantheon is incombustible, and is perhaps the cheapest as well as the most durable and unconsumable roof which could have been erected over so large a building.

The dome of the temple of Bacchus is also internally hemispherical, though without coffers. Externally it is now covered with a common roof, which may have been the original form; such a roof is also to be seen over the dome of the temple of Jupiter, in the palace of Diocletian, at Spalatro.

The dome of one of the chambers of the Thermæ of Catania was 111 feet in diameter. In the Thermæ of Titus there are two domes, each 84 feet in diameter; and in the baths of Constantine there was one of 76 feet. There were three domes in the baths of Diocletian, of which two still remain; one is 73 feet 6 inches in diameter, and the other 62 feet 3 inches. Judging from those that remain, it would seem that in the Thermæ they were lighted from the top, in the same manner as in the dome of the Pantheon. In the neighbourhood of Puzzuoli there is a circular edifice which has a dome built of pumice-stone and volcanic tufa: its diameter is about 96 feet. The temple of Minerva Medica at Rome, was on the plan, a polygonal dome of ten sides, without any opening at the top. Domes were sometimes constructed on corbels by the ancients. In one of the octagonal rooms of the enclosure round the baths of Caracalla the corbels which supported the dome still remain, and at Catania there is a spherical dome covering a square vestibule.

The dome of Santa Sophia, at Constantinople, built in the reign of Justinian, ranks next to the Pantheon in point of antiquity, and is the most remarkable and the earliest constructed after those of the Romans. Anthemius of Tralles, and Isidorus of Miletus, were the architects. Anthemius had promised to raise a dome over this edifice, of such magnitude as to eclipse the magnificence of the Roman Pantheon. With this view, he erected four pillars at the angles of a square, at about the distance of 115 feet from each other, and nearly of the same altitude. The church was to be of the form of a cross, and vaulted with stone; he therefore threw arches over the pillars, and filled up the angular spaces between the archivaults, till he had gradually shaped them into a complete circle, at the level of the extradoses of the arches. On the ring thus formed, the dome was raised, being the first ever built on pendentives. The pressure of the eastern and western arches was resisted by four walls almost solid, forming transepts, and running longitudinally, two from the north, and two from the south sides of the pillars, to the distance of about 90 feet. The east and west arches were abutted upon by half-domes, resting on cylindrical walls, which, it was supposed, would have been sufficient to resist the pressure of the arches on the north and south; but in this the architect was mistaken; for the superstructure gave way towards the east, and, at the end of a few months, fell, taking with it the half-dome on that side. After the death of Anthemius, the superintendence of the building devolved on Isidorus, who strengthened the eastern pillars, by filling up certain voids left by his predecessor; but when the dome was turned upon them, the east end proved still too weak for the support of so great a load, and again gave way, before the work was completed. In order to counteract this thrust on the east, Isidorus now built strong pillared buttresses against the eastern wall of a square cloister that ran round the building; from which he threw flying buttresses over the void, and then raised the dome a third time, but with very little success; for though every precaution was taken to lessen its weight, by using pumice-stone and other light materials, and by reducing its thickness, the arches were so much fractured, that he was under the necessity of filling up the large arcades on the north and south sides, with arches of less dimensions, in three stories.

We have mentioned these circumstances, to show that the architects of the age to which this building is referred, were not so well acquainted with the principles of dome-vaulting, as those of more modern date: for the latter would probably have hooped or chained such a dome immediately over the arches and pendentives, so as to confine its pressure to a perpendicular thrust, or nearly so. Such was the case, in the far more ponderous dome of St. Peter's, at Rome, erected by Michael Angelo; and such, more recently, was the practice of our countryman, Sir Christopher Wren, in the cupola of St. Paul's, at London. The present dome, however, of Santa Sophia, was reconstructed by the nephew of Isidorus. It rests on the square formed at the intersection of the arms of the Greek cross; the diameter being about 111 feet, and the dome 40 feet high, and is supported by corbellings placed in the angles of the square. These corbels are surmounted by a kind of cornice on which rests a circular gallery. The lower part of the dome has a row of windows adorned with columns on the exterior, and the top is surmounted by a lantern on which is a cross. The dome of Anthemius and Isidorus, was not so high; and was partly destroyed by an earthquake a few years after its construction. In rebuilding it, the nephew of Isidorus used a very light white brick, made at Rhodes, and much lighter than the common brick.

The dome of St. Mark, at Venice, erected about the year 973, and that of the cathedral at Pisa, built early in the eleventh century, are both upon the same plan with the preceding. The church of Saint Mark, built in the tenth century, has five domes; the central dome being much larger than the others. Each dome is enclosed within four pieces of semi-cylindrical vaulting together forming a square; in the angles of this square are four corbels, which gather in the circular base of each dome. In 1523, Sansovinus, the architect, repaired the great dome, and placed a circle of iron round it to prevent its falling. A similar precaution was taken with one of the smaller domes by Andrew Tirali, in 1735, with the same successful result.

The dome of San Vitale at Ravenna, is of very curious construction. The plan of the lower part is that of a regular octagon, supported by eight piers at the angles of the dome. Between these angles are seven tall niches divided into two stories. The lower part of these niches is open, and adorned with columns. The remaining side of the dome is an arch of the same diameter and elevation as the niches; this arch forming an entrance. Above these the wall sustains a hemispherical dome, the plan being a circle within an octagon. Corbels are not employed at Santa Sophia, but the arches support the gathering over, which forms the circular base of the dome. In the base are eight windows, each window being divided in the centre by a column supporting two small arches. The dome itself is built with a double row of pipes, hollow at one end and pointed at the other, so that the point of one is received in the hollow of the preceding one, continuing thus in a spiral line until they finish at the top. Both the exterior and the interior of the dome are covered with mortar.

In 1298, the cathedral of Santa Maria del Fiore, was begun at Pisa, by the celebrated Arnolfo Lusii; but he died two years after, and no architect could be found who would undertake to execute the dome upon the vast plan that its projector had designed: it consequently remained unfinished for one hundred and twenty years; when, in a professional convocation, Philip Brunelleschi was permitted to attempt its completion. (*See* Brunelleschi.) Notwithstanding the opposition he met with, and the vapouring sarcasms with which he was treated by his contemporaries, who held his scheme to be impracticable, he carried on the building, and completed the cupola, in a manner worthy of his great reputation. This dome, which is octangular, and of great elevation, is formed of two vaults, with a vacancy between them; and is supported merely by the springing wall, without the aid of buttresses, though its dimensions exceed those of all the ancient Roman domes, with the sole exception of that of St. Peter's.

The church of St. Peter's, at Rome, is the largest temple ever built: it was begun by Bramante, in 1513, and carried on successively by Raphael, San Gallo, and Michael Angelo, the latter of whom designed the dome as it now appears. The following description, extracted from the "Encylopédie Méthodique," and the "Penny Cyclopædia," will enable the reader to form some idea of this superb work.

"The dome, which is double, is circular on the plan. The internal dome is constructed on double consoles, instead of corbellings. The double consoles are crowned with a small cornice, forming an impost for eight arches, from the upper part of which springs the dome; on the top is a lantern-light, which is not apparent externally. Up to this time domes had been constructed on walls and corbellings, but in St. Peter's at Rome a new plan was adopted. The dome of St. Peter's stands upon four piers, 61 feet 11 inches high, and 30 feet 10 inches thick, measured in a straight line with the arches. From the arches spring the corbellings, which are finished by an entablature. Upon this entablature is a plinth. The plinth is externally an octagon, and internally a circle. The external diameter of the octagon is 192 feet 9 inches, and the internal circle 134 feet 8½ inches; the thinnest part of the wall, between the octagon and the circle, is 29 feet 3 inches. On the plinth is a circular stylobate, 28 feet 6½ inches thick. This thickness is divided into three parts by a circular passage 5 feet 10 inches wide; the two walls on each side of this passage are, respectively, the internal wall 14 feet 7½ inches thick, and the external 8 feet. In the internal wall are other smaller passages, 2 feet 10 inches wide, forming flights of steps communicating with the four spiral staircases formed in the thickness of the wall of the drum of the dome. Above the circular stylobate, which is 12 feet 4½ inches high, is placed the drum of the dome, which is 10 feet 1½ inch thick, measured to the inside line of the pilasters, which decorate the interior of the dome. The pilasters themselves are 1.78 feet thick in addition. The construction is formed of rubble and fragments of brick. The interior is formed with bricks stuccoed. Externally the work is faced with thin slabs of travertine stone. The drum is pierced with 16 windows, 9 feet 3¾ inches wide, and 17 feet high. The walls are strengthened on the outside, between the windows, with 16 buttresses, constructed with solid masonry. These buttresses are 13 feet 3 inches wide, and 51 feet 6 inches in height from the base to the top of the entablature. Each buttress is decorated and strengthened with half-pilasters, and terminates with two coupled columns engaged, the diameter of which is 4 feet; the order is Corinthian. When the base of the dome had been built to the height of the entablature of the drum, Michael Angelo died; but some time before his death he had caused a model to be made, with ample details, to which he added drawings and instructions. After his death Pirro Ligorio and Vignola were appointed the architects. Giacomo della Porta, the pupil of Vignola, followed his master as architect to the cathedral; but although the designs of Michael Angelo were strictly followed, the dome itself was constructed under the pontificate of Sixtus V. Sixtus gave Giacomo della Porta as a colleague, Domenico Fontana, by whom the dome was constructed.

"On the constructions of Michael Angelo a circular attic was first formed, 19 feet 2¼ inches high, and 9 feet 7 inches thick. This attic is strengthened externally by 16 projections, 2 feet 11 inches deep, and 6 feet 4½ inches wide, placed over the buttresses of the dome; on the attic rises the double dome, the internal diameter of which at the base, is 138 feet 5 inches. The curve externally is an arc of a circle whose radius is 84 feet 1.62 inches. To the height of 27 feet 8 inches from the attic the dome is solid. At the base the thickness is 9 feet 7 inches; and as the external dome is raised higher than the internal dome, the thickness is increased as the curve ascends, so that where the dome is divided the thickness is 11 feet 4 inches. The circular space which divides the two domes is 3 feet 2¼ inches wide; the internal dome is 6 feet 4 inches thick; and the height from the attic to the opening of the lantern is 83 feet 10 inches. The diameter of the lantern is 24 feet 10 inches. The external dome is 2 feet 10½ inches thick, where it separates itself from the internal dome; and it is strengthened externally by 16 projecting bands of the same thickness. The dome is pierced with three rows of small windows, as the curves of the dome are not concentric, the space between them becomes wider as it rises; so that at the opening of the lantern the space is 10 feet wide. These domes are joined together by 16 walls or spurs, diminishing in thickness as they ascend to the lantern; at the base they are 8 feet thick, and at the summit 3 feet. The base of the lantern is arched, and pierced with small windows. Above the two domes is a circular platform, surrounded with an iron gallery. In the centre rises the lantern on a stylobate broken into 16 parts, forming projecting pedestals, above which are buttresses similar to the buttresses of the drum, decorated externally with coupled Ionic columns, 17½ inches in diameter. The space between the buttresses is filled with arched openings, which give light to the lantern. The external diameter of the lantern is 39 feet; the internal diameter 25 feet 6¾ inches; and the height from the platform to the top of the cross is 89 feet 7½ inches. The whole height, from the external plinth of the dome to the cross, is 263 feet. The total height internally, to the top of the dome of the lantern, is 387 feet.

"Sixtus V. covered the external dome with lead, and the bands with bronze gilt. During the construction of the dome it is believed that only two circles of iron were placed round the masonry, one of which was placed on the outside of the internal dome, at about 36 feet from its springing, and one foot above the division of the domes. The bands of iron of which this circle is composed are 3 inches wide by $1\frac{3}{4}$ inches thick. A similar circle is placed about the middle of the solid part of the dome at about 17 feet 6 inches above the springing of the internal dome. Near the top of the internal dome there are several holes, at the bottom of which upright iron bars appear. These bars are said to be the connecting rods which keep together other circles of iron placed at different heights within the masonry, which are finally terminated by a circle round the eye of the dome.

"The domes were constructed with such haste, that sufficient time was not allowed to the work to form solid beds as it was carried up, in consequence of which a great number of vertical settlements took place, and the circle of iron round the internal dome was fractured. To obviate the danger arising from these settlements, six circles of iron were placed round the external dome at different heights, and the broken circle of the internal dome was repaired. The first circle was placed above the cornice of the external stylobate, or continuous plinth, on which the buttresses stand; the second circle was placed above the cornice of the buttresses; the third, above the attic, at the springing of the external dome; the fourth, half way up the external dome; and the fifth under the base of the lantern. A sixth was shortly after placed at one foot below where the dome divides itself. The iron bands are flat, from 16 to 17 feet long, $3\frac{1}{2}$ inches wide, and $2\frac{2}{15}$ inches thick. At one end of the pieces of iron a hole is made; the other end is turned up, and passed through the eye of the next band. The whole of these bands are fixed with iron wedges, driven into the rubble with mallets. Sheets of lead are placed under the iron circles." (*Coupole, Encyclopédie Méthodique; 'Architecture.'*)

St. Paul's cathedral, London, the workmanship of the great Sir Christopher Wren, was begun in 1685, and finished in 1710. "The dome is placed over the intersection of the four naves. The ground plan is a regular octagon, each face of which is 44 feet $8\frac{3}{4}$ inches wide: four of these sides are formed by the four great arches of the naves; the other four sides are formed by false arches of the same size; in each of these arches there is a great niche, the base of which is pierced with two arches. By this means eight supports are obtained instead of four, and the corbellings do not project too much, as in other similar constructions. The corbellings gather in a circle, the diameter of which is 104 feet 4 inches, the octagon base being 107 feet. The corbellings are surmounted by a complete entablature, 8 feet three inches high, decorated with consoles. The drum is set back 3 feet $2\frac{1}{4}$ inches from the face of the frieze, and this intermediate space is occupied by two steps and a seat. The cornice is 98 feet $9\frac{3}{4}$ inches from the pavement. The height of the drum from the top of the seat is 62 feet $6\frac{1}{2}$ inches to the springing of the internal dome. The wall forming the drum is inclined internally 4 feet $11\frac{1}{2}$ inches, or about the 12th part of its height. This was designed by the architect to increase the resistance of the walls to the united pressure of the large internal vault, and the conical dome which carries the lantern.

"The interior of the drum is decorated with a continuous stylobate, on which is an order of Corinthian pilasters. The 32 spaces between the pilasters are filled with 24 windows and eight large niches. Externally the drum is decorated with an order of 32 Corinthian columns engaged, which are united to the wall of the drum by eight solid constructions in masonry. In each space between the constructions there are three intercolumniations, the columns being joined at their bases by wall pierced with arches. The external colonnade is surmounted by an entablature; behind this is a terrace, formed by the recessing back. The attic is 22 feet $4\frac{1}{2}$ inches high from the top of the balustrade to the under side of the cornice of the attic. Above the internal order of the drum rises the interior dome, the diameter of which at the springing is 102 feet $2\frac{3}{4}$ inches by 51 feet in height. The top of the dome has a circular opening 14 feet $10\frac{3}{4}$ inches in diameter.

"Above the attic are two steps, from which the external dome springs. The external dome is constructed of wood, covered with lead, and decorated with projecting ribs forming panels, curved at the ends. This dome terminates with a finishing which joins the base of the lantern: the circular gallery formed on the finishing is 274 feet 9 inches above the pavement of the nave. The lantern is supported on a conical tower, terminated by a spherical dome. This tower, which is joined to the internal dome at its base, disengages itself from it at the height of 8 feet 6 inches above the springing of the same. The perpendicular height of this tower is 86 feet 9 inches, and the walls are inclined 24 degrees from the perpendicular, the diameter of the base is 100 feet 1 inch measured externally, and 34 feet 1 inch at the springing of the spherical dome which finishes it. The wall of this tower is built of brick, and is 1 foot 7 inches thick, with circular rings of masonry, fastened with iron bands. The spherical dome at the top of the tower has an opening 8 feet in diameter at the summit. Between the attic and the wall of the tower are 32 walls or buttresses, which also serve to bear the ribs of the wooden external dome."—*Penny Cyclopædia.*

About the same time that Wren built the dome of St. Paul's, Hardouin Mansard, a French architect, constructed the dome of the Invalides at Paris. The plan of this dome is a square, in which is inscribed a Greek cross; in the angles of the square there are four chapels. The dome is raised in the centre of the Greek cross; the base supporting it is an octagonal figure, with four large and four small sides. The dome, which is double, rises from a springing which is common to both. The lower or internal dome constructed with masonry is spherical. The outer dome is of a spheroidal form, constructed of stone at the base, and of brick above. It is framed of wood and covered with lead, like St. Paul's, London, but the construction is much heavier. The total height to the top of the cross which surmounts the lantern is 330 feet.

The modern Pantheon at Paris, formerly the church of St. Geneviève, was built by J. G. Soufflot, who distinguished himself by his architectural works, in the reign of Louis XV. The dome, which is lofty, is sustained by four pillars, arched over the cross parts. The angular spaces are filled up with pendentives, terminating in a circular ring, on which a cylindrical wall is built, supporting the cupola. In the latter particular it is similar to St. Paul's.

Of wooden domes, that of the Halle du Blé, at Paris, is an excellent example; it being more than 200 feet in diameter, and only a foot in thickness.

A new material has been lately employed in the construction of the dome of the church of St. Isaac, at St. Petersburg, erected under the direction of the Chevalier de Montferrand. An account of the construction is given by Mr. Godwin as follows:—"The walls of the dome are carried up in solid construction of brick, with tiers of stone-bond, and are above 8 feet thick. On the level of the top of the cornice of the circular colonnade which girds the drum, there is a series of twenty-four cast-iron ribs, the feet of which rest on a cast-iron plate 7 feet wide, which runs quite round the circumference. At their head all the ribs are attached to a horizontal plate or curb, 6 feet 3 inches wide, which follows the periphery of the dome. At this height the rib is divided into 2, the one part about 12 feet 6 inches deep, following the sweep of the inner dome for a height of 20 feet, is at its summit bolted to a cast-iron perforated cylinder, 21 feet in diameter, and 7 feet high; this forms the centre aperture at the summit of the inner dome. The other part follows the line of an intermediate cone, with a catenary outline, and similar to the one in St. Paul's; it is also 21 feet long, and 2 feet 6 inches deep, and perforated to render it lighter. At this height the heads of the ribs are again secured to another horizontal plate or curb, which forms a complete circle, and is 3 feet wide; and this curb and the ribs are tied to the cylindrical opening of the inner dome, already mentioned, by radiating beams 2 feet 3 inches deep. The conical ribs have then another length of 21 feet, and their heads are again connected by another horizontal plate, from which spring the circular ribs, about 16 feet long, forming a dome to the intermediate cone, and their heads are also bolted to a cylinder, 8 feet 6 inches in diameter, and 18 inches high. But the upper portions of the ribs diverge at top, so as to form a base for the octagonal cupolino, which consists of a series of cast-iron story-posts, ribs, and bracketings, inclusive of the dome of the cupolino, with its ball and cross at the apex, which last are of brass-gilt. The filling in between the ribs consists of pots, the surfaces of which are subsequently rendered with plaster, and painted with sacred subjects. The external face of this outer dome is covered with bronze gilt in three thicknesses of leaves of ducat gold. The whole entablature and flat, and the balustrade over the peristyle of the drum of the cupola, likewise consist of cast and wrought iron framing, faced with plates of copper, to form the profiles and mouldings. The 24 pedestals of this balustrade carry winged angels of bronze, above 9 feet high, each of a single casting.

"The quantity of metal employed in the work is as follows:—

Ducat gold	247 lbs.
Copper	52½ tons
Brass	321½ "
Wrought-iron	524½ "
Cast-iron	1068 "
	1966½ tons 247 lbs.

"The roofing is wholly of iron, covered with copper. The raising of the monolithic shafts of the 24 columns of the exterior peristyle of the dome—each of which weighed nearly 66 tons—to the height of 150 feet, was an operation requiring considerable skill. The first column was raised on the 17th November, 1837, and in two months the 24 columns were completely fixed.

"The skeleton of the entablature of the peristyle of the dome is of cast and wrought iron, resting on the columns, and affixed to them by wrought-iron pins, which are let a considerable depth into the shafts, and the frame-work is also let into the cylindrical wall of the dome, securely affixed to three templates. The cornice, with its modillions and mouldings, rests on cast-iron corbels; the caissons and rosettes of the inner soffit also rest on cast-iron girders.

"The careful skill with which the architect has fulfilled his part, and the feeling for decorative art with which he has embellished the church of St. Isaac, render it one of the most striking edifices of the nineteenth century."

All the ancient Roman domes are on the convex side a much less portion of a sphere than a hemisphere; but those, from the completion of the church of Santa Sophia, to the finishing of St. Paul's cupola, are of the surmounted kind, approaching in a greater or less degree to the proportion of towers, or spires, which were so much admired and adopted in the middle ages. The sides of the section of St. Paul's dome are struck with centres in the base line, which, if continued, would meet in an angle in the axis of the dome. Since the revival of Grecian architecture, the contour of the old Roman dome has also been revived, especially in cases where other parts of the building are decorated with any of the orders. Exterior domes can never be correctly applied to buildings in the pointed style of architecture.

The following are the admeasurements of some of the principal domes in Europe, taken from Mr. Ware's "Tracts on Vaults and Bridges:"—

Domes of Antiquity.

	Feet in diameter taken externally.	Height from the ground line.
Dome of the Pantheon	142	143
" Minerva Medica, at Rome . . .	78	97
" Baths at Caracalla	112	116
" Baths at Diocletian	74	83
Temple of Mercury	68	
" Diana	98	78
" Apollo	120	
" Proserpine and Venus	87	77

Domes of comparatively Modern Times.

Santa Sophia, at Constantinople	115	201
Mosque of Achmet, "	92	120
San. Vitate, at Ravenna	55	91
San. Marco, at Venice	44	

From the time of Brunelleschi to the present period.

Santa Maria del Fiore, at Florence	139	310
The Chapel of the Medici	91	199
Baptistry, at Florence	86	110
Cathedral of St. Peter, at Rome	139	330
Chapel of the Madonna della Salute, at Venice	70	133
Chapel of the Superga, at Turin	64	128
" Invalides, at Paris	80	173
" Val de Grace, Paris	55	133
" Sorbonne, Paris	40	110
Pantheon, or St. Geneviève, Paris	67	190
Cathedral of St. Paul's, London	112	215

In the reigns of queen Elizabeth, and her successor king James I., square turrets, surmounted with domes resembling a bell in their outline, were much used.

Domes are sometimes made convex below, and concave above; the former being a much greater portion of the side than the latter: these may be denominated Moresque, Turkish, or Hindoo.

Mr. Bunce invented a dome that requires no centering; in this construction, all the abutting joints are continued in uninterrupted vertical planes; but the horizontal joints of every two stones break on the middle of the stones on either side; so that every alternate stone of a course projects upwards, and leaves a recess for the insertion of the stones of the next course. Upon this principle, the intervals, as the building approaches nearer the top, becomes more wedge-formed, and, the interior circumference being less than the exterior, the stones can be inserted only on the outside: consequently, if made so exact as just to fit into their places, they cannot fall inwardly. This mode of joining stones may be convenient, as requiring no centering; but unless the courses be nicely equilibrated, it is more liable to burst, than when a dome is constructed in the ordinary manner, since every row of stones, from the base to the top, forms an arch independent of the rest.

The equilibrium and pressure of domes is very different from that of common arching, though there are some properties common to both. Thus, in cylindrical and cylindroidal vaulting, of uniform thickness, if the tangent to the arch at the bottom be perpendicular to the horizon, the vault cannot stand; neither can it be built with a concave contour in whole, or in part; and to bring an arch to an equilibrium, whether its section be circular or elliptical, the intrados being given, both extremities of the arch must be loaded, *ad infinitum*, between the extrados of the curve which runs upwards, and the vertical assymptote rising from each foot. So, in thin domes, of equal thickness, if the curved surface rise perpendicularly from the base, it will burst at the bottom, whatever be the contour.

Yet, though dome-vaulting, in this particular, agrees with common arching, they differ materially in several other points. For, in order to equilibrate the figure of the former, after the convexity has been carried to its full extent of equilibrium around, and equidistant from the summit on the exterior side, the curvature may be changed into a concavity: here the interior circumference of the courses is less than the exterior, and therefore, whatever the pressure towards the axis, the course cannot fall inwardly, without squeezing the stones into a less compass. Hence a vault may be executed with a convex surface inwardly, and a concave surface outwardly, and be sufficiently firm.

The strongest form of a circular vault, required to bear a weight on its top, is that of a truncated cone, similar to the exterior dome of St. Paul's, London, of which it is impossible to conceive any force acting on the summit, that would be capable of disturbing its equilibrium: for the pressure being communicated in the sloping right line of the sides of the cone, perpendicular to the joints, the conic sides have no tendency to bend to one side more than to another; the gravity of the materials towards the axis, being counteracted by the abutting vertical joints.

In dome-vaulting, the case is very different: for here the contour being convex, there is a certain load, which, if laid on the top, must burst it outwardly, which weight becomes greater in proportion as the contour approximates towards the chords of the arches of the two sides, or to a conic vaulting on the same base, carried up to the same altitude, and ending in the same circular course. For example, suppose a horizontal line, tangent at the vertex, proceed from the key-stone downwards, course by course; it will be evident, that every successive coursing-joint may be made to slant as much, and consequently, that the pressure of the arch-stones of any course towards the axis will be so great, as to be more than adequate to the resistance of the weight of all the superincumbent parts. Hence it may be clearly deduced, that there is a certain degree of curvature to be given to the contour, which will just prevent the stones in any succeeding course from being forced outwardly.

The circular vault, thus balanced, is indeed an equilibrated dome; but, instead of the strongest, it is the weakest of all between its own contour and that of a cone upon the same base, rising to the same height, in a key-stone, or in an equal circular course. The equilibrated dome has therefore the boldest contour; but is the limit of an infinitude of inscribed circular vaults, all of them stronger than itself.

In other respects, circular vaulting differs from straight vaulting in being built with courses in circular rings; and in having the stones in each course of equal length, which pressing equally towards the axis, cannot slide inwardly. Circular vaults may therefore be open at the top; and the equilibrated dome, which, as we have just observed, is the weakest of all, may be made to bear a lantern of equal weight with the part that would otherwise have completed the whole. Domes of flatter contours will bear more, in proportion as they approach nearer to that of a cone: and circular vaults, that are either straight or concave on the sides, if chained at the bottom, may be loaded to any degree, without giving way, until the materials of which they are built be crushed to powder.

The foregoing description of the equilibrium and pressure of domes may be comprehended without any acquaintance with either algebra or fluxions, and will be of use to the ordinary workmen; for the satisfaction of more scientific readers, we subjoin Dr. Robison's theory.

Problem.—To determine the thickness of dome-vaulting when the curve is given, or the curve when the thickness is given.

Plate 1. *Figure* 1.—"Let B b A be the curve which produces the dome by revolving round the vertical axis A D. We shall here suppose the curve to be drawn through the middle of the arch-stones, and that the coursing or horizontal joints are everywhere perpendicular to the curve. We shall suppose (as is always the case) that the thickness K L, H I, &c. of the arch-stones is very small in comparison to the dimensions of the arch. If we consider any portion H A h of the dome, it is plain that it presses on the curve of which H L is an arch-stone, in a direction b C, perpendicular to the joint H I, or in the direction of the next superior element β b of the curve. As we proceed downwards, course after course, we see plainly that this direction must change, because the weight of each course is superadded to that of the portion above it to complete the pressure of the course below. Through B draw the vertical line B C G meeting β b, produced in C. We may take b c to express the pressure of all that is above it, propagated in this direction to the joint K L. We may also suppose the weight of the course H L united in b, and acting on the vertical. Let it be represented by b F. If we form the parallelogram b F G C, the diagonal b G will represent the direction and intensity of the whole pressure on the joint K L.

"We have seen, that if b G, the thrust compounded of the thrust b C exerted by all the courses above H I L K, and if the force b F, or the weight of that course be everywhere coincident with b B, the element of the curve, we shall have an equilibrated dome; if it fall within it, we have a dome which will bear a greater load, and if it fall without it, the dome will break at the joint. We must endeavour to get analytical expressions of these conditions. Therefore draw the ordinates b δ b'', B D B$''$, C d c''. Let the tangents at b and b'' meet the axis in M, and make M O, M P, each equal to b C, and complete the parallelogram M O N P, and draw O Q perpendicular to the axis, and produce b F, cutting the ordinates in E and e. It is plain that M N is to M O as the weight of the arch H A h to the thrust b C, which it exerts on the joint K L (this thrust being propagated through the course of H I L K,) and that M Q, or its equal b e, or δ d, may represent the weight of the half A H.

"Let A D be called x, and D B be called y. Then $b\,e = \dot{x}$, and e C $= \dot{y}$ (because b C is in the direction of the element β b). It is plain if we make $\dot{y}$ constant, B C is the second fluxion of x, or B C $= \dot{x}$, and b e and b E may be considered as equal, and taken indiscriminately for $\dot{x}$. We have also b C $= \sqrt{x_2 + y_2}$; let d be the depth or thickness of H I of the arch-stones. Then $d\sqrt{\dot{x}_2 = \dot{y}_2}$; will represent the trapezium H L; and since the circumference of every course increases in the proportion of the radius y, $d\,y\sqrt{\dot{x} + \dot{y}}$ will represent the whole course. If s be taken to represent the sum or aggregate of the quantities annexed to it, the formula will be analogous to the fluent of a fluxion, and $s\,d\,y\sqrt{\dot{x}^2 + \dot{y}^2}$ will represent the whole mass, and also the weight of the vaulting down to the joint H I. Therefore we have this proportion: $s\,d\,y\sqrt{\dot{x}^2+\dot{y}^2} : d\,y\sqrt{\dot{x}^2+\dot{y}^2} = b\,e : b\,\text{F} = b\,e : \text{C G} = \delta\,d : \text{C G} = x : \text{C G}$. Therefore C G $= \frac{d\,y\,x\sqrt{\dot{x}^2+\dot{y}^2}}{s\,d\,y\sqrt{\dot{x}^2+\dot{y}^2}}$

"If the curvature of the dome be precisely such as puts it in equilibrium, but without any mutual pressure in the vertical joints, this value of C G must be equal to C B, or to $\ddot{x}$, the point G coinciding with B. This condition will be expressed by the equation $\frac{d\,y\,\dot{x}\sqrt{\dot{x}^2+\dot{y}^2}}{s\,d\,y\sqrt{x^2+y^2}} = \ddot{x}$ or more conveniently by $\frac{d\,y\sqrt{\dot{x}^2+\dot{y}^2}}{s\,d\,y\sqrt{\dot{x}^2+\dot{y}^2}} = \frac{\ddot{x}}{\dot{x}}$. But this form gives only a tottering equilibrium, independent of the friction of the joints and cohesion of the cement. An equilibrium, accompanied by some firm stability produced by the mutual pressure of the vertical joints, may be expressed by the formula. $\frac{d\,y\sqrt{\dot{x}^2+\dot{y}^2}}{s\,d\,y\sqrt{\dot{x}^2+\dot{y}^2}} > \frac{\ddot{x}}{\dot{x}}$, or by $\frac{d\,y\sqrt{\dot{x}^2+\dot{y}^2}}{s\,d\,y\sqrt{\dot{x}^2+\dot{y}^2}} = \frac{\ddot{x}}{\dot{x}} + \frac{\dot{t}}{t}$, where t is some variable positive quantity which increases when x increases. This last equation will also express the equilibrated dome, if t be a constant quantity, because in this case: $\frac{\dot{t}}{t}$ is $= 0$

"Since a firm stability requires that $\frac{d\,y\,\dot{x}\sqrt{\dot{x}^2+\dot{y}^2}}{s\,d\,y\sqrt{\dot{x}^2+\dot{y}^2}}$ shall be greater than $\ddot{x}$, and C G must be greater than C B. Hence we learn that figures of too great curvatures, whose sides descend too rapidly, are improper. Also since stability requires that we have $\frac{d\,y\,\dot{x}\sqrt{\dot{x}^2+\dot{y}^2}}{\ddot{x}}$ greater than $s\,d\,y\sqrt{\dot{x}^2+\dot{y}^2}$, we learn that the upper part of the dome must not be made very heavy. This, by diminishing the proportion of b F to b C, diminishes the angle C b G, and may set the point G above B, which will infallibly spring the dome in that place. We see here also, that the algebraic analysis expresses that peculiarity of dome-vaulting, that the weight of the upper part may even be suppressed.

"The fluent of the equation $\frac{d\,y\sqrt{\dot{x}^2+\dot{y}^2}}{s\,d\,y\sqrt{\dot{x}^2+\dot{y}^2}} = \frac{\ddot{x}}{\dot{x}} + \frac{\dot{t}}{t}$ is most easily found. It is L $s\,d\,y\sqrt{\dot{x}^2+\dot{y}^2} = \text{L}\,\dot{x} + \dot{t}$, where L is the hyperbolic logarithm of the quantity annexed to it. If we consider $\dot{y}$ as constant and correct the fluent, so as to make it nothing at the vertex, it may be expressed thus:

L $s\,d\,y\sqrt{\dot{x}^2+\dot{y}^2}$ − L a = L $\dot{x}$ − L $\dot{y}$ + L t. This gives us L $\frac{s\,d\,y\sqrt{\dot{x}^2+\dot{y}^2}}{a}$ = L $\frac{\dot{x}}{\dot{y}}t$, and therefore $\frac{s\,d\,y\sqrt{\dot{x}^2+\dot{y}^2}}{a} = t\frac{\dot{x}}{\dot{y}}$

This last equation will easily give us the depth of the vaulting, or thickness, d, of the arch, when the curve is given. For its fluxion is $\frac{d\,y\sqrt{\dot{x}^2+\dot{y}^2}}{a} = \frac{t'\dot{x} + t\ddot{x}}{\dot{y}}$ and $d = \frac{a\,t'\dot{x} + a\,t'\ddot{x}}{y\,\dot{y}\sqrt{\dot{x}^2+\dot{y}^2}}$, which is all expressed in known quantities: for we may put in place of t any power or function of x or of y, and thus convert the expression into another, which will still be applicable to all sorts of curves.

"Instead of the second member $\frac{\ddot{x}}{\dot{x}} + \frac{t'}{t}$ we might employ $\frac{p\,\ddot{x}}{\dot{x}}$, where p is some number greater than unity. This will evidently give a dome having stability; because the original formula $\frac{d\,y\,\dot{x}\sqrt{\dot{x}^2+\dot{y}^2}}{s\,d\,y\sqrt{\dot{x}^2+\dot{y}^2}}$ will be greater than $\ddot{x}$. This will give $d = \frac{p\,a\,\dot{x}^{p-1}\ddot{x}}{y\,\dot{y}^p\sqrt{\dot{x}^2+\dot{y}^2}}$. Each of these forms has its advantages when applied to particular cases. Each of them also gives $d = \frac{a\,\ddot{x}}{y\,\dot{y}\sqrt{\dot{x}^2+\dot{y}^2}}$ when the curvature is such as in precise equilibrium: and lastly, if d be constant, that is, if the vaulting be of uniform thickness, we obtain the form of the curve, because then the relation of $\dot{x}$ to x and to y is given.

"The chief use of this analysis is to discover what curves are improper for domes, or what portions of given curves may be employed with safety.

"The chief difficulty in the case of this analysis arises from the necessity of expressing the weight of the incumbent part, or $s\,d\,y\sqrt{\dot{x}^2+\dot{y}^2}$. This requires the measurement of the conoidal surface, which in most cases can be had only by approximation, by means of infinite series. We cannot expect that the generality of practical builders are familiar with this branch of mathematics, and therefore will not engage in it here; but content ourselves with giving such instances as can be understood by such as have that moderate mathematical knowledge, which every man should possess, who takes the name of engineer.

"The surface of any circular portion of a sphere is very easily had, being equal to the circle inscribed with a radius equal to the arch. This radius is evidently equal to $\sqrt{x^2+y^2}$.

"In order to discover what portion of a hemisphere may be employed (for it is evident we cannot employ the whole) when the thickness of the vaulting is uniform, we may recur to the equation or formula $\frac{d\,y\,\dot{x}\sqrt{\dot{x}^2+\dot{y}^2}}{\ddot{x}} = s\,d\,y\sqrt{\dot{x}^2+\dot{y}^2}$. Let a be the radius of the hemisphere. We have $\dot{x} = \frac{a\,y\,\dot{y}}{\sqrt{a^2-y^2}}$ and $\ddot{x} = \frac{a\,\dot{y}^2}{\overline{a^2-y^2}|^{\frac{3}{2}}}$. Substituting these values in the formula, we obtain the equation $y^2\sqrt{a^2-y^2} = s\frac{a^2\,y\,\dot{y}}{\sqrt{a^2-y^2}}$. We easily obtain the fluent of the second member $= a^2 - a^2\sqrt{a^2-y^2}$, and $y = a\sqrt{-\frac{1}{2}+\sqrt{\frac{5}{4}}}$. Therefore, if the radius of the hemisphere be one-half, the breadth of the dome must not exceed $\sqrt{-\frac{1}{2}+\sqrt{\frac{5}{4}}}$, or 0.786, and the height will be 618. The arch from the vertex is about 51° 49′, much more of the hemisphere cannot stand even, though aided by the cement, and by the friction of the coursing joints. This last circumstance, by giving connection to the upper parts, causes the whole to press more vertically on the course below, and this diminishes the outward thrust; but at the same time diminishes the mutual abutment of the vertical joints, which is a great cause of firmness in the vaulting. A Gothic dome, of which the upper part is a portion of a sphere not exceeding 45° from the vertex, and the lower part is concave outwards, will be very strong, and not ungraceful.

"Persuaded that what has been said on this subject convinces the reader that a vaulting, perfectly equilibrated throughout is by no means the best form, provided that the base is secure from separating, we think it unnecessary to give the investigation of that form, which has considerable intricacy, and shall merely give its dimensions. The thickness is supposed uniform. The numbers in the first column of the table express the portion of the axis counted from the vertex, and those of the second are the length of the ordinates.

A D	D B	A D	D B	A D	D B
0.4	100	610.4	1080	2990	1560
3.4	200	744	1140	3442	1600
11.4	300	904	1200	3972	1640
26.6	400	1100	1260	4432	1670
52.4	500	1336	1320	4952	1700
91.4	600	1522	1360	5336	1720
146.8	700	1738	1400	5756	1740
223.4	800	1984	1440	6214	1760
326.6	900	2270	1480	6714	1780
465.4	1000	2602	1520	7260	1800

"The curve formed according to these dimensions will not appear very graceful, because there is an abrupt change in its curvature at a small distance from the vertex. If, however, the middle be occupied by a lantern of equal, or of smaller weight than the part whose place it supplies, the whole will be elegant and free from defect.

Figure 3 represents four different contours of domes, upon a square plan, No. 5; No. 1, shows a semicircle contour; No. 2, a pointed contour; No. 3, a Turkish, or Mahometan contour; No. 4, a bell-formed contour, as used in the reigns of Elizabeth and James I.

Figure 4 represents five different contours, upon an octagonal plan, No. 6; No. 1, the contour of a dome, the vertical section of which being a semi-ellipsis, with the lesser axis placed horizontal; No. 2, the contour of a semicircular section; No. 3, the contour of a dome, the vertical section of which is a semi-ellipsis, placed upon the greater axis; No. 4, the contour of a dome, the vertical section parallel to either side being the segment of a circle: No. 5, a pointed contour, formed similar to the dome of the cathedral church of Sta. Maria del Fiore, at Florence, which was both octangular upon the plan, and pointed in its vertical section.

Figure 5 represents five contours upon a circular plan, No. 6; No. 1, is formed by having its vertical section the segment of a circle, which was the general practice of the Romans, in the exterior form of their domes, as in the Pantheon at Rome; No. 2, a dome with a semicircular axal section, a form very frequently used in modern times; No. 3, an ellipsoidal dome, whose axis is the greater semi-axis of the ellipsis; No. 4, represents a dome with a parabolical contour, the vertical section being that of a curve, and the axis of the parabolical section being the same as that of the dome. This contour is more pointed than any part of an ellipsis; No. 5, represents a dome with an hyperbolical contour, the vertical section being an hyperbola; this is still more pointed than the parabolical dome.

Figure 6 shows four variations of contours: No. 1, pointed like the dome of St Paul's cathedral church, London, which is composed of two arcs of a circle; No. 2, a dome with a small concavity upwards, springing perpendicularly from its base; No. 3, another contour of a dome, with a small concavity at the top, but spreading outwards as it rises from the bottom, with a convexity in its vertical section; No. 4, a dome of the same nature as the last, but dissimilar in its form, the convex part being much quicker. Such forms as the last three may be denominated Moresque, Turkish, or Hindoo, as they are practised by the Moors, Turks, and Hindoos. This form was introduced into England in the reign of Henry VII., and in constant use in the time of Henry VIII. Its use was in the crowning of turrets, as in the octagonal buttresses of Henry the Seventh's chapel, and the towers of King's College chapel, Cambridge: the turrets at the entrance of Christ's College, Oxford, executed by Sir Christopher Wren, are surmounted with domes of this form. The bell-formed dome, *Figure* 3, No. 4, succeeded *Figure* 6, No. 2; examples of it may be seen at Audley-End, in Essex, built in the reign of James I., and in the Tower of London.

It is a property of all domes to have their horizontal sections similar to each other, and to the base of the dome.

What may be properly denominated a Roman dome, is one whose axal section is a semicircle, or the segment of a circle less than a semicircle. Among the ancients, domes were only used in covering whole buildings of a circular plan; but among moderns they are used in covering any apartment, or distinct portion of a building, which too frequently has a very insignificant appearance, and, for want of magnitude, destroys the general contour of the whole, producing a kind of mixed outline at the finish of the edifice; where in most points of view it is completely lost.

In modern architecture, the dome, when used, is generally raised upon a tower, or turret, and by this means the figure is shown more completely than if it were immediately raised from the walls; but care should be taken, that if the place over which it is to be erected be too small, it should not be adopted; and if admitted in an edifice, it should bear a good proportion to the whole mass: when a dome is properly managed, nothing adds more grace or dignity to the termination of an edifice than the domic contour.

Plate III. *Figure* 1.—*Given the plan of a square dome, and one of the axal ribs, at right angles to one of the sides; to find the curve of the angle rib, and the covering.*

The axis of a square dome is the vertical line in which the diagonal planes would intersect each other.

Let A B C D be a plan of the dome; A C and B D the intersections of the diagonal planes; E F the base of the rib; E K the height of the given rib; and the curve line K I H G F, the section of the upper surface, which comes in contact with the boarding. Produce E F to *k*; divide the curve line K F into any number of equal parts, the more the truer will be the operation; let the parts be F G, G H, H I, I K, which extend upon the straight line F *k*; the first from F to *g*, the second from *g* to *h*, the third from *h* to *i*, and the fourth from *i* to *k*; from the points G, H, I, in the curve of the given rib, draw G G′ N, H H′ O, I I′ P, parallel to A D, cutting the base of the rib E F at the points G′, H′, I′, and the half diagonal D E at the points N, O, P; also, through the points *g*, *h*, *i*, draw *n g n*, *o h o*, *p i p*, parallel to A D. Take the intercepted parts G N, H O, I P, between E F and E D, apply them successively to the lines parallel to A D, on each side of F *k*, from *g* to *n*, and from *g* to *n*, from *h* to *o*, and from *h* to *o*, from *i* to *p*, and from *i* to *p*, and through the points A, *n*, *o*, *p*, *k*, on each side of F *k*, draw a curve; then the space, A *k* D, comprehended between the two curve lines and the side A D of the plan, is the form of the whole covering for each side of the dome.

To find the hip-line of the angle rib whose base is E D.

From the points, N, O, P, E, draw N Q, O R, P S, and E T, perpendicular to E D: make N Q, O R, P S, E T, successively equal to G′ G, H′ H, I′ I, E K: and through the points D, Q, R, S, T, draw a curve, which will be the hip-line.

Figure 2.—A dome likewise upon a square plane, but the given axal rib at right angles to the side, is the segment of a circle less than a semi-circle.

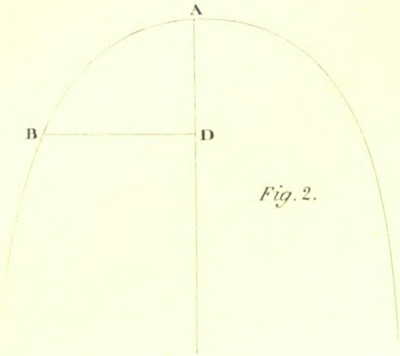


Fig. 2.

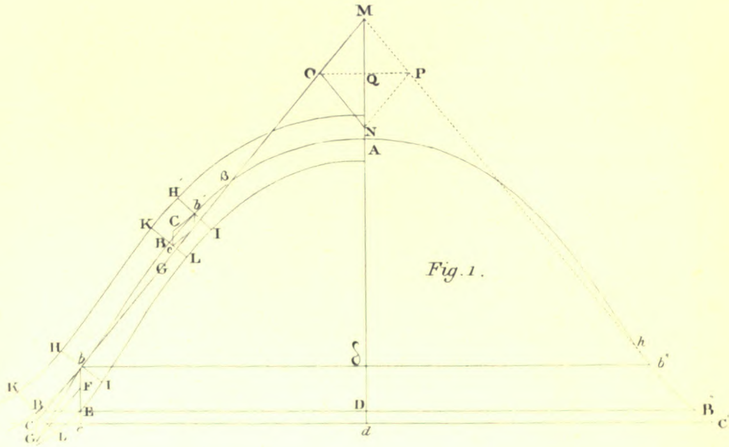


Fig. 1.

Fig. 6. No. 1.

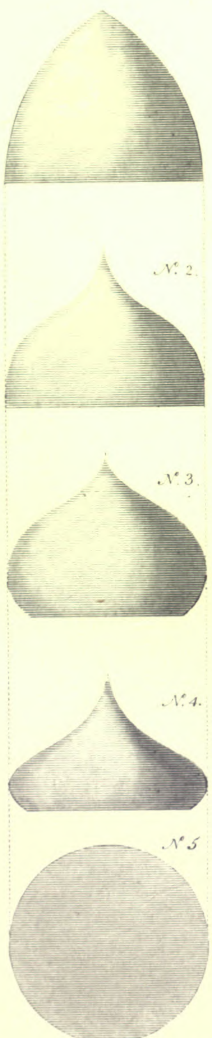


Fig. 5. No. 1.

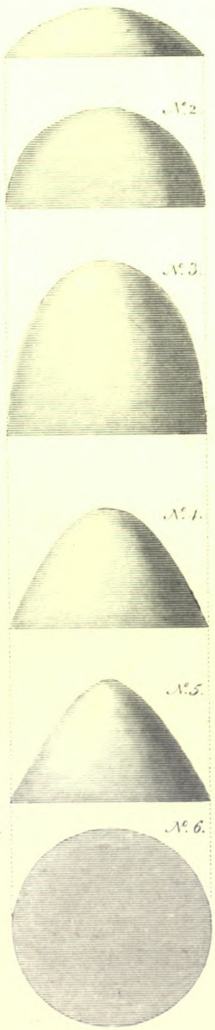


Fig. 4. No. 1.

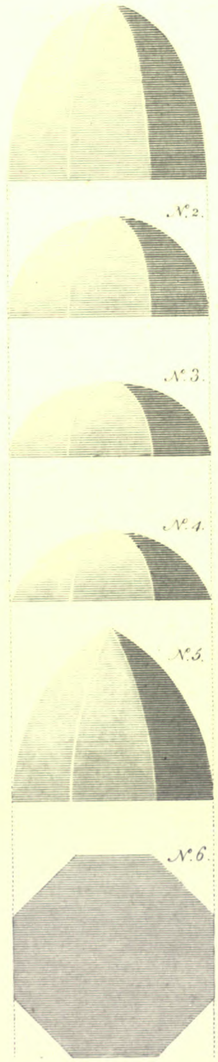
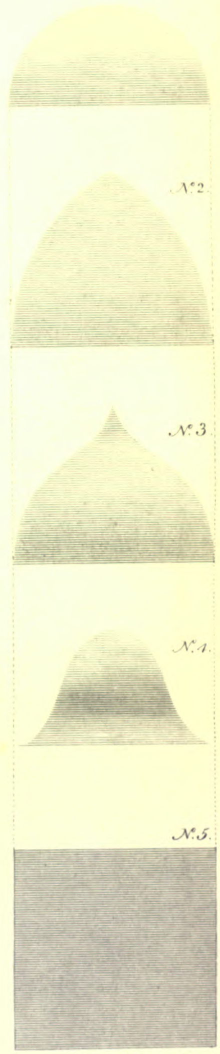


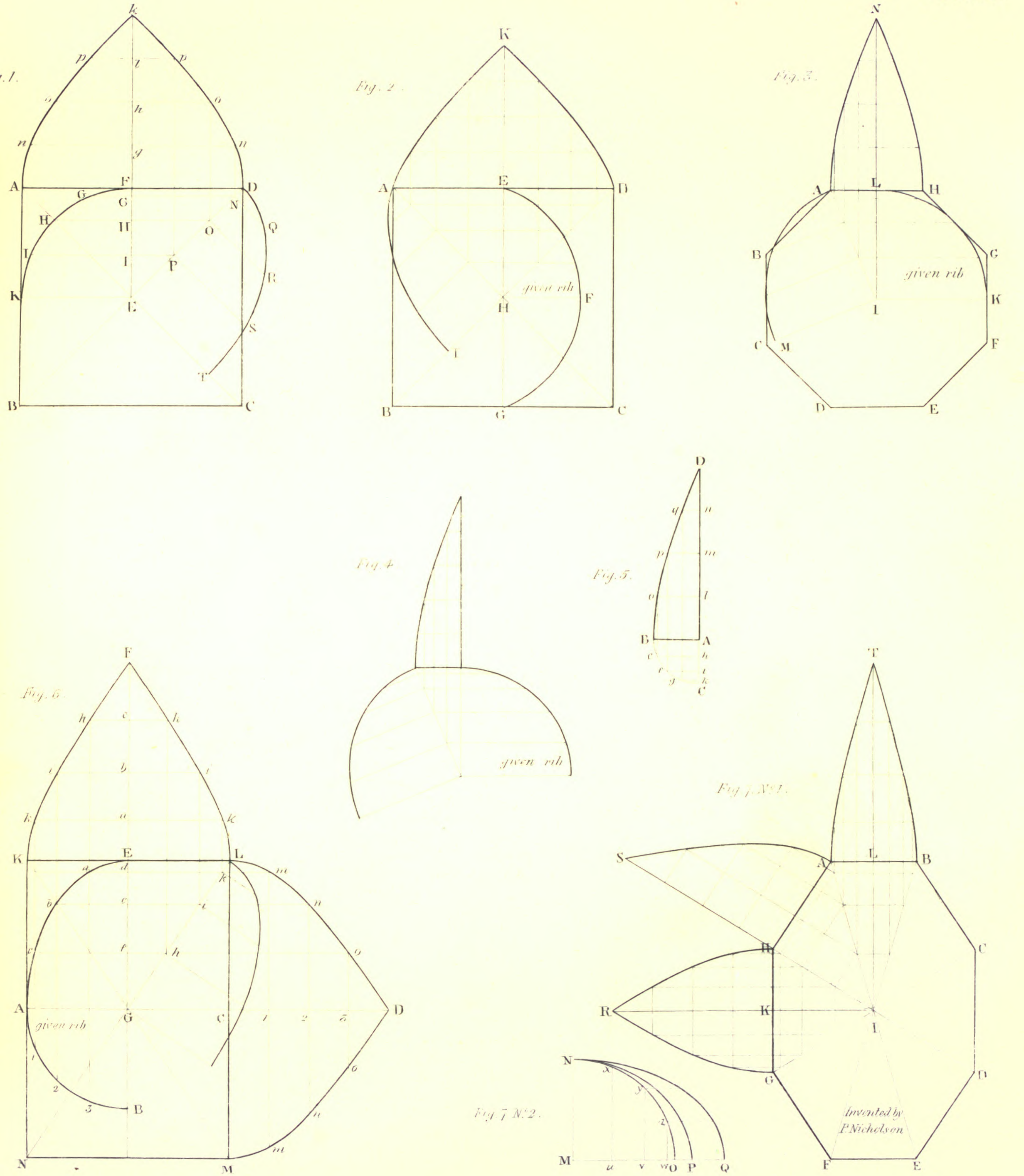
Fig. 3. No. 1.



Drawn by P. Nicholson. *Eng.d by R. Thew.*

DOMES.

PLATE III.



son.

R. Thew

Figure 3.—Plan of a polygonal dome, showing the covering extended, and the angle-rib. The method of finding the covering and angle-rib for *Figures* 2 and 3, is the same as in *Figure* 1, and may be described in the same words.

Instead of laying out the covering and angle-rib, as in *Figure* 3, of the octagonal dome, they may be laid down as in *Figure* 4, without laying down the whole plan; and if only the covering be wanted, it may be found without any part of the plan, as in *Figure* 5. Thus, let A D represent the middle of the boarding for one of the sides, and let A B, at right angles thereto, be half the breadth of the side A H, *Figure* 3; let A B, *Figure* 5, represent half the base of the rib; on A B describe a quadrant or similar figure to the given rib, I L K, *Figure* 5: make A D equal to the circumference, L K, of the given rib. The rule for this purpose will be found under those for measuring segments of circles; see the article SEGMENT; or if the arc be that of a quadrant, the quadrantal arc may be found, as in the article CIRCLE, and then taking a fourth part of the whole circle, or the half of a semi-circle. We shall here give examples both for a complete quadrant, and for a rib which is the half of a segment less than a semi-circle:

Figure 3.—Suppose the base, I L, to be 20 feet, then

$$\frac{3\frac{1}{7} \times 20}{2} = 31 \text{ feet } 5 \text{ inches.}$$

Again, suppose the base to be 12 feet, as before, but the height to be only 5 feet, then the whole chord will be 24 feet, and the versed sine 5 feet.

RULE.—Multiply the sum of six times the square of the half chord, and five times the square of the versed sine, by the chord; and divide the product by the sum of six times the square of the half chord and the square of the versed sine; and the quotient is the length of the arc, nearly.

Here the half chord is 12 feet: therefore,

$$\frac{(6 \times 12^2 + 5 \times 5^2) \times 24}{6 \times 12^2 + 5^2} = 26.69, \text{ the answer.}$$

Or thus, at full length:

then $6 \times 12^2 + 5^2 = 864 + 25 = 889$.

12	5
12	5
$144 = 12^2$	$25 = 5^2$
6	5
$864 = 6 \times 12^2$	$125 = 5 \times 5^2$
125	

$989 = 6 \times 12^2 + 5 \times 5^2$

24 whole chord, or base of two ribs.

3956
1978

889) 23736 (26.63
1778 13.315 feet for the length of the curved hip.

5956
5334

6220
5334

8860
8001

859

NOTE.—The above rule is the invention of the author.

Figure 5.—Then making A D equal to the length of the arc, divide the curve B C into any number of equal parts, and draw the lines *e h*, *f i*, *g k*, parallel to B A, cutting A C at *h*, *i*, *k*; divide the straight line A D into as many equal parts as the curve B C is divided into, at the points *l*, *m*, *n*, and draw *l o*, *m p*, and *n q*, parallel also to A B; making *l o*, *m p*, *n q*, respectively equal to *h e*, *i f*, and *k g*, and through the points B, *o*, *p*, *q*, D, draw a curve; then the space comprehended between this curve and the straight lines A D and A B, will be half the covering of one of the sides.

Figure 6.—*Given* K L M N, *the plan of an oblong dome, and the rib* A B; *to find the hip and the rib parallel to the longitudinal side, also the covering upon the longitudinal and transverse sides.*

Divide the curve A B into any number of equal parts, at the points of division 1, 2, 3, and draw lines 1 *k*, 2 *i*, 3 *h*, parallel to N K, the longitudinal side cutting the seat of the hip K G: from the points of intersection in K G draw lines parallel to K L, the breadth of the dome, to the points *m*, *n*, *o*; draw G E parallel to N K, and produce it to F; also produce A C to D; take the parts of the given rib A B, and extend them on C D, from C to 1, from 1 to 2, from 2 to 3, and from 3 to D: make 1 *m*, 2 *n*, 3 *o*, on each side of C D, respectively equal to the parallel distances from A K, comprehended between the lines A G, and K G; from the points *d*, *e*, *f*, cut by the lines parallel to K L, make *d a*, *e b*, and *f c*, respectively equal to the several heights of the given rib A B, and trace a curve through the points E, *a*, *b*, *c* A: upon the straight line E F, extend the parts E *a*, *a b*, *b c*, *c* A, of the arc E A, from E to *a*, from *a* to *b*, from *b* to *c*, and from *c* to F; through the points *a*, *b*, *c*, in E F, draw *k k*, *i i*, *h h*, parallel to K L; make the parts *a k*, *b i*, *c h*, respectively equal to the parallels of E K, comprehended between E G and K G; then K F L, is the form of the boarding for each end, and L D M, that of the sides.

The angle-rib is found the same as in the square dome.

Figure 7, No. 1.—*To find the covering of an oblong polygonal dome.*

Given the plan A B C D E F G H I, and the axal section through its breadth, a semi-circle. Take any straight line, N Q, No. 2; in No. 1, draw lines from the middle point I, perpendicular to the sides G H, H A, A B, of the polygon, and let these perpendiculars be I K, I H, and I L: on the straight line M Q, No. 2, make M O equal to I K, M P equal to I H, and N Q equal to I L, No. 1. In No. 2, draw M N perpendicular to M O; from the centre M, with the radius M O, describe the quadrant O N: divide the arc O N into any number of equal parts, say four, *w z*, *z y*, *y x*, *x* N, at the points *z*, *y*, *x*; from the points *x*, *y*, *z*, No 2, draw lines *x u*, *y v*, *z w*, cutting M O at *u*, *v*, *w*; transfer the distances M *u*, *u v*, *v w*, *w* O, to the straight line I K, No. 1. Through the points of division, draw lines parallel to H G, to cut the diagonals G I, and H I; from the points of section in H I, draw lines parallel to H A, to cut the next diagonal A I: from the points of section in A I, draw lines parallel to A B, cutting B I: take the parts O *z*, *z y*, *y x*, *x* N, No. 2, and extend them to K R, No. 1, and draw lines through the points of section, parallel to H G; make the two parts of the lines so drawn on each side of K R, respectively equal to the lines drawn parallel to H G, terminated by K I, and H I. With the greater semi-axis M P, and lesser semi-axis M N, describe the quadrant of an ellipsis N P M: through the points *z*, *y*, *x*, draw lines parallel to M P, to cut the elliptic curve: extend the elliptic curve so cut, upon the straight line H S, and through the points of section, draw lines parallel to H A; transfer each of the lines contained between H I and A I, respectively, to each of the parallels on the other side of H A; or draw lines through the several points of section in the diagonal A I, parallel to I S, to cut the lines perpendicular to H S, and the points of intersection will form the direction of the line for the edge of the covering H S A. In like manner, by describing the quadrant of the ellipsis M Q N, and by drawing lines through the points z, y, x, to cut the curve N Q, by proceeding as before, we shall obtain the covering A B T. The three coverings G R H, H S A, A T B, cover more than one-quarter of the whole, by the half coverings G R K, and L T B, of the side and end. The covering of each side so found answers to the opposite side, by turning the back for the front. Each covering, except that upon the side, and that upon the end, will cover four different sides: the covering upon the sides and ends only answer in two opposite places.

The angle-ribs of this dome are found as usual. If the circumference of each quadrant or rib perpendicular to the side, were ascertained by calculation, then the boarding could easily be laid out without the use of a plan, upon the same principle as in *Figure* 5, as is obvious from what has already been said.

To construct the ribs of a spherical dome, with eight axal ribs, and one purlin in the middle.

Plate II. *Figure* 1, No. 1.—Let A B C D E F G H, be the semi-plan, which is supposed to be divided into four equal parts, and let A H be the diameter, terminating the semi-plan; divide the semi-circumference into four equal parts, from the extremity A, to the other extremity H, of the diameter A H; and the points of division will mark the middle of the back, or convex sides of the ribs. This being the case, let B C *c b*, D E *e d*, F G *g f*, be the plans of the intermediate ribs, B C, D E, and F G, having the points of division in the middle; the lines B *b*, C *c*, D *d*, E *e*, F *f*, G *g*, being the places of the vertical sides, and parallel to the lines drawn from the middle of B C, D E, F G, to the centre. Draw V X, No. 2, parallel to A H, No. 1: from the side A *a*, B C *c b*, D E *e d*, &c., draw lines cutting V X, perpendicular to A H; then taking V X for the under side of the kirb or wall-plate, draw its proper thickness. In the elevation, No. 2, of the dome, the front ribs are quadrants, forming a semi-circle with the upper side of the wall-plate, which is of course the diameter; the curves of the sides of each of the other ribs are the quadrants of an ellipsis of the same height with the front rib, and their projected places, from the plan upon the kirb V X, gives the lesser semi-axis. To form the purlins, place the section of one of them in its situation, and, circumscribing its angles, draw the square *m n o p*, draw *m q*, and *n r*, parallel to V X, and the lines from the several angles of the purlins, also parallel to V X; then, where they cut the opposite rib V X form the section of the purlin, and then the circumscribing square *q r s t*. First form a ring, whose greater diameter is *m q*, or *n r*, and whose inner, or less diameter, is *p t*, or *o s*, and whose thickness is *m n*, or *p o*; the ring being thus formed, gauge lines from each of the sides, as is shown by the section; then cut off the angles made by the horizontal and perpendicular surfaces, between each two lines, on each two adjoining sides, and the purlin will be formed. The ribs of this dome are not complete quadrants, as they abut upon the upper kirb W Y at the top.

The method of covering this dome is, to suppose the surface polygonal; the principle is the same as is shown in *Plate* III.

Figure 2.—The ribs of an elliptic dome are formed in the same manner as in *Figure* 1, and the covering as in the preceding Plate; the covering of one quarter being found, answers for the whole, as has been observed. It may be noticed, once for all, as a general rule to cover any dome, divide a quadrant of the plan into as many equal parts as there are to be boards in each quarter, then draw lines from the points of section, to the centre of the plan, and draw chords by joining each two adjacent points, so that there will be as many triangles formed as there are boards: from the centre of the plan, draw a perpendicular to each of the chords, meeting each chord; make the length of each perpendicular the base of a rib, and take the common height of the dome as the height of each rib, and place it at the extremity, at right angles to each base; and describe the quadrant of a circle or ellipsis, according as the base and height may be equal, or unequal. To find the covering for any side, divide the curve of the upper side of the rib, so found, into any number of equal parts, and draw lines perpendicular to the base to intersect therewith, and the whole will be completed, as shown in *Plate* III.

No. 6, shows the covering over I O N; No. 7, over I N M; No. 4, the middle rib; No. 5, the rib between the side and end ribs.

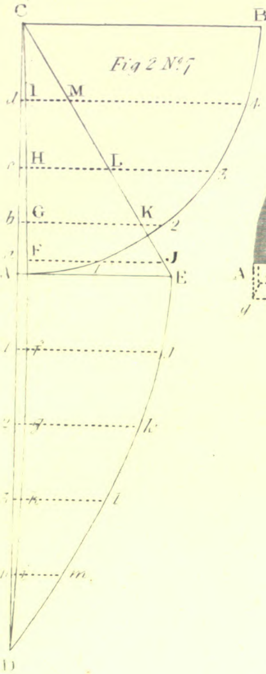
To find the solidity of a square dome, the axal sections through the middle of the sides being semi-circles.

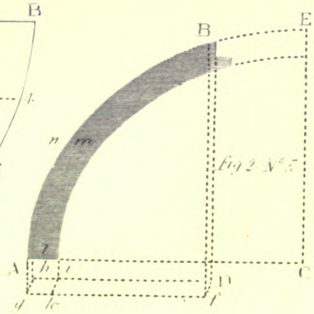
Let the radius of the circle be represented by r; suppose then, in the vertical section, that we draw any line parallel to the base, for the section of the generating plane, which is equal to the side of the generating square. Suppose the axis to be drawn upon the section, and the part of the axis from the summit to the generating line, to be denoted by x and y, to denote the half generating line, we shall then have, by the property of the circle, $y = (2\,r\,x - x^2)\,\frac{1}{2}$, and consequently $2\,y = 2\,(2\,r\,x - x^2)\,\frac{1}{2}$ the whole length of the side of the generating square.

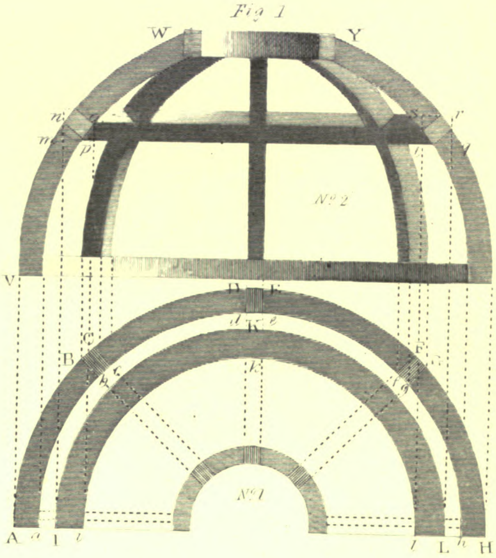
Therefore, $4\,y^2 = 4\,(2\,r\,x - x^2)$

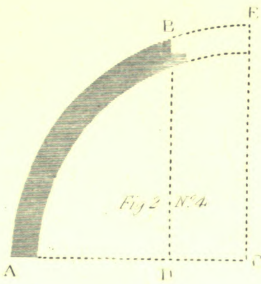
and $4\,y^2\,\dot{x} = 4\,\dot{x}\,(2\,r\,\dot{x} - x^2)$ the fluxion of the solid. The fluent of $4\,y^2\,\dot{x} = 4\,r\,x^2 - \frac{4\,x^3}{3}$ for the solidity of the segment of the dome. Now, therefore, if the solidity of the whole dome be required, it is only supposing x to become equal to r; we then find $4\,r\,x^2 - \frac{4\,x^3}{3} = 4\,r^3 - \frac{4\,r^3}{3} = \frac{8\,r^3}{3}$. Suppose $d =$ the diameter, equal to $2\,r$, and $a = r$, the altitude, then will $\frac{8\,r^3}{3} = \frac{2\,d^2 a}{3}$, that is, the solidity of the dome is equal to two-thirds of the circumscribing rectangular prism. If in the above dome all the horizontal sections had been circles instead of squares, the dome would have been spherical; let us suppose that $p = .7854$, the area of a circle, the diameter of which is unity, then in the case of the segment of the sphere we have $p\left(4\,r\,x^2 - \frac{4\,x^3}{3}\right)$ for the solidity of the dome when less than a hemisphere; or, putting $2\,r = d$, and a equal to the altitude of the segment, then $\left(4\,r\,x^2 - \frac{4\,x^3}{3}\right) = p\left(2\,d\,a^2 - \frac{4\,x^3}{3}\right)$ and the hemispheric solidity is $p\,\frac{2\,d^2\,a}{3}$. The same form of expression may be shown for all polygonal domes whatever: it is only using a proper multiplier for p, when the radius of its circumscribing circle is unity.

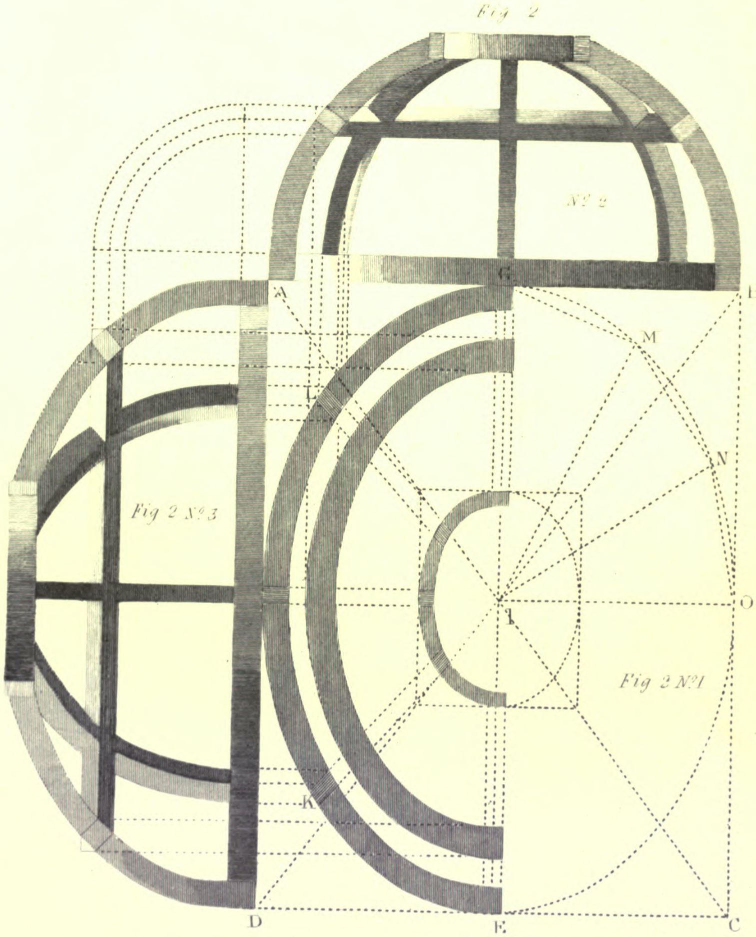
Suppose it were required to find the solidity of a trun-

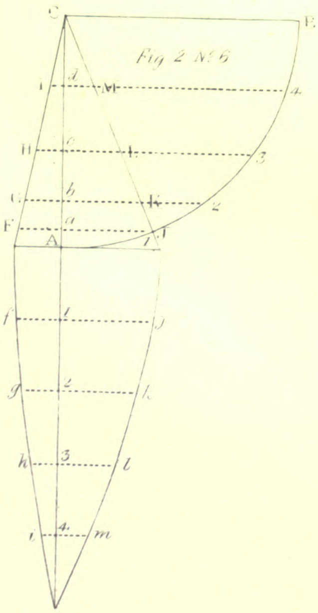












Invented & drawn by P. Nicholson

Engd by R. T

cated hemispheric dome, let $x =$ the altitude of the dome, as before, then, by the nature of the circle, we have
$y^2 = r^2 - x^2$ equal to one quarter of the generating square.
$4\,y^2 = 4\,r^2 - 4\,x^2$ for the generating square.
$4\,y^2\,x = 4\,r^2\,x - 4\,x^2\,x$ the fluxion of the solid.

The fluent of $4\,y^2\,x = 4\,r^2 x - \frac{4\,x^3}{3}$: now let $d =$ the diameter equal $2\,r$, and a equal the altitude of the dome, then $4\,r^2\,x - \frac{4\,x^3}{3} = d^2\,a\,\frac{4\,a^3}{3}$ equal to the solidity of the square truncated dome, and $p\left(d^2\,a - \frac{4\,a^3}{3}\right)$ equal the solidity of the circular dome. Let us suppose the same expression to be applied to a hemispheric dome,

then $p\left(d^2\,a - \frac{4\,a^3}{3}\right) = p\left(d^2\,r = \frac{4\,r^3}{3}\right)$

$= p\left(d^2\,r - \frac{d^2\,r}{3}\right) = p\,\frac{2\,d^2\,r}{3} = p\,\frac{2\,d^2\,a}{3}$, the same formula as above.

Practical application of the preceding rules.

To find the solidity of a dome less than a hemisphere, upon a square plan, when its axal sections, parallel to the sides, are circles.

From twice the diameter of the vertical section multiplied into the square of the altitude, subtract the third part of four times the cube of the altitude, and the remainder is the solidity of the square segmental dome.

Example.—Suppose the altitude of the dome to be 4 feet, and the diameter of the vertical section 20 feet, the solidity of the dome is required.

20	4
2	4
40 twice the diameter of the vertical section.	16 square of the altitude.
16	4
640	4
$85\frac{1}{3}$	16
$554\frac{2}{3}$ solidity required of the square dome.	4
	64
	4
	3)256
	$85\frac{1}{3}$

Suppose now a circular dome of the same dimensions: Then

.7854
$554\frac{2}{3}$
31416
39270
39270
435.1116
2618
2618
435.6352 feet, the solidity required.

To find the solidity of a truncated square dome, the axal section being that part of a semi-circle left by cutting off a segment parallel to the diameter.

From the square of the side of the base, multiplied into the altitude of the dome, subtract the third part of four times the cube of the altitude, and the remainder is the solidity required.

Example.—Suppose the side of the base 20 feet, and the altitude 6 feet, what is the solidity?

20	6
20	6
400	36
6	6
2400	216
288	4
2112 solidity of the dome required.	3)864
	288

But if the horizontal sections had been circles instead of squares, we should then have the solidity of the circular dome as follows:

2112
.7854
8448
10560
16896
14784
1658.7648 the solidity of the dome when the horizontal sections are circular.

It may here be remarked, that the segment and truncated domes make together a complete square dome, each side of the base being 20 feet, and the altitude 10 feet.

Now the solidity of the segment dome is $554\frac{2}{3}$ feet.
and that of the truncated dome . . . 2112
Therefore the whole square dome whose vertical section is a semi-circle, is . . $2666\frac{2}{3}$

Now, the rule for measuring a square dome with semi-circular vertical sections parallel to the sides of the base, is to take two-thirds of the area of the base, multiplied into the height:

20
20
400 area of the base
10
3)4000
$1333\frac{1}{3}$
$1333\frac{1}{3}$
$2666\frac{2}{3}$ the solidity, as before.

But as it may be objected by many, that, when a square or circular dome, whose vertical section is the segment of a circle, is required to find its solidity, it is difficult to find the diameter of the vertical section, and that it would be more eligible to find the solidity from the side or diameter of its base, and the altitude of the section: in order to save the trouble of finding the diameter, we shall here show the investigation of another rule, independent of any foreign or adventitious dimension.

Let s equal the side of the square base,

then $\frac{s}{2}$ is equal to half the side of the base;

and if d be the diameter of the section, and a its altitude, then, by the property of the circle,

$$\frac{s^2}{4} = a\,(d - a) = d\,a - a^2$$

$$\text{therefore, } d\,a = \frac{s^2}{4} + a^2$$

$$\text{consequently, } d = \frac{s^2}{4a} + a$$

$$\text{and } 2\,d = \frac{s^2}{2a} + 2\,a$$

Therefore, by substituting $\frac{s^2}{2a} + 2\,a$ for $2\,d$ in the formula $2\,d\,a^2 - \frac{4a^3}{3}$, we obtain $\frac{as^2}{2} + \frac{2a^3}{3}$ for the solidity of the segmental dome, independent of the diameter of the section.

This rule may be expressed thus:

To half the area of the square base, multiplied into the altitude, add two-thirds of the cube of the altitude, and the sum will be the solidity of the dome.

Let us take the same example as at first, and we shall find the side of the square of the base to be 16 feet: therefore,

16	4
16	4
96	16
16	4
256 square of the base.	64 cube of the altitude.
4 altitude.	2
2)1024	3)128
512	$42\frac{2}{3}$
$42\frac{2}{3}$	
$554\frac{2}{3}$ cubic feet, as before, in the segmental dome.	

The solidity of any dome whatever may be found by the following general rule:

To the areas of the two ends, add four times the area in the middle; then, one-sixth of the sum multiplied by the altitude, gives the solid contents. This rule applies to all domes whose vertical section is contained between any two opposite arcs of the same circle, and two parallel lines, and will even apply to those domes which are the segment of a sphere. In the seccond example, the side of the square of the base being 20, and of the top 16, the middle area will be found to be 364.

20	16	364
20	16	4
400 area of base.	96	1456
	16	256
		400
	256 area of top.	
		2112 solidity.

Because multiplying and dividing by 6, gives the same number.

To find the solidity of a hollow square truncated dome, the shell being of equal thickness, supposing each edge of the base equal to the diameter of the circle of which the section is a part.

We found before, supposing $d =$ the side of the square base, and a equal the altitude, that the solidity of the solid dome was expressed by $d^2\,a - \frac{4a^3}{3}$, then to find the solidity of the shell, it is only finding the solidity of two solid domes, of the same altitude, but of different dimensions at the base, and deducting the greater from the less.

Now let D be the side of the base to the external surface, and d the side of the base corresponding to the internal surface; then the solidity of the solid comprehended within the external surface, and the two parallel planes forming the end, is $\quad D^2\,a - \frac{4a^3}{3}$:

In like manner, the solidity of the solid which would fill the cavity, is $\quad d^2\,a - \frac{4a^3}{3}$;

then, by subtracting the latter of these expressions from the former, we obtain $\quad D^2\,a - d^2\,a = a\,(D^2 - d^2)$

for the solidity of the shell.

This rule may be thus expressed in words:

Multiply the difference of the areas of the bases by the altitude of the dome, and the product will give the solidity of the shell.

Example.—Suppose the side of the base, between the external convex surface, to be 20 feet, and the side of the base of the internal cavity, or bason, to be 18 feet, the solidity of the shell is required.

18	20
18	20
144	400 area of the base contained between the convex surface.
18	324 area of the base contained between the concave surface.
324	76 difference of the areas of the bases.
	6
	456 solidity of the shell, as required.

To find the convex surface of a dome.

Let the diameter B G $= d$

B A $= x$

and C A $= y$

B C $= z$

we have, by similar triangles,

A O C and C E D, C A : C O : : C E : C D

that is, $y : \frac{d}{2} : : \dot{x} : \dot{z} = \frac{d\dot{x}}{2y}$:

but since the fluxion of the surface whose sections are circular is denoted by $2\,p\,y\,\dot{z}$, where p is equal to 3.1416;

therefore, we have $2\,p\,y\,\dot{z} = p\,d\,\dot{x}$

and the fluent of $2\,p\,y\,z = p\,d\,x$: therefore, the superficies of the segment of a hemispheric dome is equal to the convex surface of a cylinder of the same altitude, and of a diameter equal to the diameter of a great circle of the sphere; now, when the segment becomes a hemisphere, then $p\,d\,x = \frac{pd^2}{2}$, but since $p = 4 \times .7854$, we shall have $\frac{pd^2}{2} = 2 \times .7854d^2$; that is, the convex area of the hemispheric dome is double the area of its base; and since the area of any segmental dome is the same as that of a cylinder of the same altitude, and of a diameter equal to that of its great circle; it follows also, that the convex surface of any truncated dome is equal to the surface of a cylinder of the same altitude, and of a diameter equal to the great circle of the sphere.

To find the convex surface of the segment of a dome, independent of the diameter of the great circle.

Let D = the diameter of the great circle,
a = the altitude of the dome,
d = the diameter of the base of the dome;

then, by the property of the circle, $\text{D}\,a - a^2 = \frac{d^2}{4}$,

therefore $\text{D} = a + \frac{d^2}{4a}$,

But $p\,\text{D}\,a$ is equal to the convex surface; therefore

$p\,\text{D}\,a = p\,a^2 + \frac{pd^2}{4} =$ the area of the convex surface $= p\left(a^2 + \frac{d^2}{4}\right)$. Therefore,

To find the area of the segment of a dome:

Multiply the sum of the square of the altitude and the fourth part of the square of the diameter of the base, by 3.1416, and the product will be the superficies of the dome.

Example.—What is the superficies of the segment of a dome, the diameter of the base being 17.25 feet, and the height 4.5 feet?

```
       17.25                       4.5
       17.25                       4.5
       -----                       ---
        8625                       225
       3450                       180
      12075                       -----
      1725                        20.25
      ---------
   4 )297.5625
      ---------                             [base's diameter.
       74.3906 the fourth part of the square of the
       20.25   square of the altitude.
      ---------
       94.6406 the sum.
        3.1416
      ---------
       5678436
       946406
     3785624
     946406
   2839218
   ------------
   297.32290896 feet, the surface required.
```

To show that the superficies of any portion of a sphere, contained between any two parallel planes, is equal to the product of a circumference of a great circle into the distance of the parallel planes; that is, equal to the surface of a cylinder, the base of which is equal to the great circle of the sphere, and the altitude equal to the distance of the parallel planes:

Let A equal the altitude of the segment of the sphere, including both the altitude of the segment wanting, and the distance of the parallel planes; also, let a equal the altitude of the segment wanting; and let c be the circumference of the great circle.

Then, whether the segment include the part contained between the parallel planes, or be the segment cut off, the area of the curved surface will still be expressed by the product under the circumference of the great circle and the height of the segment; therefore, $c\,\text{A}$ is equal to the superficies of the segment, including that of the solid contained between the two parallel planes; also, $c\,a$ is the superficies of the segment cut off; but the difference between the areas of the curved surfaces of these two segments is equal to the curved surface of the solid contained between the two parallel planes; therefore, $c\,\text{A} - c\,a = c(\text{A} - a)$ is the surface of the sphere contained between the parallel planes.

It would, however, be very desirable to have another substitute in terms of the upper and lower diameter of the solid, in place of the diameter of a great circle; for this purpose, we shall here give the following rules:

Given any two parallel chords in a circle, and their distance, to find the distance of the greater chord from the centre.

To the square of the distance between the chords add the square of half the lesser chord. The difference between this sum and the square of half the greater chord, divided by twice the distance of the chords, gives the distance from the greater chord to the centre.

Example.—Suppose the greater chord, C D, is 48 feet, and the lesser, A B, 30 feet, and their distance, E O, 13 feet; what is the distance, E F, from the centre to the greater chord, C D?

```
 13     30 = 15                48 = 24
 13     --   15                --   24
 --      2   --                 2   --
 39          75                     96
13           15                    48
---          --        [chord.     --            [chord.
169          225 square of the less  576 square of greater
             169 square of distance. 394
             ---
             394               26) 182 (7 dist. required.
                                   182
```

Given the chord of a circle, and its distance from the centre, to find the radius of the circle.

To the square of the half chord, add the square of the distance from the centre, and the square root of the sum will be the radius required.

Example.—Given the chord C D, 48 feet, and its distance E F from the centre, 7 feet, the radius of the circle is required.

```
   48 = 24          7 × 7 = 49
   --   24
    2   --
        96
       48
       ---
       576
        49
       ---
       625 (25 the radius required.
       4
       ---
   45) 225
       225
```

Suppose, then, that we would wish to obtain the area o. the curved surface of a dome, contained between two parallel planes, the greater of which is 30 feet diameter, and the lesser 20 feet diameter, and the distance between them being 5 feet.

```
 10 × 10 = 100        15 × 15 = 225
  5 ×  5 =  25                  125
          ---                   ---
          125           1,0) 10,0 the difference.
                              10. feet,
```

the distance of the greater chord from the centre.

$(15)^2 = 225$
$(10)^2 = 100$

$325\ (\ 18.02$ the radius of the circle.
1

$28\ )\ 225$
224

$3602\ )\ ..\ 10000$
7204

$.2796$

Say then, that the diameter is 36 feet, omitting the very small fractional part .02.

Then $36 \times 3.1416 = 113.976$ the circumference of a great circle.

Therefore $113.976 \times 5 = 569.880$ feet, the superficial content of the dome.

Figure 2.—In order to show the truth of the above rule, for finding the above diameter of a circle, from the two chords, and the distance between them being given;

Let $y =$ F I, the height of the lesser segment;
$h =$ F B, the distance between the chords;
$x =$ B D, the distance from the nearest chord A G, to the centre I;
$C =$ A B, half the greater chord A G;
$c =$ E F, half the lesser chord;

Then, by the property of the circle, we have

$$\text{F I} \times \text{F K} = \overline{\text{E F}}^2 = c^2$$

and $\text{B I} \times \text{B K} = \overline{\text{B A}}^2 = C^2$
But $\text{F I} = y$
and $\text{F K} = y + 2x + 2h$
also $\text{B I} = y + h$
and $\text{B K} = y + h + 2x.$

Therefore $y \times (y + 2x + 2h) = c^2$ first equation;
$(y + h) \times (y + h + 2x) = C^2$ the second equation;
$y^2 + 2xy + 2hy = c^2$, the first actually multiplied;
$y^2 + hy + 2xy + hy + h^2 + 2hx = C^2$, the second multiplied.

Then by putting n in the place of $x + h$ in each of these equations,
the first becomes $y^2 + 2ny = c^2$
and the second $y^2 + 2ny + 2hx = C^2 - h^2$

$y^2 + 2ny + n^2 = c^2 + n^2$ by completing the square of the first. Therefore
first value of $y = (c^2 + n^2)\frac{1}{2} - n$

$y^2 + 2ny = C^2 - h^2 - 2hx$ second transposed;
therefore $y^2 + 2ny + n^2 = C^2 - h^2 - 2hx + n^2$
$y + n = (C^2 - h^2 - 2hx + n^2)\frac{1}{2}$; the second
value of $y = (C^2 - h^2 - 2hx + n^2)\frac{1}{2} - n.$

Then by making the first and second value of y equal to each other, and by taking away the negative quantity $-n$, which is common to both sides, and squaring the equation, we obtain

$$c^2 + n^2 = C^2 - h^2 - 2hx + n^2$$
or $c^2 = C^2 - h^2 - 2hx$
or $2hx = C^2 - c^2 - h^2$

and consequently $x = \dfrac{C^2 - c^2 - h^2}{2h} = \dfrac{C^2 - (h^2 + c^2)}{2h}$
which expression agrees with the rule.

The second rule for finding the radius of the circle, is only to find the hypothenuse of a right-angled triangle: the two sides containing the right angle being given, the square of the hypothenuse is equal to the sum of the squares of the two sides by the 47th Proposition of Euclid.

DOMESTIC ARCHITECTURE, that department of the art which relates especially to the design and erection of edifices adapted to private purposes as distinguished from those erected for public uses, more particularly of such as are employed as private dwellings. Although holding an inferior position in the scale when compared with other branches of the art, domestic architecture is of sufficient importance at the present day to merit the greatest attention of the professional man. Amongst the ancients this department held a very low position, all the energies of the architect being employed on the public buildings and temples. Such a term would scarcely have been understood amongst the Greeks and Egyptians, and but little amongst the earlier Romans, their private dwellings scarcely deserving the name of buildings. As luxury increased at Rome, the houses of private individuals increased in size and magnificence, as well as in accommodation, and the country-residences of the higher classes seem to have been buildings of some importance; Pliny's villa contained thirty-seven apartments on the ground-floor. Specimens of Roman houses exist at Herculaneum and Pompeii, as well as some few elsewhere. There is a villa at Bignor in Sussex, which contains 74 rooms, and covers an area 630 feet in length, by 335 feet in breadth.

Of English Domestic architecture, we need say little in this place; the term can scarcely be applied to any habitable buildings erected previous to the reign of Henry VII., and the buildings of this date will be dilated upon when treating of the style known, after the name of the reigning family, as the Tudor style. Up to the period in which this style prevailed, all the larger residences in England were fortified more or less. For an account of the earlier of these edifices we refer to CASTLES. *See* also HOUSE, TUDOR or ELIZABETHAN ARCHITECTURE, VILLA, ROMAN ARCHITECTURE, &c.

DOMICIL, or DOMICILE, (*domicilium*, a mansion), in general, the place of residence of an individual or family; in a more restricted sense, where a person resides only for a time.

DONJON, or DONGEON, the principal tower of a castle usually raised on a natural or artificial mound, in the innermost court or ballium. Its lower part was used as a prison, and it was frequently called the donjon-keep. Hence the modern term dungeon.

DOOKS, pieces of wood, about nine inches in length, inserted in stone or brick walls; the term is used in Scotland, and is of the same import with the London term, *plugs*, or *wood bricks*.

DOOR, (from the Saxon *dor*), the gate of a house, or the passage into an edifice, apartment, &c.

The construction of doors naturally divides itself into two branches, viz., the formation and proportion of the aperture, or opening, which, in outer walls, belong to the mason or bricklayer; and framing of the gate or leaf, by which the entrance is to be secured, together with its appurtenances, which appertains to the joiner's department.

The proportion of the aperture must always be according to the size and intention of the building, and should be attended to above every other consideration: in general the dimensions may be in the ratio of one to two, for large doors, and from three to seven in those of less size.

Entrances are of two kinds; doors and gates. The former are used only for the passage of persons on foot; the latter admit horsemen and carriages. Doors are used for churches, public edifices, dwelling-houses, and apartments: gates serve as inlets to cities, fortresses, parks, gardens, &c. Apertures of gates, being always wide, are usually arched; while the figure of doors is generally a parallelogram.

According to Vitruvius, the hypothyron, or aperture for doors, should be as follows:—"The height from the pavement to the ceiling of the temple being divided into three parts and a half, two of the whole parts were allowed for the height of the door. These two parts were subdivided into twelve smaller parts, of which five and a half were allowed as the width of the door at the base; and the upper part was contracted according to the following rules: if not more than 16 feet high, the contraction was one-third of the width of the jamb on the face; if the height was more than 16 and not more than 25 feet, a fourth part of the width of the jamb only was employed; and from beyond 25 feet, and not exceeding 30 feet, one-eighth only."—*Vitruvius*, book iv.

Public buildings, palaces, and noblemen's mansions, where a great concourse of company may be expected, should have doors of much greater dimensions than those of buildings of inferior rank; from six to twelve feet may be taken for the width of the outer entrance, and from four to six feet for those in the interior; in private houses, the latter, if they have but one leaf, should never be more than three feet and a half in breadth, nor less than that of the windows. In all cases their height should be proportioned to that of the story in which they are placed, except where they are used for laying two apartments into one; in which case they will be of a height less than double the width.

Vitruvius, as we have before observed, has prescribed rules for Attic, Ionic, and Doric doors, all of which have their apertures wider at the bottom than at the top; examples of this shape may be seen in the ruins of the temple of Minerva Polias at Athens, the temple of Vesta at Tivoli, and in other Greek and Roman remains. These doors possess the advantage of shutting themselves, to which they probably owe their invention; and they may be conveniently adopted in modern houses, as they rise in opening, and will clear a carpet, though when shut, they go close down upon the floor.

The principal entrance to a building of any magnitude should be in the centre, as productive of the greater symmetry of appearance, and as communicating more readily with the various apartments of the interior. In the principal rooms, the door should be two feet, at least, from the return of the wall, to admit of furniture being placed close up in the corner.

The lintels of exterior doors should always range with those of the windows. Apertures placed in blank arcades, are usually placed at the same height as the springing of the arch: when they have dressings, the head of the architrave, or cornice, is generally on the level of the impost.

The decorations of a door-way commonly consist either of an architrave surrounding it, with or without a cornice, or with a complete entablature: consoles are sometimes introduced, flanking the architrave jambs, and supporting the ends of the cornice. When the architrave jambs are flanked with pilasters, whether of the orders, or of some emblematical form, the projections of their bases and capitals are always less than that of the surrounding architrave, and the architrave over the capitals is similar to that over the door itself. Doors are sometimes decorated with one of the five orders, and in very considerable buildings, the entrance is adorned with a portico, so as to resemble an ancient Grecian temple.

In embellishing the piers of gates, or outer doors, it should be remembered, as a general rule, that as the pier is itself only an inferior building, it should never be richer than the front of the house. As for instance, where the front of the latter is ornamented with Doric columns, the Ionic should not be found in the piers; and it would be better to omit columns altogether, than use the Tuscan order for piers in any case. If the Ionic or Corinthian orders be used in the front of the house, the Doric or Ionic may be with propriety introduced in the piers. Niches are almost always introduced into piers, for which reason the columns do better on pedestals, because the continued moulding from their cap forms an agreeable ornament under the niche.

The wooden closures by which the apertures are opened or closed, come within the province of the joiner: these are properly the doors, and are either framed, battened, or ledged, as described in the following articles. In ordinary, and even in good houses, frequently, the doors are of deal; in noblemen's mansions, they are often of mahogany, solid or veneered, and sometimes of wainscot, especially when the building is in the antique style. Apartments reserved for the reception of money, plate, jewels, &c. are usually secured with iron doors; and in the descriptions of ancient temples, we read of doors of ivory, brass, silver, and gold.

Door, *Baize*, the inner door of an apartment, covered with baize for securing the room from the influx of the cold air.

Doors, *Batten*, though formerly much in use, are now confined to buildings in the pointed style of architecture. They consist of boards glued together, to the size of the aperture, with styles, rails, and munnions, made of battens, nailed upon them, so as to give the appearance of a framed door. This may be done, either on one or both sides; and the door is accordingly denominated single or double battened. The vertical joints should be hid by the munnions of the framing; and the latter, instead of being glued, should be bolted through to a framing behind, which will make them very strong. The large gates and doors of ancient British edifices are thus constructed. The practice of imitating the framing of Grecian and Roman doors, is not, however, to be recommended in modern times, especially if no bolts be used: for the stuff, however well seasoned, will be subject to the influence of the atmosphere, and shrink or swell, as the air is dry or damp. It is scarcely necessary to remark, that this evil will be enhanced in proportion as the wood is less seasoned.

Doors, *Framed*, which are either single, folding, double, or double margin, are employed in all descriptions of buildings, and consist of styles, rails, panels, and, in most cases, of munnions also. The framing includes all the parts but the panels, and is held together with mortices and tenons. The styles are the vertical parts of the framing at the sides. The rails are the horizontal pieces, tenoned into the styles. Munnions are parts of the framing, tenoned into the rails. The panels fill up the holes left in putting the framing together, and are let into grooves cut in the internal edges of the styles, rails, and munnions. Doors are generally framed in rectangular compartments; though other forms, as circles, ellipses, lozenges, &c. may be adopted, according to the fancy of the proprietor, or the taste of the builder. Framed doors are either square or moulded; the former are used only in common houses. Mouldings are of various forms, some confined within the framing, and others projecting beyond it. The mouldings and form of the panels of the door, generally regulate those of the window-shutters.

Folding doors, or *doors of communication*, are made in two breadths, and have a pair of styles to each leaf.

The Building Act (7 and 8 Vict. cap. 84) requires that openings through party walls be secured by wrought-iron doors.

"Such openings must not be made wider than six feet, nor higher than eight feet, unless in each case, and upon special evidence of necessity for convenience or otherwise, the official referees shall previously authorize larger openings.

"And the floor, and the jambs, and the head of every such opening, must be composed of brick or stone, or iron work throughout the whole thickness of the wall.

"And every such opening must have a strong wrought-iron door on each side of the party wall, fitted and hung to such opening without wood-work of any kind; and such doors must not be less than one-fourth of an inch thick in the panels thereof.

"And each of such doors must be distant from the other not less than the full thickness of the party wall."

Double doors are contrived to close against each other, in opposite directions, the one opening outwards, the other going inwards, in order to keep the apartment warm: the inner door being generally covered with baize.

Double margin doors, are single doors, with a broad piece running vertically down the middle, called the *staff-style*, imitating the two internal styles of folding doors when shut.

Whatever kind of door be adopted, it should, for the sake of uniformity, be used in all the apartments of the same story.

Farther particulars may be seen under ARCHITRAVE, and JOINERY.

The term *door* is sometimes applied to the gates of locks or sluices.

DOORWAY, the entrance or aperture in which the door is hung. Doorways are usually rectangular in shape, but sometimes arched. In the early styles previous to the introduction of the arch, all apertures consisted by necessity of an horizontal lintel supported by two vertical jambs, although not unfrequently the jambs inclined converging upwards. Doorways were enriched in a variety of ways, often by a platband running round the jambs and lintel, and sometimes by an entablature above the lintel. An elaborate work upon the subject has been published by Professor Donaldson.

Soon after the introduction of the arch, that form was applied to doorways, the form of the arch, whether semicircular, pointed, or otherwise, being determined by the date and style of the building. Of the first form, the Romanesque style affords us some very beautiful specimens; witness that of the Temple Church, London, which is a very fine example, and consists of a compound arch, that is to say, a series of concentric and receding arches, each arch with its pier being profusely adorned with pillars and enriched mouldings of all kinds. These doorways seem to have been admired in all ages, for frequently, when all the rest of a church has been pulled down to make room for one of a more elaborate or more fashionable style of architecture, the old Romanesque doorway has been preserved, and worked up in the new structure. For exquisite examples of doorways in the pointed styles, we have only to refer to the magnificent western entrances of the Continental cathedrals, and the smaller and less elaborate, though not less beautiful, examples in our own country.

DOORWAY-PLANE, a term sometimes applied to the space between the doorway properly so called, and the larger door archway within which it is placed. This space is frequently ornamented with sculpture, &c.

DORIC ORDER, the most ancient Grecian order of architecture, was first used in building the temple of Juno at Argos, at the period when Dorus, father of the Dorians, reigned in the Peloponnesus; though, according to Vitruvius, its symmetry and proportions were not fixed till Ion, the nephew of Dorus, and chief of the Ionians, led an Athenian colony into that part of Asia Minor which was afterwards distinguished by his name, and there built a temple, after the fashion of those in the Dorian states, the columns of which were six diameters in height, taking the proportion from the ratio that a man's foot bears to the height of his body.

The Doric is distinguished, in general appearance, from the succeeding orders, by its bold and massy proportions, as well as by its comparative want of ornamentation; all its parts are bold and prominent, its details few and imposing.

Its origin is stated by Vitruvius to have been derived from the primitive buildings of the Greeks, which were made of timber; but others derive the style from the stone structures of Egypt, and others from those of Persia and the East. It would be the more natural method to discuss this subject ere proceeding farther, but as the discussion could not be readily understood without some previous acquaintance with the details and general character of the order, it may be as well to turn our attention to these matters first of all.

This order then consists, like the others, of column and entablature, but differs from them in this, that the first mentioned division comprises only two members, the shaft and capital; the base, which is indispensable in the other orders, being omitted in this, at least in the earlier and purer examples, as practised by the Greeks. The reason of this omission has been accounted for in various ways by different writers; Vitruvius will have it, that the base was first introduced in the Ionic order to represent the sandal or covering of a woman's foot, and that in the Doric, which resembled in some way or other a strong muscular and barefooted man, this member was not appropriate. Some are of opinion that the omission was occasioned by the close proximity of the columns in this order, which would not admit of any excrescence at the base. It is true the intercolumniation is very contracted, and the addition of any base, especially of a square one with its angular corners, would render the passage between the columns extremely narrow and inconvenient; indeed, even without a base, the space was inconveniently small, and was felt to be so, as we gather from the fact that the intercolumniation of the portico opposite the entrance-door was increased in width, evidently to afford readier access to the interior; notwithstanding, we can scarcely bring ourselves to conclude that this was the reason of the absence of a base. We rather incline to believe that a base had as yet never been thought of, the idea had not yet suggested itself; in Egyptian temples, from which we believe the Doric order to have emanated, the columns were usually devoid of bases, and it is but reasonable to presume that in their earlier essays, the Greeks aimed at nothing more than a copy, and did not think either of addition or improvement.

The Doric shaft then rises immediately from the platform on which the building stands, but this platform was usually raised on a series of three or more steps or gradations, the risers of which are proportioned not to the capacity of the human step, but to the magnitude of the building. The shaft, when compared with those of the other orders, is of stunted and massy proportions, its height being only 5 or 6 times greater than its lower diameter; the upper diameter, however, is of much smaller dimensions, the column converging rapidly towards the capital, a circumstance which gives an appearance of great stability. Towards the top of the column, a narrow channel is carved out round the shaft, so as to form an annulus in recession, and this marks the division between the shaft and capital, although a portion above this is in form nothing more than a continuation of the shaft. The shaft was almost universally fluted, very few exceptions to the contrary existing; the number of the flutes is either 16 or 20, and their profile is that of a segment of a circle less than a semi-circle, being much broader and flatter or shallower than those of the succeeding orders. These flutes meet each other in a sharp arris, without the intervention of fillets, which are universal in the later orders; a slight fillet, however, is to be found in examples at Eleusis, Sermium, Rhamnus and Thoricus, but so narrow as to be insignificant. Much pains have been taken by various authors to account for the introduction and use of those flutes, but in our opinion without success; one supposes that they are imitations of the crevices in the stems of the trees out of which the timber-huts, the primitive models of the stone structures, were constructed; another, that the idea was occasioned by the rain-streak running down the shafts of the columns; and a third, that flutings were hollowed out for the purpose of resting spars in the crevices. Such hypotheses are doubtless very ingenious, although not to all minds equally convincing; for our own part, we do not see the absolute necessity there is to account for the reason and origin of every small member or ornamental detail. We require no further reason for the use of flutes, beyond the effect produced by them as a means of decoration, and as such we think their origin very easily accounted for. In the majority of Egyptian examples, from which—to prejudge the question—we suppose those of Greece to have been derived, the columns were reeded, or ornamented with projecting staves instead of recessed flutes; nor are the two methods of decoration so dissimilar and unconnected, for we have only to remove the staves to produce the flutes: and besides these methods we find another, in which the columns are what is called canted, that is to say, have their horizontal sections rectilineal polygons, the faces of the polygon or sides of the column being flat, instead of convex or concave. Thus we have three kinds of polygonal columns, the first of which seems to possess the primitive form, and the others to be merely enriched variations of the same. At Amada in Nubia, there is a very curious illustration of the progress made in the improvement and enrichment of columns, where in the same building we find one column a mere pier or simple parallelopiped, and another and adjoining one both rounded off at the corners and fluted; this last bears a remarkable resemblance to the Grecian Doric, on which account we shall have to refer to the subject again ere the close of this article. Specimens of Doric canted columns are to be found in the portico of Philip, king of Macedon, and in the temple of Cora; the flutes, however, are the most prevalent, as they are the most beautiful means of enrichment; the pleasing effect produced by them is attributable mainly to the diversity of light and shade so created, but this is not their only advantage; they likewise give a variety and lightness of appearance to the column, which would otherwise appear heavy, and at the same time, by the diminution of the breadth of the channels as viewed by the eye, add to the apparent circularity of the column. We have no specimens of reeded columns in this order. The flutes diminish in width as they reach the top of the shaft, to correspond with the diminution of the shaft; they are carried above the necking of the capital, and usually terminate immediately below the annulets, butting upon a plane surface perpendicular to the axis of the columns, or parallel to the horizon, as in the Propylæa at Athens. In other cases, as in the temples of Theseus and of Minerva at Athens, as well as in the Portico of Philip, in the island of Delos, the upper ends of the flutes terminate upon the superficies of a cone, immediately under the annulets, in a tangent to the bottom of the curve of the echinus of the capital. The same kind of termination takes place in the temple of Apollo, at Cora, in Italy; but in this example, the conic termination of the flutes is not immediately under the abacus, but at a small distance down the shaft, leaving a small portion quite a plain cylinder, and thus forming the hypotrachelium or neck of the capital. Palladio and other Italian authors have terminated the flutes of the shafts of their design of Doric columns in the segments of spheres tanged by the surfaces of the fluting. In some few instances the shaft is fluted only at the upper and lower extremities, the other part being left plain, although probably with the intention of being ornamented in a similar manner at some future time. Examples of this are to be found at Eleusis and Thoricus in Attica, at Egesta and Selinus in Sicily, at the temple of Apollo at Delos and at Rhamnus, which last forms a peculiar instance, the columns of the pronaos being fluted the whole length of the shaft in front; with eleven channels, having at the back nine plain surfaces. We have above stated the number of channels to be 16 or 20, but the latter is by far the more usual; examples of which practice are, the Parthenon, Theseum and Propylæa at Athens, with others at Corinth, Delos, Eleusis, Rhamnus, Thoricus, Bassæ, Agrigentum, and in the temple of Ceres, at Pæstum. There are but few examples with only 16 channels, of which number are those at Sunium, and the upper range of the interior columns in the temple of Neptune at Pæstum, in which last mentioned building there are specimens of columns with as many as 24 flutes. The channels were not always circular, but sometimes semi-ellipses, and at others eccentric curves. Doric antæ were never fluted.

The first object which attracts notice in passing the eye up the column, and which breaks the outline of the fluting, is what is termed the hypotrachelium, or under-necking of the capital. This consists of one or more channels cut in recession round the upper part of the shaft; in some instances, as at the temple of Minerva at Sunium, in the Agora at Athens, and in most of the examples at Agrigentum; this division is so fine as almost to escape notice, and in others is very prominent, the channels varying both in size and number. In the Parthenon, and in the Propylæa at Eleusis, and at Rhamnus, there is a single rectangular groove; at the Propylæa at Athens, a groove chamfered on the upper edge, and at the Theseum, a groove chamfered on both edges, so as to form an acute angle at the meeting of the chamfers. At Corinth there are three channels similar to those in the Propylæa at Athens, having a fillet between each two, as also at the temple of Apollo at Bassæ, but in this example the channels are of a curvilinear section. At Pæstum there are three fine channels, which, at their junction with the arrises of the flutes, are cut into the shape of diamonds, the projecting edge of the arris being chamfered off. The hypotrachelium of three channels is considered a mark of antiquity, for although they are not of necessity found in all ancient examples, yet they are never inserted in those of later date. Some writers consider those channels as the commencement of the capital, while others are inclined to think them but a continuation of the shaft. In the other orders the corresponding member is certainly the division between the two parts, all above being giving to the capital, and all below to the shaft; the difficulty in this case arising from the fact of the continuation of the flutes above this point, the space between the hypotrachelium and annulets being precisely similar to the lower portion of the shaft, yet at the same time it is difficult to assign any other reason for the introduction of the grooves, except they serve to mark the division between the two members of the column. Without the intervention of such a mark as this the capital would have appeared stunted and heavy, but, as it is, the shadow produced by the sinking, marks to the eye a distinct division, and, in appearance at least, increases, at the same time, the length and comparative lightness of the capital.

Above the hypotrachelium, the shaft, with its fluting, is continued for a short distance, and meets the annulets of the capital in a curve or *apothesis;* this portion forming, according to our notion, the necking of the capital. The annulets come next, and form the lower portion of what may be termed the capital-proper, about which there exists no difference of opinion. The following particulars of the number and form of annulets in different examples are furnished by a contributor to "The Builder," to whose valuable writings, on this subject, we shall have occasion to advert more than once in this article:—

"The annulets, in Grecian Doric columns, vary as well in their profile as in their number. Some examples may be interesting, to show the exhaustless genius of the Greeks, even in details the most minute, and that although the general principles of art in the Doric order are the same, yet that they could produce great variety in their details. In the Parthenon, that best and purest of all examples, we find, under the echinus of the capitals in the porticos, five rings, placed on a slope, continued, as it were, from the lower link of the echinus, and in the columns of the pronaos of the same edifice, there are but three rings. In the temple of Theseus, the profile of the annulets is somewhat similar to that of the Parthenon; the rings are four in number, and the under side of the lower arris of each ring is slightly undercut. In the example from the portico at Athens, presumed to belong to the Agora, or market-place, we see how widely the artist departed from the graceful and flowing outline of earlier patterns; this, of the age of Augustus, is one of the latest known examples of Grecian-Doric, yet in many points it cannot be safely recommended for modern imitation. In the temple of Apollo Epicurius, at Bassæ, a building of the pure age of Greek art, the annulets are four in number, resembling in their contour those in the Parthenon, excepting that the second and third rings recede a little from a line drawn from the first to the fourth. At Rhamnus, where are two temples, at Sunium, and in the Dodecastyle portico of Ceres at Eleusis the rings are three in number, profiled like the best examples at Athens; at Egesta and Selinus, they are three in number; at the temple of Jupiter Olympus, at Agrigentum, of Apollo in the isle of Delos, and in the portico of Philip at the same place, at Corinth (where the annulets have a great projection, and are very deeply undercut), in the Hypæthral temple at Pæstum, in the temple of Diana, in the Propylæa at Eleusis, in the Propylæa at Athens (an excellent example) and at Thoricus, the rings are four in number. At the latter place the annulets are remarkable, and probably singular in their way. In the capital from the Pseudodipteral temple at Pæstum, in which many peculiarities are observable; the immense size and projection of the abacus seem to crush the echinus, which has beneath it two rings, under which the flutings curl in the form of leaves. At Selinus, Mr. Woods noticed some remarkable features in the capitals:—'The shape of these capitals is very peculiar; I have seen nothing like them in Greece, except a fragment on a very small scale which I noticed at Corfu. The common Grecian-Doric capitals in the best examples form a sort of ogee, and we find this curve at the third temple, but in the great temple, and in two of the three smaller ones, a deep hollow interrupts the flow of the lines.' These capitals were each cut out of a block of stone thirteen feet square."

The next member of the capital is the echinus, which is similar to an ovolo, or quarter-round moulding, and which, spreading out from above the annulets, serves to support the overhanging abacus. In the best examples it is usually very flat in profile, being little more than a frustum of an inverted cone, having its base rounded off at its edge, and quirked, as it were, where it meets the abacus. Its use seems to have originated from an imitation of the cushion-capitals of the Egyptians, the lower portion only being reserved in Grecian buildings. The diameter of the top of the echinus is equal to, or somewhat greater than, the lower diameter of the column. We refer again to the writer above alluded to.

"In those buildings which belong to the best age of Grecian art—the days of Pericles, and his chief architects, Callicrates and Ictinus—as seen at Athens, Bassæ, Sunium, Thoricus, Eleusis, Rhamnus, and elsewhere, we shall find that the echinus has its lower part either very slightly curved or else perfectly straight; whilst, in buildings of later date, and of equivocal taste, we find that the moulding nearly resembles an elongated or ovate quarter-round, as in the Agora at Athens, and in a building at Cadachio. Professor Donaldson has drawn notice to the general principle which "directed the Greeks in composition of their Doric capitals. From the necking to the abacus, the outline is that of a cyma-reversa, having a projection that varied according to the era, or style of art peculiar to the country; the existing Attic examples being but slightly projecting, while the immense abacus of the orders now remaining at Corinth, Pæstum, and in Sicily, gives a bolder profile to the capital." Some idea may be formed of the vast proportions of the temple of Jupiter, at Agrigentum, when we find that the echinus of each column is formed of two stones, each weighing $21\frac{1}{2}$ tons, held together by plugs or dowels by the centre stone of the abacus, which is in three pieces. In the capitals of the antæ of Greek examples the echinus is generally undercut, so as to form that remarkable moulding called the hawk's-beak, or bird's-beak moulding. The proportionate depth of the abacus and echinus to each other, is not always the same; but, as a general rule, it may be held, that the former member should have the greatest depth. In the Parthenon, the relation, in this respect, is as 11 to 9; at Sunium and at Bassæ, as 7 to 6; at Thoricus, as 6 to 5; at Eleusis, as 12 to 9. In the best examples with which we are acquainted—as, for instance, in the Parthenon and Theseum—the echinus has nearly the same projection as the abacus (it is actually the same in the temple of Apollo Epicurius, at Bassæ); and we shall find, that the sharper is its outline—that is, the more it is remote from the quarter-round—the more it is held in estimation; and that, as it approaches the ovolo in form, so it may be traced to belong to a declining period, or one nearer to the time of the Roman use of the Doric order. If we grant for a moment, that timber construction afforded the first hints for architectural composition, and that the origin of the abacus may be traced to the intervention of a cube of wood between the column and its entablature; where will the advocates of this system find the prototype of the echinus? To the Greeks we must look for adoption of this beautiful moulding, which connects, in such a happy manner, the square abacus with the circular shaft; and truly may it be said to be their own invention, even if we are compelled to admit, that some slight hint for it is to be found among the heavy capitals of Egypt. Professor Hosking has well observed: "Greek architecture is distinguished for nothing more than for the grace and beauty of its mouldings; and it may be remarked of them generally, that they are eccentric, and not regular curves. They must be drawn, for they cannot be described, or struck; so that, though they may be called circular, or elliptical, it is seldom that they are really so; not but that they may be; but if they are, it is considerably the result of chance, not of design. Hence, all attempts to give rules for striking mouldings are worse than useless, for they are injurious; the hand alone, directed by good taste, can adapt them to their purpose, and give them the spirit and feeling which render them effective and pleasing."

The abacus at the top of the capital is of the simplest description, being merely a square slab of stone, of considerable thickness, harmonizing well with the massy appearance of the entire column. It projects considerably beyond the upper part of the shaft, and sometimes even beyond the lower diameter, and always advances in front of the general surface of the epistylium. Where the abacus overhangs beyond the foot of the column, it is considered as an indication of the antiquity of the building; examples of which occur at Corinth, Pæstum, Egesta, and elsewhere. This completes the description of the column.

It may be well to mention in passing, that Doric antæ differ from columns, in maintaining the same width from top to bottom, which equals the average diameter of the column. They have a simple moulding and groove at their base; the capital likewise is very simple, and the abacus and other mouldings are much narrower than in the capital of the column. Antæ are never fluted.

The Doric entablature consists as usual of three members, architrave, frieze, and cornice, the first or lowermost of which, otherwise termed the *epistylium*, is simply a plain fascia surmounted by a broad fillet termed the *tænia*, which forms the separation between it and the frieze, and to which another fillet, with small cylindrical guttæ depending from it, is attached in separate portions beneath each triglyph of the frieze. The epistylium recedes from the face of the abacus, projecting beyond the upper diameter of the shaft, but falling short of the extremity of the lower diameter, so as only partially to overhang the column. A line dropped vertically from the face of the architrave would cut the abacus, pass without the upper portion of the shaft, but fall within it ere it reached the base. The average height of this member, inclusive of the tænia, is equal to the upper diameter of the column.

Above the architrave is the frieze, which forms the most characteristic feature in the whole entablature, although of no greater dimensions than the epistylium. The height of the two members is nearly equal, with but slight variations in any example, the frieze being seldom, if ever, the deeper, more frequently the shallower of the two. The peculiar ornamentation of this portion of the entablature gives it its specific character; being divided into a series of projecting and recessed panels. The distinguishing feature is the *triglyph*, which is a slightly projecting tablet, somewhat wider than the semi-diameter of the base of the column, and channelled vertically with three grooves, or γλυφες, whence the name triglyph. These channels are so disposed, that there shall be a space in the centre of the projecting slab, with a channel on each side of it, and beyond these again, on either side, another equal space, with a half-groove outside, on the edge of the slab, which indeed is nothing more than a chamfered edge. The two channels, and the two halves on the extremities together make up the three grooves, or *glyphs*.

Beneath each triglyph, and attached to a fillet, are a series of guttæ or drops, immediately under the tænia of the architrave. This decoration we have alluded to in describing the epistylium, but although it is attached to that member, it belongs, strictly speaking, to the triglyph, of which it is a continuation; its position, however, in this place, serves a very useful purpose, for it both gives a variety to the otherwise monotonous surface of the architrave, and, at the same time, presents to the eye a sort of connection between this portion of the entablature and the frieze above it. The guttæ are six in number, of a conical form, and are said to represent drops of rain that have trickled down the channels of the triglyph, and settled beneath the tænia; others again suppose them to represent the heads of nails, or screws, used in the wooden structure. The channels of the triglyph are of a triangular section, and are not continued the entire height of the block, although at the bottom they butt against the tænia. Each triglyph is surmounted by a capital, or slightly-projecting band, which, in the Greek examples is of very slight projection, and is not returned at the sides, except in the case of triglyphs at the angles of the building. The position of these ornaments is such, that there shall be one over the centre of each column, and one midway between every pair of columns; but there is an exception to this disposition at the angles of buildings, where the triglyph is not placed over the centre of the column, but is brought up quite to the edge or outer angle of the frieze, so that a line dropped perpendicularly from the outer edge of the corner triglyph, would touch the base of the column. This disposition gives occasion for an alteration of the intercolumniation between the two end columns, these being brought closer together by the space of half a triglyph; an advantage is obtained by this means, inasmuch as an appearance of greater strength is given to the extremities of the colonnade.

The spaces between the triglyphs are called *metopes*, and are usually filled up with sculptures in bas-relief, from which circumstance the frieze was called by the Greeks *zoophorus*, because it contained representations of living figures, men or animals. These metopes are usually of a square form, their breadth being equal to the height of the frieze, but there is a slight variation in different examples. In the Doric portico at Athens, the breadth of the metope is 3′,, 3″ and 3′,, 3″.6, while the height is 3′,, 0″. 7, including the band or capital over it; or without the band, 2′,, 9″ . 05; in the temple of Minerva at Athens, the height of the metope, without the band, is 3′,, 11″ . 15, and its breadth 4′,, 3″ . 35: in the Propylæa, the breadth is 3′,, 8″ .25, and the height 3′,, 9″ . 85, including the band and the bend over it; and in the Theseum, the breadth is 2′,, 6″ .475, and the height 2′,, 5″, without the band. Each metope is surmounted with a band, or capital, similar to that of the triglyph, though not of equal width or projection.

The entablature belonging to the monument of Thrasyllus is an exception to the general rule, the frieze being without the characteristic addition of triglyphs, their place being filled up with wreaths; the guttæ, however, are retained, but instead of being disposed at intervals, they are continued uninterruptedly beneath the fillet.

The Doric cornice consists of few but bold parts, the most characteristic of which are the mutules. These are a series of shallow plates attached to the soffit of the corona, sloping forward, so that the bottom of the mutule in front is considerably lower than at the back, and having their soffits studded with cylindrical or conical guttæ; these guttæ were eighteen in number, and placed in three rows of six each. A mutule was placed over each triglyph, and an intermediate one over each mutule; their width being equal to that of the triglyphs. Under the mutules was generally a plain band, but sometimes an ogee is found in this place. The corona is a boldly-projecting flat moulding, of somewhat greater depth than the abacus of the capital, and is generally finished off above with a small ovolo and fillet supporting the cymatium, which consists of two similar mouldings, but of more imposing dimensions. In raking cornices the mutules are omitted, but a new moulding, termed the *epitithedas*, is added as a finish, which is either an ovolo or cymatium.

When used, the epitithedas was continued a little way at the angles, and terminated against a carved block. The pediment in this order is of a low pitch, and always about the same height, whatever the span may be; upon an average the height equals that of the entablature, more or less, but is scarcely ever so great as to make the tympanum higher than the entablature.

Having completed this general description of the order, it may be as well to say a few words about the proportions observed in the different parts.

The height of the column varies from four times the lower diameter, as in the earliest existing example at Corinth, to $6\frac{1}{2}$ times, as at the portico of Philip, but in the purest examples the height is about $5\frac{1}{2}$ times the lower diameter, the upper diameter being $\frac{1}{6}$ less than the lower. The entablature varies from $1\frac{3}{4}$ to 2 diameters in height, of which $\frac{2}{5}$ go to the epistylium, $\frac{2}{5}$ to the frieze, and the remainder to the cornice.

To afford more detailed information, we give the following proportions from the temple at Sunium, and the accompanying table, as prepared by Mr. Brown.

"The proportions of the temple at Sunium are thus ordered: make the column 6 diameters high, and the entablature $\frac{3}{10}$ of the column, or divide the whole height into 13 parts, of which give 10 to the column, and 3 to the entablature. The upper diameter of the column is $\frac{3}{4}$ of the lower. The capital $\frac{1}{2}$ a diameter, which, being divided into 5 parts, 2 are to be given to the abacus, 2 to the ovolo and annulets, and 1 to the necking. The length of the abacus $1\frac{1}{8}$ diameter. The entablature is to be divided into 8 parts, giving 3 to the architrave, 3 to the frieze, and 2 to the cornice. In dividing the cornice, take $\frac{3}{7}$ for the cymatium, fillet, and moulding, $\frac{3}{7}$ for the corona alone, and leave $\frac{1}{7}$ for that part of the fascia which appears below a horizontal line drawn from the lower front edge of the corona. The whole projection of the cornice is 1 diameter, reckoning from the centre of the column. The capital of the triglyph to be $\frac{1}{9}$ of the whole height of the frieze. The capital or fillet of the architrave to be $\frac{1}{2}$ of the height of the architrave. The architrave to overhang the upper part of the shaft by $\frac{1}{2}$ the difference between that and the lower diameter. In distributing the triglyphs, take $1\frac{1}{4}$ diameter, or 75 minutes for the width of the triglyph and metope, and of this give $\frac{3}{8}$ to the former, and $\frac{5}{8}$ to the latter, or nearly 28 and 47 minutes. Thus a monotriglyph intercolumniation will be 75+75—60=90 minutes, or $1\frac{1}{2}$ diameter."

A Table of the Proportions of some of the Grecian Doric Orders, according to the Module of Sixty Parts, formed at the bottom of the Shaft of the Column.

	Lower Diameter.	Upper Diameter.	Height of Column.		Architrave.	Frieze.	Cornice.	Intercolumniation.		Pedestal.
	Minutes.	Minutes.	Diam.	Min.	Min.	Min.	Min.	Diam.	Min.	Rise.
Propylæa, or Entrance into the Citadel of Athens	60	—	—		—	—	—	—		—
Portico of the Agora, at Athens	60	47	6	$2\frac{1}{2}$	40	42	21	1	$2\frac{1}{2}$	1 7
Temple of Minerva, or Parthenon at Athens	60	47	5	$33\frac{1}{2}$	43	43	32	1	$17\frac{3}{4}$	1 91 4
Temple at Corinth	60	$44\frac{3}{8}$	4	4	$48\frac{5}{8}$	—	—	1	14	—
Temple of Theseus at Athens	60	$46\frac{3}{8}$	5	$42\frac{1}{8}$	50	$49\frac{1}{2}$	—	1	$37\frac{1}{2}$	1 81 2
Temple of Minerva at Sunium	60	$45\frac{3}{4}$	5	54	$48\frac{1}{2}$	$48\frac{1}{2}$	—	1	28	—
Temple of Jupiter Nemeus, near Argos	60	49	6	31	$38\frac{5}{8}$	$43\frac{1}{2}$	—	—		—
Temple of Jupiter Panhellenius at Argive	60	$44\frac{1}{2}$	5	24	$51\frac{1}{8}$	$51\frac{1}{2}$	—	1	41	—
Portico of Philip, King of Macedon, at Delos	60	$49\frac{1}{2}$	6	$32\frac{1}{2}$	$38\frac{1}{2}$	$43\frac{3}{4}$	$25\frac{1}{2}$	2	$42\frac{3}{8}$	—
Temple of Apollo at Delos (plain shaft)	60	$42\frac{1}{2}$	6	$3\frac{3}{4}$	$49\frac{3}{8}$	$42\frac{1}{2}$	—	—		—
Temple of Minerva at Syracuse	60	46	4	$24\frac{1}{2}$	$44\frac{1}{2}$	40	—	1	$5\frac{3}{8}$	—
Temple of Juno Lucina at Agrigentum	60	$45\frac{1}{8}$	4	42	55	45	—	1	15	—
Temple of Concord at Agrigentum	60	46	4	$48\frac{1}{4}$	$46\frac{4}{5}$	$46\frac{1}{8}$	25	1	$10\frac{3}{8}$	—
Temple of Selinus	60	46	4	$21\frac{3}{4}$	$46\frac{1}{8}$	$44\frac{3}{8}$	—	1	$2\frac{1}{8}$	—
Temple of Jupiter Selinus	60	$35\frac{1}{2}$	4	$34\frac{1}{2}$	52	$44\frac{3}{8}$	26	—		—
Pseudo-dipteral Temple at Pæstum	60	$40\frac{1}{8}$	4	27	50	—	—	$59\frac{1}{2}$	$67\frac{3}{8}$	—
Hexastyle Temple at Pæstum	60	43	4	$47\frac{3}{4}$	$45\frac{3}{4}$	$44\frac{3}{4}$	$24\frac{3}{4}$	1	$1\frac{1}{8}$	—
Hypæthral Temple of Neptune at Pæstum	60	$41\frac{1}{4}$	4	8	$42\frac{1}{8}$	$40\frac{1}{2}$	$21\frac{1}{2}$	1	$4\frac{3}{4}$	—
Inner Peristyle of Temple of Neptune	60	43	1	$13\frac{1}{8}$	39	—	—	1	$22\frac{3}{4}$	—
Upper Columns to ditto	60	$44\frac{1}{8}$	3	50	68	—	—	2	49	—
Temple of Egesta (plain shaft)	60	$44\frac{3}{4}$	—		$49\frac{3}{4}$	$52\frac{3}{8}$	$40\frac{3}{4}$	1	11	—

In comparing the above with the table on the next page, in which the dates are given, it will be readily observable with what regularity the proportionate height of the columns increased from the earliest example at Corinth to the latest, the Agora at Athens: the last, however, forming somewhat of an exception to the rule, the height being less in this case than in the two previous examples, viz; those of the temple of Jupiter Nemæus, and of the Portico of Philip of Macedon. The diminution of the shaft will be seen to average about 15 minutes, the upper diameter ranging from $49\frac{1}{2}$ in the portico of Philip, a late example, to $35\frac{1}{2}$ in the temple at Selinus, one of the earlier buildings; thus affording additional proof of the comparative lightness of the later structures. We have to call attention likewise to the general equality in height between the architrave and frieze, noticing at the same time one or two exceptions in which there is a considerable variation, especially in that at Agrigentum; the height of the architrave of the upper colonnade in the temple of Neptune is remarkable, as is also that of the frieze and cornice at Egesta.

The following useful, though somewhat different table, is the compilation of the writer to whom we have previously alluded.

This table exhibits at one view the proportions of the columns in some of the principal buildings in Greece and its colonies, concluding with the scale which the Roman and Italian schools assigned to the Doric.

Date of Erection.	Name of Building.	Name of Architect.	Height of Column. ft. in.	Diameter. ft. in.	Number of Diameters high.	Number of Columns in Portico.	Number of Columns on the side.
About 800 B. C.	Temple at Corinth		23 8	3 10	$4\frac{2}{35}$	6	—
600 or 700 B. C.	Great Hypæthral Temple at Pæstum		28 10	7 0	$1\frac{1}{21}$	6	14
500 B. C.	Temple at Selinus		32 6	7 6	$4\frac{1}{3}$	6	12
	Octostyle at Selinus		48 7	10 7	$4\frac{3}{5}$	8	16
	Temple of Minerva at Syracuse	Probably Archias of Corinth.	28 8	6 6	$4\frac{16}{39}$	—	—
About 450 B. C.	Temple of Hercules at Agrigentum		33 0	7 0	$4\frac{5}{7}$	6	14
	Temple of Concord at ditto		22 2	4 8	$4\frac{3}{4}$	6	—
500 B. C.	Temple of Jupiter Panhellenius at Egina	Libon.	17 1	3 2	$5\frac{9}{10}$	6	—
About 461 B. C.	Temple of Theseus		18 7	3 3	$5\frac{28}{39}$	6	13
448 B. C.	Parthenon	Ictinus.	34 0	6 2	$5\frac{14}{37}$	8	17
About 430 B. C.	Temple of Apollo at Bassæ	Ictinus.	19 6	3 7	$5\frac{19}{43}$	6	15
	Temple of Minerva at Sunium	Ictinus.	19 7	3 4	$5\frac{7}{8}$	6	—
Age of Pericles.	Temple of Ceres at Eleusis	Corabus.	—	6 6	Supposed $5\frac{1}{2}$	12	—
Age of Pericles.	Temple of Diana Propylæa at Eleusis		14 10	2 7	$5\frac{3}{4}$	2 in antis.	—
	Temple at Rhamnus	Alcamenes, a pupil of Phidias.	13 4	2 4	$5\frac{1}{2}$	6	12
	Temple of Apollo, Delos		18 8	2 11	$6\frac{2}{5}$	—	—
About 338 B. C.	Portico of Philip of Macedon, Delos		18 8	2 10	$6\frac{2}{5}$	—	—
	Temple of Jupiter Nemæus		33 8	5 2	$6\frac{16}{31}$	6	—
100 B. C.	Agora, at Athens		26 2	4 4	$6\frac{1}{25}$	4	—
Time of Augustus.	Theatre of Marcellus, at Rome		21 0	3 0	7	—	—
About 80 A. D.	Coliseum		27 3	2 10	$9\frac{21}{34}$	—	—
About 300 A. D.	Baths of Diocletian		—	—	8	—	—

The intercolumniation of this order differs from that of all the others, inasmuch as the intercolumns are determined not by the diameters of the column, but by the arrangement of the triglyphs; and the different methods, instead of being distinguished as *pycnostyle*, *eustyle*, *aræostyle*, *&c.*, are comprehended under the terms *monotriglyph*, *ditriglyph*, *&c.*, according to the number of triglyphs over each intercolumn; the former term designating the arrangement in which there is but one triglyph between the columns, the latter that in which there are two within the same limiis. This method of disposing the columns naturally arises from the employment of the triglyph, for this ornament forms so conspicuous an object in the elevation, that it was necessary to make its position conform with the other principal members of the order, of which the column is the most important, so that the colonnade and entablature might present to the eye a similar arrangement. Had the triglyphs been placed in the frieze without reference to the position of the columns, the eye, after passing up the length of the column, would have been confused upon reaching the frieze, and probably would have stopped short at that member, there being nothing to carry it upward to the cornice. Did we adopt the Vitruvian theory, the position of the triglyph would readily be accounted for in another way, for it stands to reason, that the feet of the rafters would be placed immediately over their support.

It being necessary then that the triglyph should stand over the centre of each column, and the proportion of the metope or space between the triglyph being determined, we only require the height of the frieze, and the intercolumniation is fixed. The width of the metope being about equal to the height of the frieze, and the triglyphs somewhat less, it is evident, that to place a column under every triglyph, would be impracticable, without increasing the height of the frieze quite beyond proportion; there would be scarcely room for the feet of the columns, much less for any space between. It became necessary therefore to place another triglyph in the centre of each intercolumn, with two metopes instead of one: this arrangement answered very well, and is the most frequent in Doric temples, and indeed is seldom departed from in any buildings. By inserting another triglyph, you are compelled to add another metope, and this makes the intercolumn half as wide again, which is almost too wide to suit the requirements of taste, as well as the proportions and construction of Doric buildings. There are very few instances of this arrangement, and these only in the centre intercolumn opposite the entrances, where greater space was required; this is especially noticeable in the Propylæa, where a large space was required for the admission of chariots. It may be supposed, that the monotriglyphic method would cause the columns to appear too closely set, and this certainly would be the case in some instances, where the columns are less than a diameter and half apart, were it not that the shafts converge so rapidly towards the upper diameter as to leave a space under the soffit of the architrave, even in such instances equal to more than twice the upper diameter.

The peculiar position of the extreme triglyph has already been noticed in speaking of that member, as also the effect produced by it in lessening the extreme intercolumn by the space of half a triglyph; but there still remains to notice another peculiarity, which was first published by Mr. Donaldson; we allude to the inward inclination of the outer columns.

"The axis of the columns of the Parthenon," says he, "both on the flanks and on the fronts, as well as those of the temple at Egina, and of Concord at Agrigentum, have a considerable inclination inwards (a circumstance I am not aware to have been before noticed) though not to such a degree as required by Vitruvius, and not confined, as he directs, to the columns of the peristyles only." Vitruvius thus directed:—"The bases being thus completed, we are to raise the columns on them. Those of the pronaos and posticum are to be kept with axes perpendicular: the angular ones excepted, which, as well as those on the flanks right and left, are to be so placed, that their interior faces towards the cella be perpendicular. The exterior faces will diminish upwards, as above mentioned. Thus the diminution will give a pleasing effect to the temple."

Mr. Bartholomew alludes to the same circumstance thus:—"The ancients, knowing how much more secure were their fabrics when made to settle together and consolidate by their own gravity, set the lateral columns of their temples with their axes falling towards the cells, so that the inner faces of the shafts of the columns should be perpendicular, and the outer faces of them receding the whole quantity of columnar diminution, in order to afford to the building a more solid, pyramidal, and graceful appearance; and by this shrewd device they rendered the avenues between the side-walls and the colonnades of their temples no wider next the soffits of the architraves than down upon the pavement; and it is not improbable, that the preservation of this symmetry led to the omission of the inner columns of the ancient Pseudodipteral temples; whereas the moderns, in general, not attending to his dynamic and optical nicety in architecture, so set their columns, that when we walk down a modern collonnade, we cannot divest ourselves of the idea that the axes of all the columns are falling outwards: and, indeed, accurate admeasurement would often find this to be no illusion, since the work, not erected so as to fall together, will, in general, with the slightest inevitable settlement, expand at its upper part." It is worthy of remark, that, in many instances, the angular columns are made somewhat thicker than the others, so as to give them an appearance of much greater strength.

Having arrived thus far, we cannot do better than give descriptions of some of the more noted edifices belonging to this order, amongst which are the Parthenon, Theseum, the ancient temple at Corinth, the Propylæa at Athens, and the Poseidonium at Pæstum. The following accounts are selected from Mr. Godwin's lectures on Architectural Antiquities."

"The Parthenon, or the temple dedicated to the virgin-goddess Minerva (the Greek word *παρθένος*, signifying a virgin), was designed by Ictinus and Callicrates, about the year 438 B.C., whilst Phidias wrought the marble figures into life by his magic touch. This temple, erected upon the site of the old Hecatompedon destroyed by the Persians, is justly looked upon as the finest example of the Grecian Doric, and has excited for 22 centuries the admiration and delight of all who have seen it. With the words of the noble author before quoted, all will probably agree. 'In the majestic simplicity of its general design, the grandeur of its proportions and the exquisite taste and skill displayed in the execution of its ornamental parts, it is undoubtedly the most perfect, as well as deservedly the most celebrated, production of Grecian art.' (Lord Aberdeen's Inquiry, p. 142.)

"When Sir George Wheeler and Dr. Spon visited this edifice, A. D. 1676, the temple was entire. In the year 1687 Athens was besieged by the Venetians, when a shell falling on the structure, the Parthenon was reduced to the state in which it was seen by Stuart and Revett. This celebrated temple had at each end a portico of 8 columns in front, and on the sides were 30 more, making 46 to the colonnade which surrounded the cell of the building. The breadth of the front of the building is 101 feet, the length 227 feet on the upper step, and the height 65 feet. The columns are 6 feet 1 inch in diameter, those at the angles are 2 inches more, and the distance from column to column is 7 feet 11 inches. The sculptures of the Parthenon extended to a range of 1,100 feet, consisting of upwards of 600 figures. Behind the great porticos, there are two of smaller dimensions, which are called the pronaos and posticus; these inner porticos have in each 6 columns. The portion of the building enclosed by the columns was divided by a cross wall into two parts, whereof the larger, called the cella or naos (ship) answered to our nave; the smaller part, in which was the public treasury, was called the opisthodomus. In this part, according to Wheeler, were six columns, but no vestige remains of them. The cell, where was placed the famous statue of Minerva by Phidias, was open to the sky in the centre (whence such a temple was called hypæthral from the Greek *ὑπὸ*, under, and *αἰθὴρ*, *æther*, air), having a colonnade round it, supporting a gallery above, in which was a second row of columns. These have all likewise disappeared, but the circles were traced by Stuart on the pavement whereon the lower range of columns had stood. The sculptures in the pediment of the eastern front represented the introduction of Minerva among the assembled gods, giving us an admirable idea of the mythology of the ancients, each of the deities being distinguished by his or her peculiar symbols. The metopes or spaces between the triglyphs, recorded the battles between the Centaurs and the Lapitha, a fruitful subject of illustration among poets as well as sculptors, and a favourite theme with the Greeks, from their famous heroes Hercules and Theseus bearing a prominent part in the contest; fifteen of these metopes are in the British Museum. The western pediment contained a representation of the contest between Minerva and Neptune (in the opinions of Colonel Leake and Mr. Cockerell, this contest was in the eastern pediment); but the most celebrated sculpture is that which represents the Panathenaic procession: this composition is 3 feet 4 inches high, and was continued in the frieze quite round on the outside wall of the cell of the temple. The figures of these groups, which occupy a length of 520 feet, are generally allowed to be of finer execution than those in the metopes.

"'With respect to the beauty of the basso-relievos,' says the great Flaxman, 'they are as perfect nature as it is possible to put into the compass of the marble in which they are executed, and that of the most elegant kind.' Another sculptor, Rossi, calls them 'jewels.'

"The Panathenaic procession, which, with fifteen of the metopes, formerly likewise belonging to the Parthenon, now adorns the British Museum, under the name of the Elgin Marbles, consists, as before observed, of many hundred figures. Among them are several equestrian figures, which are designed in the most admirable manner, and are remarkable for the varied attitudes of the horses, and for the ease and grace of the riders. Other figures in the procession are charioteers in their cars, one of whom is supposed to be the victor in a chariot-race, as a man is about to crown him. Then follow men carrying trays; then the sacrificers and the oxen, each Athenian colony sending an ox to this great festival. Females are also present; some carrying dishes or pateras, others bearing pitchers of water. Two of the young females had situations of great importance, their office being to carry the sacred baskets. Several gods and goddesses are likewise introduced: they are seated to denote their dignity. These figures are all in high relief, so that they are visible at some distance; and although it is impossible now to decide how much was the actual work of Phidias himself, it is highly probable that they, as well as the other sculptured decorations of the temple, were all designed by the great master. (It is known, he practised the art of painting previously to that of sculpture.) It has been ascertained, that they are as carefully finished behind as before, and in places which could not be visible when once they had reached their destination; hence, it is justly inferred, that all these sculptures had to undergo the ordeal of a searching criticism of the public eye, before they left the artist's studio.

"In addition to the embellishments already described, which adorned the temple, Phidias made the celebrated statue of Minerva which stood in the cell, or open part of the building. This figure, formed of ivory and gold, was thirty-seven feet high. Pausanias says that it stood erect; the goddess was represented with her garments reaching to her feet, helmeted, and with a Medusa's head on her breast; in one hand she held a spear, and on the other stood a Victory of about four cubits high. Monsieur Quartreinere de Quincy, who bestowed great pains in investigating the subject of ancient sculpture, has calculated, that the value of the gold employed on this famous statue was equal to £130,000 sterling.

"A fac-simile of the Parthenon, as far as the architecture is concerned, has been erected at Edinburgh, on the Calton-hill, in a situation resembling the Athenian Acropolis. Mr. Bankes proposed it as the model for the Fitzwilliam Museum, at Cambridge. The proportions of its Doric order are imitated in the portico of Covent Garden Theatre.

"The Temple of Theseus which is generally reckoned to belong to the age of Pericles, and earlier in date than the Parthenon, is one of the noblest monuments of Athenian magnificence, and, in the the time of Stuart, was one of the most perfect. 'The sanctuary of Theseus was raised by the Athenians after the Medes were at Marathon, when Cimon, the son of Miltiades, expelled the people of Scyros, a retribution for the death of Theseus, and carried his bones to Athens.' (Pausanias.)

"Plutarch places this event at a date which is generally considered equivalent to the year 467 B.C. The Parthenon is, by some writers, believed to have been commenced about 448 B. C. (the year in which Cimon died), and to have occupied sixteen years in erection. In the opinion of Lord Aberdeen, 'The temple of Theseus may be considered as nearly coeval with the buildings of the Acropolis, or perhaps of an origin somewhat earlier.' (Inquiry, p. 143.) The Theseum is built of Pentelic marble, and is raised upon two steps, being peculiar in this respect. The portico at each end consists of six columns in front; at each side are eleven columns, not counting the angle-columns of the portico; so that the building is surrounded by thirty-four columns. Behind the porticos are others, consisting of only two columns between antæ; there are three deep recesses, which lead to the cell. There is here no division in the internal part, where it is presumed that the remains of Theseus were buried. This temple is 104 feet long, 45 feet wide, both dimensions being taken on the upper step, and 25 feet 2 inches high; the diameter of the columns is 3 feet 3 inches. The sculptures in the metopes were representations of the exploits of Theseus, and of the labours of Hercules, who appears to have been honoured in this temple, as well as Theseus, his kinsman and friend. The frieze of the wall behind the eastern portico was adorned with a representation of a battle and victory, in which six of the divinities are present; three of whom are Jupiter, Juno, and Minerva. Among the combatants is one of superior stature and dignity, hurling at his assailants a stone of prodigious size; he is supposed to be Theseus, in the act of overthrowing the Persians at Marathon. The battle between the Centaurs and Lapithae was sculptured on the wall behind the western portico. The sculptures (of which are casts in the British Museum) are, according to Pausanias, supposed to be the work of the famous Michon.

"It has been discovered of late years, that the Parthenon, and nearly all the buildings at Athens, had colours applied to their different enrichments; but it does not appear that the advocates of Greek polychromy have clearly made out that this practice belongs to the pure age of Pericles and Phidias. It is much more likely to have been introduced long after their time.

"The temple of Corinth is probably the most ancient specimen of the Doric order in existence. It is built of a rough porous stone, and is supposed to have had porticos of six columns, five of which remain in the western front, and six are seen on one flank; its arrangement, perhaps, was similar to that of the temple of Theseus; the columns are 5 feet 10 inches in diameter, and their shafts, 21 feet in height, are composed each of a single stone. There is no sculpture upon the temple, as all above the architrave has long since disappeared. Since Stuart's time, five of the columns which appear in the flank, in his work, have been blown into fragments by gunpowder, to assist in building the house of a governor of Corinth. Lord Aberdeen observes, 'It has been said, that this temple was dedicated to Venus; but, in fact, no information is to be obtained respecting its origin. Whatever may have been its destination, no one can doubt, from the appearance of the ruins alone, that they formed part of a structure of the most remote antiquity.

"One of the noblest efforts of the genius of Ictinus is to be seen in the temple of Apollo Epicurius, in Arcadia. It offers many architectural peculiarities, and exhibits a greater variety of details than are usually met with in the Grecian temples.

"Pausanias, speaking of this building, which is at Bassæ, near Phigalia, states, that 'the temple of Apollo Epicurius (the deliverer), which, together with the roof, is of stone, surpasses all the temples which are in Peloponnesus (with the exception of that in Tegea) in the beauty of the stone, and harmony of the proportions.'

"The entrance to the temple was facing the north, contrary to the usual practice. The temple was 47 feet broad, 125 feet long, and ascended by three steps. There were six columns in each front, and fifteen on each flank, all 3 feet 7 inches in diameter, and 19 feet 6 inches high. In the interior of the cell were *attached* columns, of the Ionic order, of a very ancient character, (together with a single insulated column of the Corinthian order,) over which, on the four sides of the cell, ranged the sculptured frieze. The columns and walls are constructed of the hard and beautiful limestone of the country, but the sculpture and roof are of marble. It would not appear, from Mr. Donaldson's description, that any decorations existed in the pediments, or metopes. 'The arrangement of the engaged columns of the cella is very peculiar. A similar disposition has never hitherto been found, though, perhaps, in the temple of Apollo Didymæus, at Branchidæ, near Miletus, the projecting pilasters conveyed the same effect, less distinctly expressed. The spaces between the Ionic columns seem to afford admirable situations for statues, as they would be secured by the columns on each side, and by the soffits above, from the occasional inclemencies of even that mild atmosphere.'

"The Propylæa, a Doric structure, forms the only entrance to the Acropolis of Athens. Pausanias says, 'There is only one entrance to the Acropolis, it being in every remaining part of its circuit a precipice, fortified with strong walls. The entrance was fronted by a magnificent building, called the Propylæa, covered with roofs of white marble, which surpassed, for beauty, all that he had before seen. This was begun during the ministration of Pericles, B.C. 437, and was finished in five years (Mnesicles being the architect), at an expense equivalent to £464,000. The front of the Propylæa consisted of six columns, and at the back of the building was a small portico; between the two was the wall, in which were five gates. The centre reached from the platform to the height of the entablature; it was 13 feet wide, and was used on solemn occasions for the chariots. The road-way was between two rows of Ionic columns; a gate of 6 feet wide, and of less height than the centre, occupied each side, and beyond them were two smaller doorways, which were used for ordinary passage. On the right of the Propylæa was a building called the temple of Victory-without-wings. On the left, was an edifice adorned with paintings, the work of Polygnotus; the subjects chiefly from Homer; and it is supposed, that herein stood a group of the Graces, draped, the performance of the celebrated Socrates, who pursued his father's profession of a sculptor, until he devoted the energies of his wonderful mind to the study of philosophy.

"Similar in plan to the building at Athens, is the Propylæa at Eleusis, and, in design, little inferior to its Athenian prototype. It was erected, together with the Temple of Ceres, to which it served as a vestibule, and the connected Temple of Diana-Propylæa, by Pericles, for the solemnization of the Mysteries of Ceres, the most sacred among the religious rites of Greece.

"The Propylæa bears a striking resemblance to that at Athens, having at each end a portico of six columns, five gates, and two rows of Ionic columns within. To make the central opening large enough to admit chariots, the usual arrangement is departed from, by the addition of a triglyph in the frieze over the space between the central columns. The pavement, the steps, and every part of the superstructure, were of fine Pentelic marble; the roof, also, was covered with marble slabs, worked into the shape of tiles; the joints of these tiles were covered with others, which follow the slope of the roof, to prevent the admission of water. This ingenious contrivance was the invention of Byzes, of Naxos; and it was so highly appreciated by the Greeks, that they honoured the inventor with a statue. The termination of the joint-tiles was formed by an upright tile, on which was painted the lotus. Byzes lived 580 years before the Christian era.

"After passing through the Propylæa at Eleusis, the votaries had to enter another building, forming a second vestibule to the grand mystic temple. The order in this building was the Ionic. Beyond this vestibule was the Temple of Ceres, which was protected by the sacred inclosure, or wall. In front was a portico of twelve columns, which have the peculiarity of not being fluted from top to bottom, as Doric columns usually are, but their shafts plain throughout their whole height, with the exception of a part at their top and at the bottom of each, about 7 inches high, which is fluted. Within the temple, according to a passage in Plutarch, it is imagined there were two ranges of columns, with others over them. The architect of this building was Xenocles.

"In front of the Eleusinian Propylæa was the temple of Diana Propylæa, presenting an arrangement in its porticos differing from any examples we have hitherto noticed; instead of columns at its angles, antæ, which are often improperly called pilasters, terminate its fronts: the distinction between the Greek antæ and Roman pilasters is very great. The former were never diminished (or so slightly as not to appear so to the eye), and were not fluted, their capitals consisted of straight lines; whereas the Roman pilasters were diminished like their columns, frequently fluted, and their capitals generally resembled those of the accompanying columns. The temple of which we are speaking, was small, with a front measuring only 20 feet 10 inches on its upper step; its length 39 feet 9 inches, and its height to the top of the cornice 20 feet 6 inches; the building was of Pentelic marble, but with roof-tiles of baked clay.

"At Olympia, in the Peloponnesus, once existed a magnificent hexastyle temple of Jupiter, of which the dimensions are presumed to have been 230 feet by 95 feet. Mr. Dodwell measured a column, of which the diameter was 7 feet 3 inches. Within this building was enshrined the master-piece of Phidias, his statue of Jupiter, of gold and ivory, 50 cubits high.

"At Rhamnus in Attica, on the sea-coast, is a fine Doric temple of Nemesis, which stands in a noble situation, elevated 300 feet above the sea. Pausanias says that it was built by Alcemenes, the pupil of Phidias. This temple, and a smaller one adjoining it, dedicated to Themis, were inclosed by a wall of white marble, remains of which are yet to be traced. The temple of Nemesis had at each end porticos of 6 columns, and flanks containing 12 each; the external columns, like those to the temple of Ceres, were only fluted at top and bottom. It is ascertained that the mouldings of the cornices were painted red, a practice adopted by the Greeks in other temples. The details in this building are very fine. Close to it is the small building which bears the name of Themis, but which is supposed to be the original temple of Nemesis, injured by the Persians; and the Greeks not caring to repair a structure desecrated by their enemies, chose rather to erect another. The smaller building is in fact of an earlier style, being one of the class called *in antis*, a mode of building well known to be of great antiquity. It is very similar to the small temple of Diana at Eleusis.

"At Sunium, which is a promontory forming a southernmost point of Attica, are the remains of two Doric buildings; one is a Propylæa, the porticos of which have two columns placed between antæ. The other building is a temple dedicated to Minerva-Sunias. The portico consisted of 6 columns, and 10 have been ascertained on the flanks; but the building is so much in ruins, that the exact number cannot be clearly made out. The structures are of marble, highly finished, and belong to the best ages of Grecian architecture. 'The striking remains of the temple of Minerva on the promontory of Sunium are, in all probability, to be attributed to the same authors.'

"At Thoricus, about eight miles to the north of Cape Sunium, are the remains of a singular Doric building, which was found half-buried in the sand, which being cleared, a portico was discovered, having 14 columns on each front, and 7 in each return; and as no remains of walls were discovered within the area, it is conjectured that the building was not a temple, but an open portico, perhaps an agora; these columns are only fluted at their upper and lower extremities.

"Leaving Attica, we shall now pass into Sicily, where we find the remains of one of the most astonishing specimens of Doric architecture, surpassing in magnitude all that we have hither to noticed. This is the celebrated temple of Jupiter Olympius at Agrigentum, now called Girgenti, and which Virgil styled, from a neighbouring river, Agragas. It was the wealthiest and most powerful city of Sicily, and according to Diogenes Laertius, contained within its territory 800,000 persons. 'The temples of Agrigentum, numerous and costly as they are, appear to have arisen during little more than a single century. The prosperity and independence of the city commenced with Theron, about 450 years before Christ; after the battle of Himera (fought on the same day as that of Salamis), his thoughts were entirely turned to its decorations, and the Carthaginian prisoners were made to assist by their labour in the erection of trophies to perpetuate the glory of their conquerors. The Agrigentines continued in this employment until a second and more successful invasion of the Carthaginians found them occupied in completing the temple of Jupiter Olympius, the greatest in the island, and one of the most stupendous monuments of ancient times.'

"The temple of Jupiter was, in its proportions, truly colossal, and it ranked among ancient Greek temples as second only to that of Diana at Ephesus, (which was 425 feet long, and 220 feet in breadth); it was 369 feet in length, its breadth 182 feet, and its height 120 feet, in which dimensions Mr. Cockerell is of opinion that it exceeded the building at Ephesus. Unlike other Doric structures, in this temple the columns are not detached from the walls, thus they present only the appearance of half-columns; these, however, are 13 feet in diameter, so that if the columns had been disengaged, their circumference would have been more than 40 feet, a dimension exceeding the largest columns in Egyptian architecture. (The Roman-Doric column, erected by Sir Christopher Wren, called the Monument, is only 15 feet in diameter, though of a proportion much loftier). The echinus of the capitals is formed of two large stones, each weighing 21½ tons; the triglyphs are in single stones, each weighing 12¼ tons; few of the stones employed in the entablature weigh less than 8 tons; and a man could stand in one of the flutings of the columns. As compared with a modern building, we may observe, that the width of the cell is two feet more than the nave of St. Paul's, and the height exceeds it by 18 feet. The front portico, in which were 7 columns, had the battle between the Gods and the Titans represented in the pediment; and in that of the other portico was sculptured a representation of the siege of Troy, in which each hero was distinguished by the peculiarity of his dress and arms. (Diodorus). In the interior was a double row of pilasters ranging like the pillars of a cathedral; the attic story above the pilasters was supported by the figures of the rebellious and defeated giants, most appropriately placed there to contribute to the glory of Olympian Jove, whose power they dared to oppose. The proportions of the Titans are as vast as the other parts of the structure: being 25 feet in height; with heads alone 3 feet 10 inches, and chests 3 feet across.

"The other temples of Agrigentum were very numerous; in the year 1790, by Sir Richard Colt Hoare, 11 could be traced in different stages of dilapidation. The next in size to that of Jupiter was one dedicated to Hercules, which was 154 feet long, and 55 feet broad, having 6 Doric fluted columns in each front, and 14 on each flank; the columns were 7 feet in diameter at bottom, and only 4 feet 10 inches below the capitals, showing a very great diminution.

"At Selinus, or Selinuntium, (so called from the great quantity of parsley, σελινον), on the southern coast of Sicily, were six magnificent Doric temples, probably the largest ever erected in this style, and which appear to have been overthrown by an earthquake. One of these is believed to have been 331 feet long, and 161 feet broad, with columns 60 feet high; a stone, which is supposed to have formed part of an architrave, is 40 feet long, 7 feet deep, and 3 feet thick, and some of the columns were found to be 12 feet in diameter, and others 10 feet 10 inches, and 48 feet high. Near these ruins were the remains of a hexastyle-peripteral temple, computed to have been 186 feet long, and 76 feet broad on its upper step, and to have had 36 columns in all, 6 feet 8 inches in diameter. Another temple, not far from these, was 232 feet by 83 feet on its upper step, with fluted columns, 6 in each front, and 16 on the flanks. The other three temples are supposed to have been unfinished when they were thrown down. One of these had porticos of 7 columns in front with 17 on each flank; another had 6 columns in the porticos, and 16 on each flank. In the quarry near Campo Bello, whence it is presumed the materials were derived, are yet some shafts of columns, 10 feet in diameter, and one of 12 feet, still joined to their natural bed of stone. Mr. Wood measured one block of an architrave, 26 feet 2 inches long, 4 feet 9 inches wide, and 6 feet 10 inches high. The city was, 409 B. C., nearly destroyed by the Carthaginians.

"At Segeste, the ancient Ægesta, is a famous Grecian-Doric temple, almost entire, standing in a splendid situation on the brow of a precipice. There are 6 columns in each front, and 14 at each side, making 36 in all; these are about 30 feet high; the length of the building is 190 feet, its width 78 feet; the stones composing the architrave are of great size, and one extends over two columns: the date of it erection, as well as the nature of its dedication, are unknown. The columns, which are fluted, are 6 feet 7 inches in diameter at the base, and 4 feet 11 inches below the capital.

"In a notice of Grecian-Doric architecture, we must not omit to speak of some ancient temples in Italy, namely, at Pæstum, the ancient Posidonium, so denominated from its tutelary God, Neptune, who, by the Greeks, was called Ποσειδων. From its unhealthiness, the place had, in very early times, fallen into decay, and Augustus visited the temples as venerable antiquities in his day; but they were completely forgotten, until in 1755 discovered by an artist of Naples. Among the ruins, which are very extensive, are three buildings of imposing character, two of them are temples. The temple of Neptune, raised on 3 steps, was 194 feet long, and 78 feet broad, having 6 fluted columns in each front, and 14 (including the angular ones) at each side. The entablature and capitals were equal to half the height of the columns, of which the shafts only were 27 feet, the lower diameters 6 feet 10 inches, the upper diameter 4 feet 8 inches, and with 24 flutings; the intercolumns are 7 feet 7 inches wide. The cell is 90 feet by 43 feet, having 14 columns in 2 rows, with shafts 16 feet 11 inches high, 4 feet 9 inches in diameter, and with 20 flutings. These columns support a deep architrave, on which rises another set of columns, about 11 feet high. The largest stone in this building is 13 feet 8 inches by 4 feet 8 inches by 2 feet 3 inches. Professor Wilkins, in this temple, detects a close resemblance to the temple of Solomon, (Prolusiones). The temple of Ceres is in a lighter style than the former building. It is 108 feet long, and 48 feet broad, with the same number of columns, as in the temple of Neptune; the diameter of the columns is at bottom 4 feet 3 inches; at top, 3 feet 3 inches; and their shafts have 20 flutings. The third building is called a Basilica, because there is no appearance of a cell, or altar. It is 170 feet long, and 80 broad; and it is raised on three steps, having nine columns in each front (the only example of such arrangement), and eighteen on each side, with the lower diameter 4 feet 6 inches, and 20 flutings. Both fronts have a vestibule, and the interior was divided by columns. The date of these structures is unknown. One of the most ancient Doric temples in Greece is in the island of Egina; this was a hexastyle temple, dedicated to Jupiter Panhellenius. "It is said by Pausanias to have been built by Eacus, considerably before the Trojan war, a story wholly incredible, but which serves to prove that it had outlived all tradition of its real origin. It is still nearly entire." There were twelve columns on each flank, making thirty-six in all, of a porous stone, covered with a thin stucco, and the architrave and cornice were painted in colours. Fifteen statues, formerly belonging to this temple, are now at Munich: they are supposed to represent the Greeks and Trojans contending for the body of Patroclus; they have been restored by Thorwaldsen. Illustrations of the Temple of Jupiter have been published by Mr. C. R. Cockerell, and have proved a valuable addition to our knowledge of Doric architecture.

Modern examples of this order are to be seen in Covent Garden Theatre; the Corn Market, Mark Lane, where the details of the monument of Thrasyllus are copied; in the new galleries and entrance of the British Museum, where polychrome is introduced; and at the entrance-gateway to the Terminus of the North Western Railway.

The origin of the Doric order has ever been a disputed point amongst writers upon the subject, some following one theory, and some another. Vitruvius, whose opinion is valuable, as coming from the oldest writer upon architectural matters, will have it, that the earliest stone temples of Greece were but imitations of the wooden structures previously employed, and that the members of the Doric order, both structural and ornamental, owe their origin to similar parts in the less permanent building. This primitive mode of building is supposed to have been similar, in some respects, to the log-houses erected by colonists of the present day, consisting of trunks of trees fixed vertically in the ground, at short distances from each other, and forming the support to the several members of the roof. From the various portions of this timber construction, are supposed to have been derived those of the later stone edifice. The following opinion as to some of the corresponding parts of the two kinds of structures, is given by Vitruvius:

"In the upper part of all edifices, timbers, called by various names, are disposed, which, as in names so in uses, differ. The trabes are those laid over the columns, parastatæ and antæ, in the contiguations and floors. If the span of the roof is great, under the culmen, in the top of the fastigium, are disposed columens (from whence columns derive their name), transtræ, and capreols; but if the span is small, columens and canthers, projecting to the extremities of the eaves. Above the canthers are the templats, and over them, but under the tiles, are the assers, projecting so far as to shelter the walls. Thus each, according to its use, has its proper place and order. This disposition of the work, the artificers, when they erected sacred edifices, imitated in sculptures of stone and marble; and this invention the ancient workmen thought proper to pursue. Thus, whenever they constructed any building, they laid the joists from the interior walls to the extreme parts, then built up the interjoist, and, to give the work a pleasing appearance, adorned the top with a cornice and fastigium; then, as much of the joists as projected beyond the wall they sawed off, which, appearing unhandsome, they made tablets, like triglyphs now in use, fixed them against the sawed ends of the joists, and painted them in wax, that the sectures of the joists might not offend the sight. Thus, the triglyphs, interjoists, and opæ, in Doric work, had their origin from the disposition of the timbers of the roof.

"Afterward, in other works, some made the canthers, that were perpendicularly over the triglyphs, to project outward, and carved their projecture; hence, as the triglyphs arose from the disposition of the joists, so the mutules under the corona were derived from the projecture of the canthers; wherefore, in stone or marble structures, the mutules are represented declining, in imitation of the canthers; and, also, on account of the droppings from the eaves, it is proper they should have such declination.

"From this imitation, therefore, arose the use of triglyphs and mutules in Doric work; for it cannot be, as some erroneously assert, that the triglyphs represent windows; because triglyphs are disposed in the angles, and over the quarters of the columns, in which places windows are not permitted; for, if windows were there left, the union of the angles of buildings would be dissolved; also, if the triglyphs are supposed to be situated in the place of the windows, by the same reason, the dentils in Ionic work may be thought to occupy the places of windows; for the intervals between the dentils, as well as between the triglyphs, are called *metopæ;* the Greeks calling the bed of the joists and assers, *opas* (as we call it *cava, columbaria*); so, because the interjoist is between two opæ, it is by them called *met-opæ.* As the triglyphs and mutules in the Doric order are founded upon those principles, so the dentils, in the Ionic, derive their proper origin from the workmanship; and as the mutules represent the projectures of the canthers, the dentils in the Ionoic order are in imitation of the projecture of the assers."

This theory is a very plausible one, so far as it goes; and were we unable to account for such matters in a different way, it might be passed over as correct, but for one objection, and that alone at once throws discredit upon the whole account. The difficulty may be put in this way: if the prototype of the stone structure were constructed of timber, how comes it, that the proportions of the former are of so heavy and massive a character? and how is it, that the columns are so thickly set? Timber construction would have led to very different results; slenderness and lightness are the characteristics of buildings of such material, and so, necessarily, of its antitype. The reverse, however, is the case; and not only so, but we find, that the older the edifice, (and therefore the more similar to its prototype) the heavier, also, its proportions; whereas, if Vitruvius's theory be correct, the contrary should be observable. But, besides this, we can account for all the details alluded to by Vitruvius in a very different, and, to our mind, far more satisfactory manner, as we shall attempt to explain presently.

As regards the date of the introduction of this style of building into Greece, nothing can be stated with certainty; neither can it be satisfactorily ascertained in what locality it first appeared: great differences of opinion exist on both subjects. Vitruvius, as usual, decides the matter without any apparent difficulty. He says:

"The most ancient and first invented of the three kinds of columns is the Doric; for, when Dorus, the son of Hellenus, and the nymph Opticos, reigned over all Achaia and Peloponnesus, the temple of Juno, in the ancient city of Argos, was erected, and this order happened to be used in the fane. The same order was also used in the other cities of Achaia before the laws of its symmetry were established.

"Afterward, when the Athenians, according to the responses of Apollo and Delphos and the common consent of all Greece, transplanted, at one time, thirteen colonies into Asia, apportioning to every colony a leader, they gave the chief command to Ion, the son of Xuthus and Creusa, whom also the Delphian Apollo acknowledged for his son. These colonies he conducted to Asia, seized on the territory of Caria, and there founded many large cities, as Ephesus, Miletus, Mynuta, (which last was formerly overflowed with water, and its rites and privileges, by Ion, transferred to the Milesians), Priene, Samos, Teos, Colophon, Chios, Erythræ, Phocis, Clazomenæ, Lebedus, and Melite. This latter, on account of the arrogance of the citizens, was destroyed in the war declared against it, by the unanimous determination of the other cities, and, in its place, by the favour of king Attalus and Arsinoe, the city of Smyrna was received amongst the Ionians. When those cities extirpated the Carians and Leleges, they, from their leader, Ion, called that territory Ionia.

"There they began to erect fanes, and constitute temples to the immortal gods. First, they erected the temple of Apollo Panionias, in the manner they had seen it in Achaia; which manner they called Doric, because they had seen it first used in the Dorian cities. In this temple they were desirous of using columns, but were ignorant of their symmetry, and of the proportions necessary to enable them to sustain the weight, and give them a handsome appearance: they measured the human foot, and finding the foot of a man to be the fifth part of his height, they gave that proportion to their columns, making the thickness of the shaft at the base equal to the sixth part of the height, including the capital. Thus the Doric column, having the proportion, firmness, and beauty of the human body, first began to be used in buildings."

The former part of this statement may or may not be correct, but if its credit stands upon an equal footing with that of the latter part, we shall not be justified in placing much confidence in it; for ere we can give credence to his opinion respecting the proportions of the order, we must suppose the men of that age to have been of a very different description to those of the present day.

If Vitruvius be correct in his supposition regarding the introduction of the order, we must suppose several temples to have been erected in this style before Homer's time, but, if so, it would appear strange that one, generally so minute in his descriptions of persons and places, should not have given us some description of them. It is true, that he alludes to three or four temples,—to those of Minerva at Athens and Troy, and of Apollo and Neptune at Delphi and Ægæa, respectively,—still he has not given any description of them, and leaves us entirely to conjecture: according to the account of Pausanias, the temple at Delphi was nothing better than a hut covered with laurel and branches. But if we discard the account given by Vitruvius, we shall not be much nearer the goal, having no data to work upon. If we allow the name of the order to give us some clue as to its origin, we are still in the same predicament, for many provinces bore the name of Doris; and at best, as Lord Aberdeen remarks, a name is often the least satisfactory mode of accounting for the birth of the thing which bears it. Many are of opinion that the order was first employed in the cities of Corinth, Sicyon, and Argos, shortly after the return of the Heraclidæ, but others suppose it to have originated amongst the colonists of Asia Minor, and there certainly does appear some reason for supposing that the temples here were far in advance of those in Greece-proper.

In whatever part of Greece the Doric order was first employed, there seems very good reason to believe that it had its origin in Egypt, or rather perhaps that the temples of that country suggested the idea; nor is there any *prima facie* grounds for rejecting this supposition, for we know, in the first place, that Greece was, at least, to some extent, colonized from Egypt; Cecrops was from that country, and Cadmus from one not far distant; and besides this, we know that in after times the Greeks were in the habit of trading with Egypt, and were held in so great esteem by Amasis, that he gave them the city of Naucratis, and afforded them every encouragement and convenience. Another internal evidence of the connection of the two people is afforded in the identity of their mythology.

But let us consider the architectural features observable in the buildings of the two countries. In general appearance they agree; they are both of massive proportions, and both consist of similar parts, columns, entablature, and such like. Nor are they less similar in detail; in Egyptian temples we have an entablature consisting of three members, architrave, frieze, and cornice, the first of which, like the Doric, is comparatively plain, and the last simple, but bold. The similarity of the frieze in both styles is remarkable, extending even to triglyphs and mutules, and in both styles are those features equally essential. The similarity of the columns may not be at first so apparent, although we can point out many Egyptian columns without bases, with square plain abaci, and may suggest the probability of the Grecian echinus being copied from the lower portion of the bulging or cushion-capitals of Egypt: the annulets round the necking of the capital are likewise of very frequent occurrence in that country. As regards the rest of the column, it is true, speaking generally, that Egyptian specimens are not fluted, neither do they diminish, like the Greek, from the lower to the upper diameter; instead of concave flutes, however, we have convex rods, or probably reeds; and if the latter, we have only to divide them vertically down the centre, and we have the Doric flutes. But even if this last idea be too fanciful, the difference between a cabled and fluted column is not so great, the ornamentation is decidedly of a similar character; end even if this be disallowed, there are specimens of fluted columns in Egypt, and specimens which altogether bear a very marked resemblance to the Grecian-Doric. These columns were first noticed by Mr. Barry, who considers them of greater antiquity than any Grecian specimens. The first is a portico of two fluted columns in antis, about 5½ diameters in height, and surmounted by a plain abacus; the flutes are 20 in number, and of shallow contour; the columns are without bases. The next example is from Kalaptchic on the Nile, the abacus of which is square, and 11 inches thick; the shaft, which has a trifling diminution, is 7 feet 8 inches high, and 3 feet 2 inches diameter. The circumference is in 24 divisions, whereof 4, which are at right angles with each other, are flat faces, covered with hieroglyphics, and the other intervening ones are sunk into flat elliptical flutes a quarter of an inch deep. Another specimen is to be seen at Amada in Nubia, consisting of two columns, one of which is a simple parallelopiped, and the other, at the corner of the building, is both cylindrical and fluted, leaving, however, a square abacus similar to that of the parallelopiped, which, in this case, is the only capital; the base is also of a square plan. Of these two columns, the former is evidently the earlier design, the latter, previously of the same shape, whether for convenience or otherwise, has been rounded off at the corners and somewhat ornamented.

Were it allowable to select portions from these examples and place them together at discretion, there would be no great difficulty in forming a very perfect specimen of Grecian-Doric, but even without such a metamorphosis, we suggest, there can be no difficulty in perceiving a great and indubitable similarity between the structures of Egypt and the earlier ones of Greece, the likeness being more striking in some examples than in others, yet not being entirely absent in any. We may conclude, therefore, we presume, that there is a very strong probability of the Doric order having been derived from the architecture of Egypt.

This order, as practised by the Romans and Italians, differs in some essential particulars from that above described, and in process of time its original character seems to have been all but entirely lost, the identity being evidenced only by the remains of some few details. The few points in which the resemblance between the Greek and Roman orders is preserved, are—the employment of triglyphs and metopes in the frieze, and of mutules in the corona, the fluting with arrises instead of fillets, when indeed flutes were introduced, and the general form of the capital consisting of echinus and abacus. The distinctions are much more numerous, amongst which may be mentioned the elongation of the shaft and the not unfrequent absence of flutes; the addition of a base, variations in the form of the capital and of the several members of the entablature, the amplification of mouldings and such like; so that were two examples, one of each kind, placed before a person unacquainted with the subject, he would have greater difficulty in tracing their resemblance, than in pointing out their incongruities.

The height of the column is increased from six to eight diameters, and in some cases, as recommended by Vitruvius for porticos, to eight and a half. It is either fluted or left plain, and sometimes is partially fluted, the channels extending about two-thirds of the shaft, the remaining portion below, from the base upwards, being left blank.

The addition of the base follows very naturally the elongation of the shaft, for were it still to be omitted, the lower portion of the column would look too small, and would give to the edifice an appearance of weakness; the columns would seem unsteady; whereas in the Greek examples, the massive proportions and the rapid spreading of the shaft from the capital downwards, gives the effect of strength and stability. The base generally used is that termed the attic, and consists of a plinth, a torus, a hollow moulding or scotia with a fillet above and below it, upon the uppermost of which is another torus and fillet, out of which the shaft rises with an apophyge; a simpler base, however, is sometimes made use of, comprising only a torus and two shallow fillets above it, and occasionally merely a plinth and simple fillet.

In the capital, the sunk annulets of the Greek examples are converted into projecting fillets in the Roman; the shaft is separated from the cap by an astragal which gives much greater distinctness to the necking, which again is sometimes relieved with rosets and buds, or other ornament. Above the neck are three flat annular fillets, and these above the ovolo surmounted by the abacus. The ovolo, however, is not of so much importance as in the Greek order, nor of the same severe contour; the abacus likewise is much shallower, and has the addition of mouldings on its top. The height of the capital is equal to $\frac{1}{2}$ a diameter, or 1 module, but this is not always the case, for in the Theatre of Marcellus at Rome, it is 33 minutes, and in the Coliseum as much as 38.

The architrave is often similar in appearance to the Greek, but is of less height, being equal to only two-thirds of the frieze, or half a diameter; in a few instances, the architrave is composed of two fascias. The new frieze is also very similar to the old one, with some slight exceptions, the mutules being frequently filled with ox-skulls and patteras, and sometimes left plain; the capitals of the triglyphs are of greater projection than before, and are returned at the ends. The triglyphs besides are in Roman examples, invariably placed over the centre of the columns, so that the ends of the frieze are finished with half-metopes, and not with triglyphs as in the Grecian order. In the Coliseum, the triglyphs are entirely omitted.

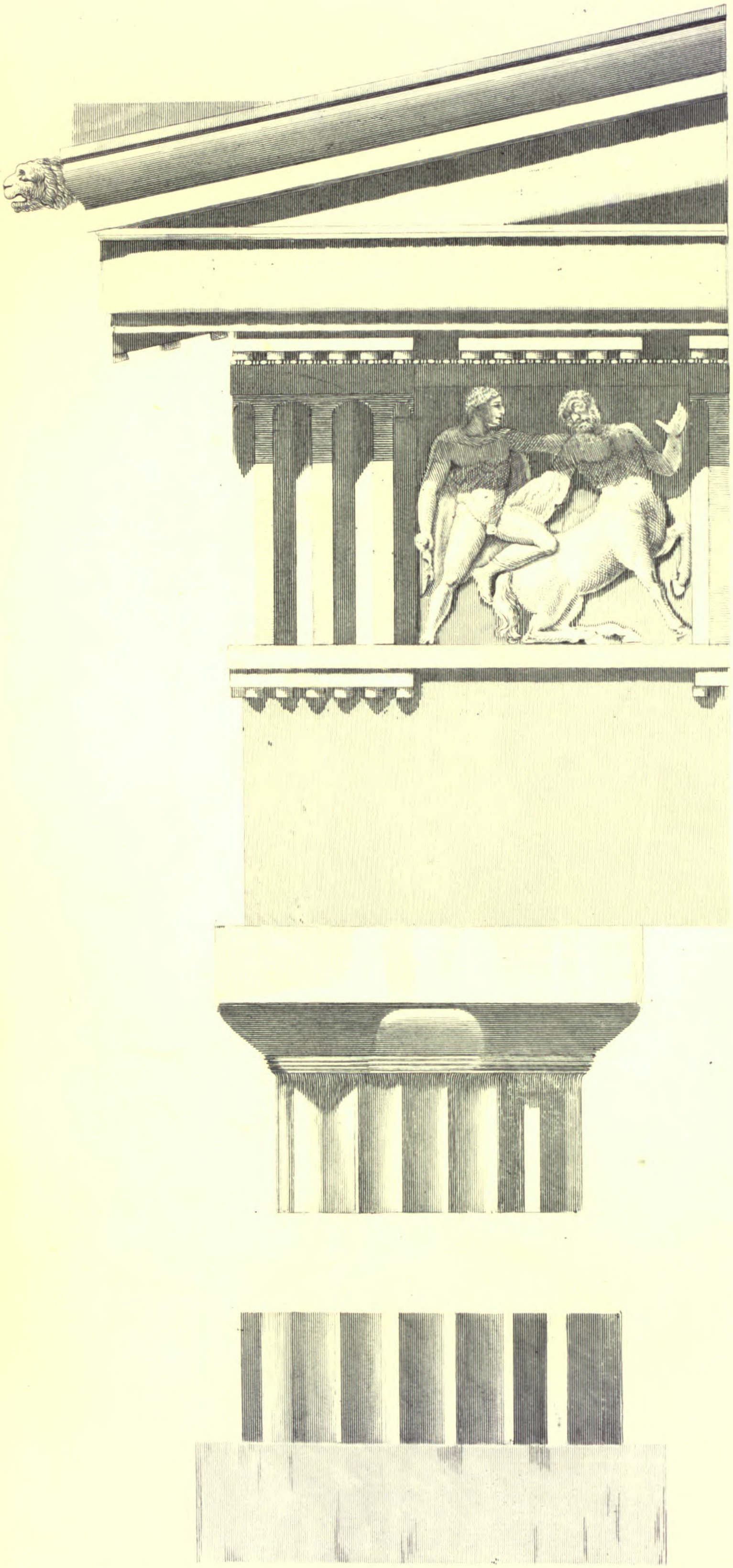
The cornice differs considerably from the Grecian, having its soffit flat and the mutules square, with a similar interval between them. In Grecian examples, the guttæ generally appear in front below the mutules; but in the Roman, they do not so, and are sometimes even omitted; sometimes the mutules entirely disappear, as in the Theatre of Marcellus, where dentils with an ogee bed-mould are substituted in their place, and the Basilica at Vicenza, designed by Paladdio, has merely a bold ogee and ovolo in their place. The intervals between the mutules are frequently enriched with panels and sculpture. The mutules and band are surmounted by a small ogee moulding, and under them is an ogee or ovolo forming a bed-moulding. The mutules support the cornice-proper, consisting of the corona, an ogee and fillet, and a cavetto finished at the top with a fillet.

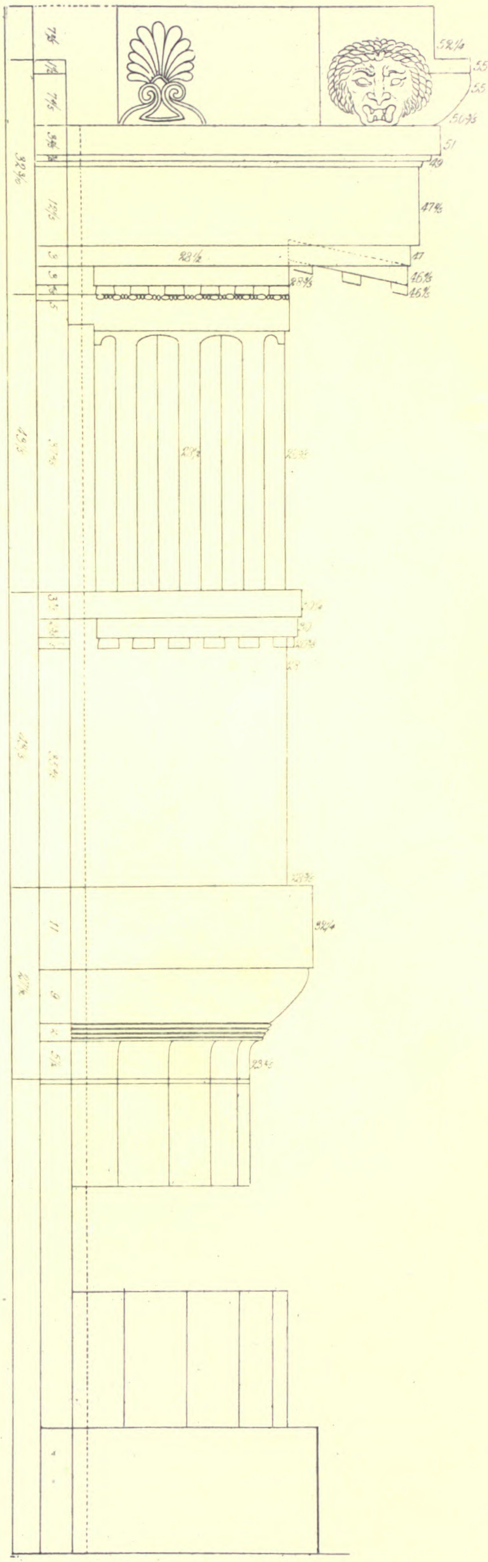
With Vitruvius's account of the order, we conclude this article; it runs as follows:—

"Some architects," says he, "have maintained that temples should not be built of the Doric order, because it occasions an imperfection and an inconvenience in the symmetry; for this reason it was rejected by Tarchesius, Pytheus, and also by Hermogenes: the latter, after he had prepared marble materials for a Doric temple, altered them, and from the same materials, raised an Ionic temple to Bacchus. However, it was not because the appearance was unhandsome, or the manner or form ignoble; but because it impeded the distribution, and the arrangement of the triglyphs and lacunars was unsuitable to the design; for it is necessary that the triglyphs should be disposed over the middle quarters of the columns; the metopes which are between the triglyphs, be made as long as high; and the triglyphs over the angle columns be placed at the extremities, and not over the middle quarters. So that the metopes which adjoin the angular triglyphs, are not square, but more oblong by half the breadth of a triglyph. Those who would make all the metopes equal, contract the extreme intercolumn half the breadth of a triglyph; but this, whether it is done by lengthening the metope, or by contracting the intercolumn, is a defect. On this account, the ancients avoided the use of the Doric order in sacred edifices. Following, however, our method, we shall give the explanation of this order, as we have received it from the masters; so that those who attend to these precepts will here find described the rules by which they may erect a temple in the Doric manner, without fault or imperfection.

"The front of the Doric temple, where the columns are erected, is, if tetrastyle, divided into 28 parts; if hexastyle, into 44. Of these parts one will be a module, called in Greek, embates, by which the distribution of the whole work is regulated. The thickness of the column is two modules; the height, including the capitals, 14. The thickness of the capital one module, the breadth two and the sixth part of a module. The thickness of the capital is divided into three parts, of which one is for the abacus with its cymatium, another for the echinus with its annulets; and the third for the hypotrachelion. The columns are diminished in the same manner as described for Ionic columns in the third book.

"The height of the epistylium with the tenia and guttæ is one module. The tenia is the seventh part of a module.

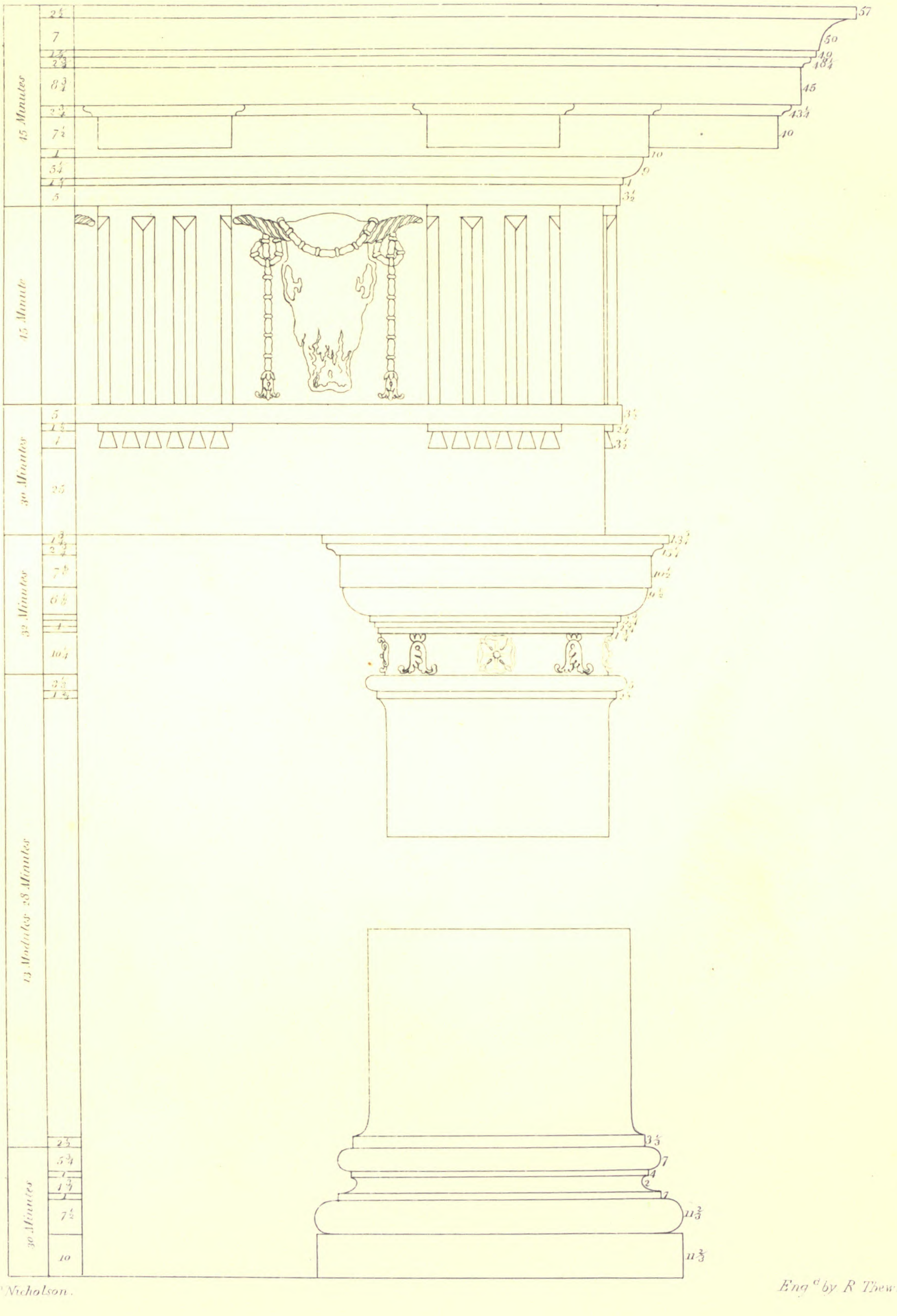




Drawn by P. Nicholson.

DORIC ORDER, PLATE 2.

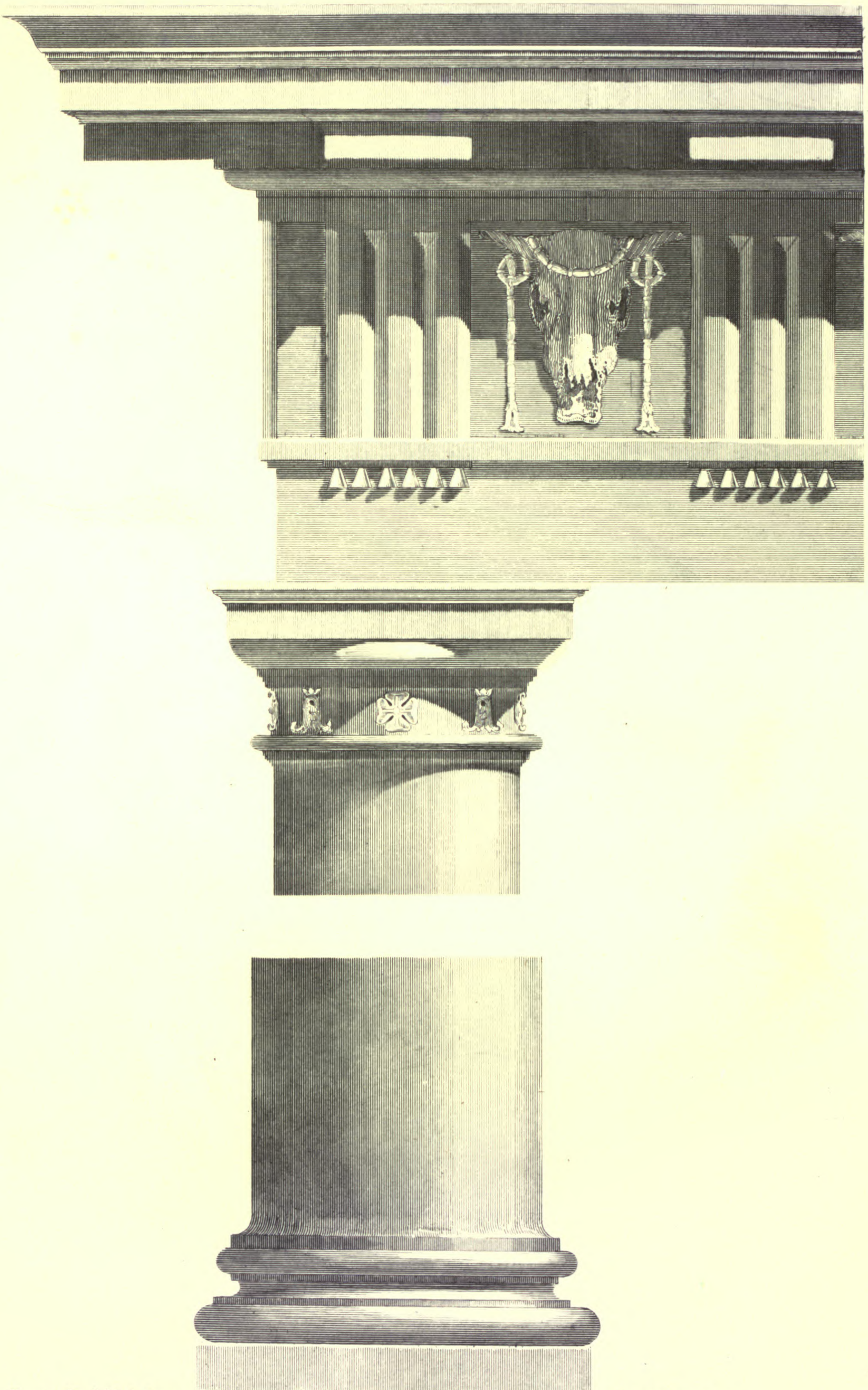
FROM SIR WILLIAM CHAMBERS.



Drawn by P. Nicholson. Eng^d by R. Thew.

DORIC ORDER, PLATE, III.

MODERN.



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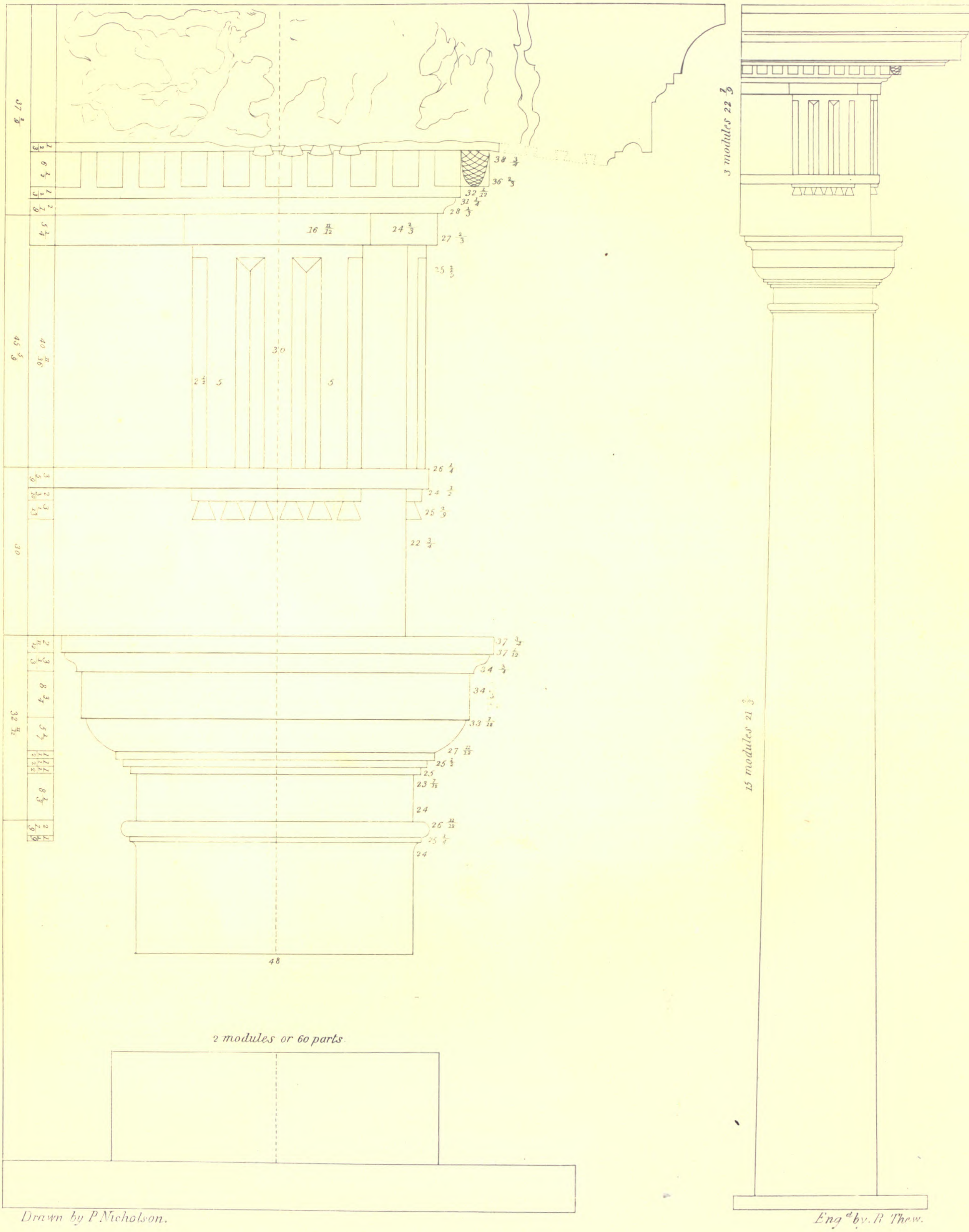
DORIC ORDER.

FROM THE THEATRE OF MARCELLUS AT ROME.

PLATE IV.



Drawn by P. Nicholson.

Eng.d by R. Thew.

The length of the guttæ, under the tenia, coincides with the perpendicular of the triglyphs. Their height, with the regula, is the sixth part of a module. The breadth of the bottom of the epistylium answers to the hypotrachelion at the top of the columns.

"Upon the epistylium, the triglyphs, having the metopes between them, are placed; being one module and a half high, and one module broad in front; they are so distributed, that those which happen over the angle, as well as over the intermediate columns, may be perpendicular to the middle quarters thereof; two are left in the intercolumns; and in the middle intercolumn of the pronaos and of the posticus, three; for, by this enlargement of the middle interval, the approach to the image of the god is rendered more commodious and free from impediment.

"The breadth of the triglyph is divided into six parts; of which, five are placed in the middle, two and a half being on either side. The middle one makes the regula, or femur, which the Greeks call meros. On either side this, are the channels, sunk as if imprinted with the elbow of a square. To the right and left of these, another femur is formed, and at the extremities, semi-channels are slanted.

"The triglyphs being thus disposed, the metopes, which are between the triglyphs, are as high as long. At the extreme angles, semi-metopes are impressed, half a module broad. Thus, the metopes, intercolumns, and lacunars, being regularly distributed, all defects will be avoided. The capital of the triglyph is made the sixth part of a module.

"Over the capital of the triglyphs, is placed the corona, projecting the half and the sixth part of a module, having a Doric cymatium below, and another above. The thickness of the corona, with the cymatiums, is half a module. In the under part of the corona, perpendicular to the triglyphs, and to the middle of the metopes, the directions of the viæ, and the distribution of the guttæ, are to be so contrived, that there may be six guttæ in length, and three in breadth. The remaining spaces (the metopes being broader than the triglyphs) are left plain, or have the sculptures of thunderbolts. Near the edge of the same corona a line is enchased, which is called scotia. The tympan, sima, corona, and the rest, are executed in the same manner as has been described for the Ionic order.

"The foregoing is the method for composing diastyle works; but if the structure is to be made sistyle and monotriglyph, the front of the temple, if tetrastyle, is divided into twenty-three parts; if hexastyle, into thirty-five. Of these, one part will be a module, by which the work is to be regulated, as before written. Then, over every epistylium, two metopes and triglyphs are disposed. In the angles, this species is larger than the former by as much as the space of the bisected hemitriglyph. So that there happens in the middle epistylium, under the fastigium, the space of three triglyphs and three metopes, for the enlargement of the middle intercolumn renders the entrance of the temple more spacious, and gives an appearance of dignity towards the statue of the god.

"Upon the capital of the triglyphs the corona is to be placed, having, as before said, a Doric cymatium at bottom, and another at top. The thickness of the corona, with its cymatiums, is half a module. The under part of the corona, perpendicular to the triglyphs and to the middle of the metopes, is to be divided, for the direction of the viæ, and the distribution of the guttæ; all the rest are the same as has been mentioned in the diastyle species.

"The columns are to be wrought in twenty striæ, which, if made flat, form twenty angles; but if they are hollowed, they are to be thus performed: A square is described whose sides are equal to the interval of a striæ; in the centre of the square, the central point of the compasses is placed, and a circular line drawn touching the angles of the square; and that portion of the curve which is between the lines of the circle and the square, forms the hollow of the striæ. Thus, the Doric column will have its proper kind of striature. With regard to the swelling which it has in the middle, it is the same as has been described for Ionic columns."

To exemplify this order, and illustrate the true Grecian Doric, we have chosen that beautiful specimen from the magnificent portico of the Parthenon, at Athens, exhibited in *Plate* I.: the proportions are numbered in minutes, in the usual way. The outline exhibits the profile of the flank, and the finished order shows the profile on the front of the portico, adjoining that represented by the outline.

Plate II.—Outline of the modern Doric.

Plate III.—A finished plate of the same, from Sir Wm. Chambers, who took his example from Vignola.

Plate IV.—Roman Doric, from the theatre of Marcellus, at Rome; showing both the outline and finished plate.

DORMAN, a cross beam.

DORMAN-TREE, a joist, or sleeper.

DORMANT, or DORMER, a window made upon the sloping plane, or side of a roof, with a glass frame perpendicular to the horizon.

Dormer windows occur frequently in domestic edifices of the Gothic style, in which they form a very picturesque feature. Their frequency is especially remarkable in the old halls, &c., of France and Flanders.

DORMANT-TREE, see SUMMER.

DORMITORY, a sleeping room.

DORON, the Grecian palm, whence their bricks were called *tetradoron*, and *pentadoron*.

DOS D'ANE (French), an obtuse ridge, formed by the intersection of two inclined planes. The term is synonymous with our word, coped.

DOSEL, or DOSER, a rich hanging of tapestry or other stuff, or screen of ornamental woodwork employed to decorate the back of an altar, throne, &c.

DOUBLE VAULT, two vaults of brick or stone, carried up separately, and including between them a hollow or cavity, such as that of St. Peter's, at Rome.

DOUBLE BUILDING, one in which the walls are carried up double; sometimes cellars are carried up with double walls, and double vaults, so as to include a cavity of air in order to keep the wine cool.

DOUBLE COLUMN. *See* COLUMN.

DOUBLE CURVATURE, the curvature of a curve, of which no part can be brought into a plane, such as the cylindro-cylindric curve, &c.

DOUBLE DOORS, those where two doors are made in the same aperture, in order to keep the apartment warm. *See* DOOR.

DOUBLE FLOOR, one constructed of binding and bridging-joists. *See* FLOOR.

DOUBLE-HUNG SASHES, are those where the window consists of two sashes, each of which is moveable by means of weights.

DOUBLE MARGIN DOOR, that which represents two doors in the same breadth, but is, in fact, only one door. *See* DOOR.

DOUBLE TORUS. *See* MOULDING.

DOUBLE WINDING STAIRS. *See* STAIRS.

DOUBLING, the same as eaves-boards; the term is used in Scotland.

DOUCINE, or DOUCHINE, (from the French), the *sima-recta*.

DOVE-COT, a small building or box in which domestic pigeons breed.

DOVE-TAIL, in joinery, a piece of wood formed like the tail of a dove.

DOVE-TAILING, the method of fastening one piece of wood to another, by projecting pins, cut in the form of dove-tails in one piece, and let into hollows of the same form in the other. Dove-tailing is either exposed or concealed; concealed dove-tailing is of two kinds, lapped and mitred.

DOVE-TAIL MASONRY. *See* MASONRY.

DOVE-TAIL MOULDING. A moulding used in Norman buildings, so called from the shape of the running ornament employed in its decoration, which consists of a fillet, tracing in its progress the form of a dove-tail, the alternate dove-tails being inverted, and having one side common to both.

DOVE-TAIL NOTCH, a *common* dove-tail notch is that where the bottom is in the form of a trapezoid.

An *undercut* dove-tail notch is that where the bottom is a parallelogram of greater breadth than the width of the parallelogram cut out of the surface; the excess in breadth being alike on both sides.

DOVE-TAIL SAW, a saw used for dove-tailing. Its plate is about 9 inches long, and has about 15 teeth in every inch; a rigid iron or brass back is added, to give stiffness to the plate.

DOWEL, the pin or tenon used in joining together two pieces of any substance. This pin or dowel is of wood or iron, and is thus used. Holes corresponding to each other are made in the boards to be joined; one-half of the pin is inserted into the hole in the one piece, and the other piece is then thrust home on it.

DOWELLING, or DOWELING, the fastening together two boards by the method above described.

DRAG, a term applied to anything bearing down, or rubbing upon another; thus, a door is said to drag, when its hinges are so loosened, that the lower edge rubs upon the floor: and the term is also applied in masonry to a thin plate of steel indented on the edge, used for finishing the dressing of soft stone which has no grit.

DRAGON-PIECE, a beam bisecting the wall plate, for receiving the heel or foot of the hip-rafters. It is most commonly a very short piece of timber, fixed at right angles into another piece, called the *angle-tie*, or *diagonal-tie*, which is again supported by each adjoining wall-plate being cocked down thereon.

DRAGON-BEAMS, according to Neve, are said to be "two strong braces or struts, that stand under a bressummer, meeting in an angle under the shoulder of a king-piece." —Neve's *Builder's Dictionary.* The writers of the present work have never heard the term applied to story-posts and bressummers, nor have they been able to learn any such application of it; the word *beam* is improper for any piece of timber, that stands slanting as a brace or strut. Neve's *Builder's Dictionary* was an original work; and it is probable that the author, who subscribes himself "Philomath," (a lover of learning) instead of architect, carpenter, joiner, mason, &c., might have been misinformed by the workmen, among whom he made his inquiries. The *Builder's Dictionary*, in two volumes, was copied from Neve, as was the *Dictionary* of the first volume of the *Builder's Magazine;* and we may farther add, most of the Cyclopædias and Encyclopædias have applied the term in the same way as Neve, and have used the same words in describing it. But with regard to the application of the term *dragon-piece*, as it is defined above, we can refer the reader to the oldest books that are published; see page 230, in the *Rules for framing roofs*, at the end of Godfrey Richards' *Palladio*, where that author says, "3. Dragon-beams for the hip to stand on," and immediately following, he says, "4. Beam or summer, wherein the dragon-beams are framed;" referring at the same time to *Figure* c, or Plate c; see also our review of carpentry, at the end of Godfrey Richards' *Palladio.* The sense in which Godfrey Richards uses the term, is the same as that now in use. It is true, that Moxon explains dragon-beam in the same way as Neve, but he refers to no figure. The second edition of Godfrey Richards' *Palladio* is dated 1676, and the first edition must be much more early. The first edition of Neve's *Builder's Dictionary* is dated 1703; we have also the corroboration of Batty Langley, see *Plate* II. of the *Addenda*, consisting of fourteen plates of roofs, at the end of his designs, where he says, "*a e*, *b e*, *c e*, *d e*, dragon-pieces to receive the feet of the hip-rafters" so that Godfrey Richards and Batty Langley apply the same meaning to the term. We have been thus particular, because a proper explanation of the word, as it is used, has not been given, and to show that it is an injury to a work, to describe a term which has no existence, or, if it has, must be confined to some remote corner.

DRAIN, a subterraneous passage for water. If a building is obliged to be erected in a damp soil, it will be proper to drain the ground before the foundation is laid. In large buildings, there must be one principal drain, and several smaller ones, depending on the extent of the ground; and observe, that those with circular bottoms are better than those which have straight ones, as the water will run much deeper in the former, than in the latter, and will consequently clear away the sediment much easier. The large drain ought to be of sufficient height to admit a person to clean it with ease. Circular, barrel, or cylindric drains, are much stronger than common drains, in which the sides are formed by vertical walls. *See* DRAINAGE and SEWERAGE.

DRAINAGE. As we shall have occasion to treat this important subject at some length, and as, in so doing, it is desirable to consider the question both in its more comprehensive and general sense, as well as in its details, we shall refer the reader to the article SEWERAGE. Under that head, we shall enter fully into the various methods of house drainage, as suggested by the improved knowledge of modern times, and describe the extensive works which have been constructed for this purpose in the metropolis. See CLOACA, SEWER, SEWAGE.

DRAUGHT, in architecture, the representation of a building on paper, explanatory of the various parts of the exterior and interior, by means of plans, elevations, and sections, drawn to a scale, by which all the parts are represented in the same proportion as the parts of the edifice intended to be executed. All the horizontal parts are explained by plans; the faces of the vertical parts are represented by elevations and sections; particularly, when the plane of delineation is parallel to the faces to be represented. The vertical dimensions of buildings upon circular and polygonal plans are understood from the elevations and sections. In complex buildings, besides the general plans, elevations, and sections, a set of drawings should be made to show the detail of the small parts.

In addition to the drawings which are used in conducting the work, a perspective representation of the exterior should be furnished by the architect, in order to show the general appearance and effect of the intended edifice to the employer, and perhaps, in some instances, two or more perspective representations will be necessary, in order to bring more parts into view, which should be drawn to such points as those in which the building will be most generally seen.

When several stories of a building differ in their construction, each story requires a separate plan. The sections are generally parallel to the sides of the edifice, taken through the most complex or principal part. Most buildings require at least two sections, some many more. When the sides of a building are dissimilar, as many elevations will be necessary as the edifice has sides.

The number, the form, and disposition of rooms are shown by the plans. The architect who gives the design of a building, ought to be well acquainted with the constructive parts of carpentry, masonry, and bricklaying, before he commits his ideas to paper, or otherwise he may be liable to public censure. See Design.

Draught, in mechanics, the force or power necessary to move any machine, as a horse-mill, waggon, cart, plough, &c.

Draught, in carpentry and joinery; when a tenon is intended to be pinned to the cheeks or sides of a mortise, and when the hole through the tenon is put nearer to the shoulder than the holes through the cheeks of the mortise from the abutment, which receives the shoulder of the tenon, or which comes in contact with the shoulder of the tenon, the pin is said to draw, or have a draught.

Draught, in masonry, a part of the surface of the stone hewn to the breadth of the chisel on the margin of the stone, either according to a curve or straight line, as the surface of the stone is to be reduced to a plane or curved surface. When the draughts are formed round different sides of the stone, the intermediate part is wrought to the surface, by applying a straight-edge or templet. In large stones, particularly when the substance is required to be much reduced, sometimes several intermediate parallel draughts, dividing the stone equidistantly in its length, are made, and thus the intermediate parts may be hewn down nearly by the eye, without the application of the straight-edge or templet.

DRAUGHT COMPASSES, those provided with several moveable points, to draw fine lines in architecture. See the words Compass and Mathematical Instruments.

DRAW-BORE, when a mortise and tenon is intended to be pinned, by piercing the hole through the tenon, nearer to the shoulder than the holes through the cheeks from the abutment, in which the shoulder is to come in contact, the mortise and tenon is said to be draw-bored: see the following word.

DRAW-BORE PINS, pieces of steel, made in the form of the frustum of a cone, but rather taper, and inserted in handles, with the greatest diameter next to the handle, for driving through the draw-bores of a mortise and tenon, in order to bring the shoulder of the rail close home to the abutment on the edge of the style; when this is effected, the draw-bore pins, if more than one be used, are to be taken out one at a time, and the holes immediately filled up with wooden pegs.

DRAW-BRIDGE, in general, a bridge constructed of several boards nailed or bolted to a frame. This being fastened at one end, by means of strong hinges, to a beam laid horizontally, and parallel to the frame, and being acted upon at its other extremity by levers, or by chains, worked either by wheels or by hand; the platform thus constructed may be raised to a perpendicular direction. Drawbridges are usually placed over narrow ditches, in fortresses, at the ends of great bridges, and especially over the excavations close to the gates, so that they may be raised or let down at pleasure.

When drawbridges are made close on the outside of the gates, the masonry ought to be sunk so as to admit of the whole depth of the frame to lie within it; else the oblique fire from the besiegers' batteries would act on the edge of the frame, and soon render it unserviceable. In canal navigation, and in wet docks, swing bridges, that turn horizontally upon one end as an axis, have almost wholly superseded drawbridges. See Iron Bridge.

DRAWING, in its strict meaning, may be defined as the art of representing objects, on any convenient surface, by lines describing their form and contour. This is independent of colour, and even of shadow; because, notwithstanding form may be expressed by outline alone, shadow, while giving surface and substance, must be dependent upon form, and, in many cases, requires to be accurately defined according to the rules of perspective.

Before proceeding to describe the process of ordinary architectural drawing, we shall venture to insert some caustic, though just observations of Mr. Bartholomew, on this necessary study.

"There is no small boasting, in the present day, of architectural drawing. An architect cannot draw too well; but when he obtains much practice, he will find, that, besides designing the form and the details of his works, he has little time for drawing; in general, he has as little time for making the clean and fair copies of his drawings as the sculptor has for the stone-cutting department of his art; while, if he cannot design, and is unacquainted with the other many branches of knowledge which he should possess, he should cease to call himself an architect.

"In making drawing his sole study, (but with the interruptions which business will naturally bring,) the pupil becomes only a bad artist, and no architect at all. The pernicious folly of imagining, that he who can make an architectural drawing must of necessity be able to make an architectural building, has wrought largely towards the ruin of real architecture, and has tended more than any thing else to fill our metropolis, and other places, with white-washed and even stone ruins, which the weak have mistaken for architecture, and has led to that general disregard to structural propriety, which is the besetting sin of modern works.

"Now, the time spent in learning to draw badly; a work without truth, without philosophy, without art, without structural excellence, without geometrical ground-work, without adaptation to its purpose, without real beauty, either abstract or obvious; this time, so misemployed, might have been successfully employed by him (were architectural education such as it should be) in, by the age of twenty-five or thirty years at the utmost, learning thoroughly all the known arts of trussing, of roofing, of vaulting, of doming, of framing arches, pyramids, and all other parts of architecture in structural perfection. This safe ground-work, with the necessary growth of mind, expansion of power, freedom of ability, would lead the professing architect to soar aloft, over all the chained spirits who fancy a few water-colours alone can raise them above San Micheli and Palladio—above Wren and Chambers. They know they cannot surpass Raffaello and Buonarotti in drawing; yet they do not consider that they might with ease surpass them both in architectural design and construction: thus they choose that competition in which they cannot succeed, and neglect the one in which they might gain an easy victory. They might be the first of architects, but they choose rather to be the last of artists: instead of gazing with an astonished ignorance upon ancient buildings, they might as much surpass them as the science of the moderns surpasses that of the ancients."—'Bartholomew's Specifications for Practical Architecture.' However severe these strictures may appear, there is great truth in them, and they deserve the serious attention of the student.

Drawing is the basis of architecture, engraving, and painting; and may be divided into outlines and shadowing. The outline, or contour, represents the boundaries of an object, as they appear to terminate against the back ground; the outline, as its name implies, takes in all the parts of the body. The interior parts are marked by lines, if such be distinct on the body, and the different inclinations of the surface are defined by depth of colour, in proportion to the inclination.

In fanciful objects, whatever the figure may be, the general form should be first sketched out slightly, that what is found to be amiss may be more easily removed, and corrections more easily made. Estimate as nearly as you can the principal points of the original, and fix dots at proportional distances, disposed at equal apparent angles on your paper; then draw your lines carefully to them, beginning at the upper part, and working either from the right to the left, or in the contrary direction, according to their tendency downwards. Put in the divisions first, and when these are nearly right, mark in the smaller parts; then, having got your work altogether, examine it scrupulously, rubbing it gently with a piece of bread, in order to render the lines more obscure: revise and correct the whole as often as it may be found necessary. Compare all the parts of the copy with the original, in every direction, first horizontally and then vertically, from a given point, which may be supposed to be the centre of the picture.

Beginners should make their drawings of the same size as the original, in order to exercise the eye in measuring with exactness; after some practice, however, it will be better to vary the size from the original, in order to acquire the habit of estimating distances, that, when combined, will form parts, similar to the whole, as also to the whole mass or general contour.

After the outlines are finished, the learner may proceed to the shadows; the first lesson should be simple, only indicating the principal projections. The simplest method of forming these is, by repeated lines nearly parallel to the outline, and as he advances with more shades, these lines should be crossed by other equidistant lines. This manner of sketching constitutes that peculiar manner of drawing called *hatching*, a mode very well calculated to give freedom of hand in any style of drawing. The chief things to be attended to are, that the lines conform as much as possible to the original, bearing all their inflections in the same ratio; the intersections should not be too violent, nor the lines so strong as to have the appearance of net-work.

In architectural drawing, the shadows are made out by washing or tinting the paper with Indian ink, sepia, or bister, laid on with a camel-hair pencil: this may be done in two different ways; the one is by laying down the shades as nearly in their places as possible, with tints sufficiently dark, and softening off the edges with a clean pencil and water, and when dry, the process may be repeated again, as often as may be found necessary; the other is by working with very light tints at first, in blotches placed near each other, then blending these by a faint wash over the whole, and when nearly dry, strengthening them by filling up the interstices with other blotches: thus, by repeated blotches, the surface will acquire the degree of tint required in the various parts. This mode is called *stippling*, and in the hand of an artist is perhaps the best, at least for finished drawings. In the shadows of anything projecting from a surface, we shall, for the sake of example, suppose a pole projecting from the surface of a wall, at a considerable distance from it; the outline of the shadow next to the foot of the pole will be very dark and definite, but in proceeding towards the extremity, the edge becomes more penumbral, and at last, in a very extended shadow, is hardly definite. All shadows are darker nearer to the body than those which are more remote; attached columns and pilasters will throw a stronger shadow than insulated columns upon the wall behind, and the projections of the shadows of insulated columns will be darker, and more defined upon their edges, than those which are placed at a greater distance from the wall, and, again, the middle part of the shadows will be darker than the edges.

The shadow of a plane figure falling upon a plane parallel to it, will form a figure similar and equal to that which throws it, as the shadow of all lines on a plane, parallel to these lines, will also be parallel to the same lines which project them. Besides what has been already hinted above, there is another method, which is excellent for mouldings, particularly when small, viz., to use very little ink in the pencil; let us, for example, suppose we were to shade a moulding: take the camel-hair pencil with so little ink that it cannot run, or that it will dry the instant it is put on the paper, and run it the whole length of the moulding, upon that part which requires to be the darkest; then repeat the process in the same manner, by making the tint broader, or to spread farther over; repeat in this manner, by making the last tint spread over each edge of the preceding, keeping the edges of every tint as straight and parallel as possible, until the moulding has acquired its full variety of tints, so as to represent all the various inclinations of the original surface. If any part appear too light, it is only necessary to go over that part again, touching only the part that is too light. Or, the learner may begin the reverse way, by making the broad tints first, and proceed to make narrower and narrower tints each time.

In shadowing a cylinder of considerable width, begin at the line of demarcation of light and shade, where a plane from the luminary would touch the curved surface in a straight line of contact, and having gone the whole length of this line with a tint, soften the edges with water. Proceed in the same manner the second time with a broader tint, covering the edges of the former, and washing off the edges as before, thus continually spreading each repeated tint, until you come to the line of light, viz., where a plane extended from the luminary to the axis of the cylinder, included in the plane, would cut the surface of the cylinder. Then from the opposite edge of the representation of the cylinder, lay a light tint close to the line, as narrow as it can be put on, and soften the edge of it next to the line of light; lay a broader tint next time, and soften the edge in like manner, next to the line of light; proceed in this manner, until you come again in contact with the line of light; observing, that the depth of colour in receding from the line of light in the parts which represent equal distances, should be the same, or of an equal degree. In washing towards the line of light, the washes must be lighter and lighter, as too much colour will destroy the delicacy necessary to be preserved in the light part. If, after all, any part should appear to be too light, the defect may be made up by tinting that part only, with very little ink in the pencil. For other information, concerning the manner of preparing the tints, we shall refer to the article SHADOWING.

DRAWING-KNIFE, an edged tool, made sharp at the end, for cutting a deep incision into the wood, along a straight-edge, the edge of a square or templet, in order to enter the saw without ragging the wood. A chisel or firmer is sometimes used instead of the drawing-knife. In joinery, the drawing-knife is useful in rebating across the grain, cutting the shoulders of tenons, grooving across the fibres.

DRAWING-ROOM, a principal apartment of a great mansion, or nobleman's house, to which it is usual for company to withdraw after dinner, and in which formal visits are received. *See* DINING-ROOM. In small houses, the drawing-room may communicate with the dining-room, but in large houses, it will be no detriment, and might even be preferred by many, if the library, or an ante-room should intervene. The term is frequently written *withdrawing-room. See* ROOM.

DRAWING-SLATE, a soft stone of fine grain, used as a marking or drawing material. It is sometimes called *black chalk.*

DRAWINGS, *Working, See* WORKING DRAWINGS.

DRAWN THROUGH OR ALONG THE AXIS, OR THROUGH OR ALONG A STRAIGHT LINE, is when a plane meets a straight line, so that all parts or points in the line are also in the plane.

DREDGING. The operation of removing mud, silt, and other depositions from the bottom of harbours, canals, rivers, docks, &c., by means of a DREDGING MACHINE.

DRESS, in masonry, to prepare stones for building.

DRESSED, the preparation that a stone requires before it is ready to be used in building, &c. Stones are dressed sometimes by the hammer only, thence termed hammer-dressed; sometimes by the mallet and chisel, the face afterwards being rubbed smooth. In Scotland the term is only understood of hammer-dressing.

DRESSER, a kind of bench or table, with drawers, set in the kitchen, used for culinary purposes: it is generally reckoned as a fixture of the building, or a part thereof.

DRESSING-ROOM, a room adjoining a sleeping-room, used for dressing in, as its name implies. A dressing-room ought to have two doors, one to communicate with the sleeping-room, and another to communicate with the passage, for the valet, or servant.

DRESSINGS, all kinds of mouldings projecting beyond the naked of walls or ceilings, are called by the general name of *dressing.* In joinery, the architraves of apertures, or other appendages, as also the projecting moulding used as a finish, is called *a dressing,* and frequently *facing.*

DRIFT, the horizontal push or force, which an arch exerts from the gravitation of the stones, which are kept from descending by the inclination of the beds of the arch, and the resistance of the pier. The terms *shoot and thrust,* are also employed to express the same idea.

DRIP, the edge of a roof; the eaves; the corona of the cornice. *See* LARMIER, CORONA.

DRIPPING EAVES, when the slope of a roof is continued downwards, so as to project over the roof of a building, the part thus projecting over is called *dripping eaves,* in contradistinction to those roofs that have blocking courses, which run above the slope of the roof, and which have gutters behind for carrying off the water. Dripping eaves are prohibited, in the city of London, by the Building act.

DRIPS, steps made in flat roofs, to walk upon. This way of building is much used in Italy, where the roof is not quite flat, but a little raised in the middle, otherwise the steps would have no rise.

DRIPSTONE, the projecting moulding or cornice over windows, doorways, &c., is called a dripstone. Its use is to throw off the rain, and in some of the old buildings in the country, it has been made of an ornamental character. The dripstone is of various forms, and when a head is not used as a termination or support, a simple moulding is adopted. It is also called label, weather-moulding, and water-table.

The term *dripstone,* however, is more particularly applied to the boss at the termination of the moulding from which the rain drips, after being conducted down the moulding; the latter is distinguished by the appellation of *weather-moulding.*

DRIVER, *Pile. See* PILE DRIVER.

DROPS, in architecture, small pendent cylinders, or the frustums of cones attached to a vertical surface, the axis of the cylinders or cones having also a vertical position, and their upper ends attached to a horizontal surface.

Drops are used in the cornice of the Doric order under the mutules, and in the architrave under the triglyphs. Each mutule has three rows from front to rear, with six drops in each row, disposed at equal distances, in lines parallel to the front. The drops upon the architrave are also six feet under each trigylph, disposed also equidistantly. Drops in the form of frustums of cones, are only peculiar to Roman architecture, and to some of the temples of Pæstum; there are some Grecian-Dorics, however, wherein the drops in their vertical section have the upper part nearly parallel, and terminate below with a concavity, the part above being a tangent to the curve. In the Roman-Doric, the surface of the metopes is the same with that of the architrave, and the vertical surface of the trigylph projects at the same distance as the drops, which are hung from the tenia. In the Grecian Doric, the faces of the triglyphs are generally disposed in the same vertical surface with the face of the epistylium, and consequently, the regula and drops pending therefrom project. The Doric portico at Athens, the portico of Philip king of Macedon, and the temple of Apollo in the island of Delos, are instances wherein the surface of the epistyle is within the surface of the triglyph; but it is to be observed, in the two latter examples, that there is a drop in each angle common to every return face. All examples of the Doric order, except the portico of the Agora, or Doric portico, at Athens, have the sides of each extreme drop under the regula in the same vertical line as each edge of the triglyph above, and the whole six drops are contained within the perpendiculars, by producing the edges of the triglyphs.

In all the drops of the Doric architraves to be met with, the horizontal sections are circles, increasing towards the bottom of the drops, or of a cylindrical form, except in the instance of the temple of Apollo at Cora, in Italy, where the soffits of the drops in the architraves are inclined. It is singular, that in this example, the drops pending from the corona are continued equidistantly without interruption in three rows, two behind the front row; and that those pending from the corona are perfectly cylindrical, with level soffits, while those pending from the regula are conical, and have inclined soffits, which form an obtuse angle with the face of the epistyle. In the choragic monument of Thrasyllus, the tenia of the epistylium has a continued row of drops, but this example cannot be accounted a Doric order, having no other peculiarity to the Doric composition.

The drops pending from the soffits of the mutules, have their soffits in a plane parallel to the soffits of the mutules, and consequently, inclining; while those of the epistyle have their soffits in a horizontal plane.

The height of the drops in the cornice of the Doric portico at Athens, is little more than one quarter of their diameter, while those of the epistyle have their height more than half their diameter.

In the peripteral temple at Pæstum, the corona has no pending mutules, nor any drops. In the theatre of Marcellus at Rome, there are no mutules, the interstices between the drops are formed by excavating upwards into the soffit of the corona, and are covered on the front with a moulding, which has its soffit in the same inclined plane with the soffits of the drops, so that the drops show no geometrical elevation. In the enneastyle, or nine-column temple at Pæstum, the cornice is destroyed, and the architrave seems to have been originally without either mutules or drops.

The term *guttæ* is also applicable to what we have called *drops*.

DROVED ASHLAR, a term used in Scotland for chiseled, or random-tooled ashlar. It is the most inferior kind of hewn work used in building. It is true, that what is there called broached work, is sometimes done without being droved, but in good broached work, the face of the stone should be previously droved, and then broached. See the article MASONRY.

DROVED AND BROACHED, a term used in Scotland, in a more specific manner than that of broached work; see the preceding word.

DROVED AND STRIPED, work that is first droved and then striped: the stripes are shallow grooves done with a half or three-quarter inch chisel, about an eighth of an inch deep, leaving the droved interstices prominent. These kinds of hewn work are not used in England, or at least very seldom; the work is either regularly tooled, or rubbed smooth.

DRUIDICAL TEMPLE, stone pillars, arranged in the circumference of the circle, surmounted with an architrave or entablature, such as Stonehenge. *See* CELTIC ARCHITECTURE.

DRUM, a cylinder, generally formed of cast-iron, but sometimes of wood, and used on the inclined planes of railways, for receiving the rope which is wound round the surface of its periphery, by which movement the waggons are conveyed along the line. Drums are used when the plane is worked by a single rope.

DRUM, of the Corinthian and Composite capitals, the solid part, in the form of a vase, to which foliage, stalks, and caulicoli are attached. The drum is otherwise called *vase*.

DRUM. *See* DOME.

DRY-ROT, a highly destructive vegetable disease, affecting the timber in the foundations, and other parts of buildings, in particular soils and situations. It affects the wood, or ligneous parts, in such a manner, as to leave it connected by nothing but the small hard fibrous portions, which give it a curious tremulous appearance, but all of which, when touched by the hand in the more advanced stages of the disease, readily moulder into a brownish snuff-like dust. It is attended with a peculiar earthy smell, similar to that which issues from wood fresh dug up after having lain some time in the ground in contact with decaying animal matter, and is materially different from that natural sort of decay which takes place in wood from the presence of wetness.

On the causes of this decay numerous volumes have been written, and equally numerous have been the nostrums for its prevention or "cure." There can be little doubt that, in very many cases, dry-rot has been engendered by the extreme wetness of the timber, caused by its long immersion in the water, in docks, canals, &c. In our hastily-constructed buildings, the timber, after having been thus swelled by soaking too much beyond its former and its ultimate bulk, is frequently framed together while in this wet state, and it cannot be surprising that the dry-rot soon appears as a natural consequence of such unwise proceedings.

It has been said, that moist and warm situations, where the circulation of the air is impeded, is the generating cause of this disease; that the effluvia from timber so diseased, will carry their effects to the circumjacent timber; and that any sort of wood, dry as well as damp, so exposed, will be soon destroyed. Timber once infected cannot be restored, and the only remedy lies in cutting away the diseased parts, to prevent the extension of the evil to the remainder; and to effect even the latter, a free circulation of air must be admitted, and the parts be washed over with a strong solution of iron, copper, or zinc. Patents have been granted for various applications of the latter, as preventives of the dry-rot, the distinguishing features of the processes therein employed consisting in first preparing the timber by a good steaming, or drying out of the sap, and afterwards injecting, soaking, or boiling the timber in a solution of copperas, or other metallic salt. The following observations on this important subject were some time since addressed to the editor of the "Engineers and Mechanics' Encyclopædia," by Mr. John Gregory, who is an experienced and observant shipwright; and as they appear to mark out clearly the true cause of, and to suggest a very simple remedy for, the evil, it is right to give them a place in this work. Mr. Gregory says, "Instead of squaring a piece of timber according to the usual method, by leaving the heart of the tree in the centre, my plan is to saw it right down the middle, through the heart, into two equal parts, immediately after the tree is felled; and my reasons for this I will now endeavour to explain, to the best of my ability. It is, I believe, a well-known fact, that a tree does not, literally speaking, *die* on receiving the final stroke of the axe, but that it continues for a long period afterwards to vegetate, though less vigorously. At length, however, the sap ceases to circulate, the pores become closed, and the juices of the tree thus shut up undergo decomposition, and lay the foundation of dry-rot. It is well known, that a man, who dies in a full habit of body, soon decays; the same effect takes place in a tree full of sap, unless we adopt the same method with respect to it as the Egyptians practised with the human body, viz., that of depriving it of all moisture, which process would give to our timber a durability almost everlasting. My mind has been long impressed with this idea, which has been confirmed by my having recently noticed, that several of the timbers, in a very ancient public building, which had been sawn originally in the manner I have proposed, were *perfectly sound*, although they had withstood the dilapidating hand of time for seven hundred years; while other timbers in the same building, which had not been so cut, but apparently squared out with the heart in the centre, were perfectly rotten. That the dry-rot is certainly caused by the juices being enclosed in the heart of the timber, I have had frequent opportunities of observing during my long practical experience in the repairing of ships. In the frame of a ship in which such large quantities of timber are employed, I have uniformly noticed: First, that the decay commences in the run fore and aft, which is owing to the timbers being fitted so close together at the heels or lower ends. The evil being thus enclosed in the hearts of the timbers, and the air having no access to the exterior of them to carry off the moisture by evaporation, internal decay is the necessary consequence. I have sometimes witnessed these parts of the frame of a ship in such a rotten state, as to have been justly compared by the workmen to a heap of manure. Secondly, those timbers in the midships that have been bored off with the outside planks, are not so affected, which I attribute to the circumstance of the holes admitting a current of air through them, the destructive juices being thereby carried off. Thirdly, it frequently happens, that the floor-timbers of an old ship are found, on breaking up, to be nearly as sound as they were when first put in. Their preservation seems to be owing to the effect of the salt water, which constantly laves over them, causing them to become, in a manner, pickled; or it may be, that the salt entering into the composition of the wood, the destructive effects of its natural juices are thereby prevented. Fourthly, the planks in the bottom, nearest to the timbers, take the infection first; and where the tree-nails are not close, the disease rapidly extends endways of the grain. Fifthly, those parts of the deck-planks that lie *upon* the beams are those which are first infected with the rot, the cause of which is evident, as those parts that are *between* the beams are generally quite sound. Sixthly, in the beams of ships the decay usually commences in the internal parts, which is decidedly owing, in my opinion, to the erroneous method of preparing the timber, as before-mentioned; but when timber, so prepared, is used, I would recommend, as the best preventive of the rot, that a few holes be bored through the beam fore and aft, and, what would still add to the benefit, to bore another hole lengthways of the grain, to meet those which are bored crossways. But the best preventive, I am confident, would be the adoption of my mode of preparing the timber, viz., to saw it lengthways right through the heart, by which not only greater durability would be obtained, but great economy in the consumption of the timber."

Though, as we have before observed, volumes have been written on the subject of dry-rot, the causes of it are still, perhaps, as little understood as ever; and, as was stated by Mr. Bramley, of Leeds, in a paper read to the Society for the Encouragement of Arts, &c., "to bring the matter to the test by experiments, would require the observations of a long period, and in selected situations." "Wood used for the general purposes of man," he observes, "is cut down at different periods; and although it may be felled at the proper season, or when most free from sap or moisture, it is not always to be effected. Nay, even admitting it to have been cut down in the most favourable situation, it still abounds with such an extra proportion of moisture, as to require a regular exposure to the air prior to its being applied to use, if we wish to guard against that shrinking which always takes place where this precaution has not been taken. And although the fir-kind contains less of this watery portion, yet it assuredly possesses a considerable share; and it is in this species, he apprehends, that the evil, called *the dry-rot*, most generally occurs; as, from the facility of working the same, it is most generally applied to buildings. But, supposing it to be fir, or any other species, wood felled when abounding with any extra proportion of sap, and applied to use without the proper seasoning or exposure to a free current of air, until such extra moisture has had time to exhale, is most liable to the disease in question; and the cure, or principal prevention against it, would be the precaution of felling all wood only at the proper season, or when the sap is not in circulation. The next mode of prevention would be to use such wood only as has been for a considerable period exposed to the influence of a free current of air, or, where convenience will admit, to that of air heated to a moderate degree; such air extracting, with greater facility, the enclosed moisture, and in a more certain ratio than the irregularity of our atmosphere will allow under other circumstances."

This is not the place for examining into the comparative merits of the different processes which have been introduced for seasoning timber. The most noted of these are Kyan's, Burnett's, Payne's, and Bethell's, all of which have been described by their advocates as perfect preventives of dry-rot; it is sufficient to say, that they have all been found successful, and have also all failed. The best preventive of dry-rot, in our opinion, is to have the timber thoroughly dry before it is converted, and to let plenty of air get to it when the building is completed.

DUBBING, in bricklaying, is replacing and making good any decayed brickwork, when the wall is to be repointed.

DUN, or BURGH, the name of an ancient species of buildings, of a circular form, common in the Orkney and Shetland Islands, the Hebrides, and northern parts of Scotland. The latter term points out the founders, who at the same time bestowed on them their natal name of *borg*, "a defence or castle," a Suco-Gothic word; and the Highlanders universally apply to these places the Celtic name *dun*, signifying a hill defended by a tower, which plainly points out their use. They are confined to the countries once subject to the crown of Norway. With few exceptions, they are built within sight of the sea, and one or more within sight of the other; so that on a signal by fire, by flag, or by trumpet, they could give notice of approaching danger, and yield a mutual succour. In the Shetland and Orkney islands, they are most frequently called *wart* or *ward hills*, which shows that they were garrisoned. They had their wardmadher, or watchman, a sort of sentinel, who stood on the top, and challenged all who came in sight. The gackman was an officer of the same kind, who not only was on the watch against surprise, but was to give notice if he saw any ships in distress. He was allowed a large horn of generous liquor, which he had always by him, to keep up his spirits. Along the Orkney and Shetland shores, they almost form a chain; and by that means not only kept the natives in subjection, but were situated commodiously for covering the landing of their countrymen, who were perpetually roving on piratical expeditions. These towers were even made use of as state prisons; for we learn from Torfæus, that after Sueno had surprised Paul, count of Caithness, he carried him into Sutherland, and confined him there in a Norwegian tower. Out of our own kingdom, no buildings similar to these are to be found, except in Scandinavia. On the mountain Swalberg in Norway is one; the Stir-biskop, at Upsal in Sweden, is another; and Umseborg, in the same kingdom, is a third.

In these buildings, there is no appearance of an arch; the wall, which consists of the best flat stones the workmen could find, is well laid, is in thickness about 14 feet, and in some instances not more than 12 feet high; the structure of a dun is upon a circular plan, about 20 or 30 feet in diameter. The door of entrance is very low, and was shut up occasionally with a broad flat stone. In some instances, where the stones were not flat or well bedded, the wall is found propped up with heaps of stones, like buttresses, on the outside; so as to give the whole more the appearance of a mount, than of a building, as is particularly the case with one at Lothbeg, in the parish of Lothis. The most entire dun is that at Glenby, not far from Inverness, and described by Mr. Pennant, in his voyage to the Hebrides; from whose very curious and original account, the following particulars are extracted:—

"It is placed about two miles from the mouth of the valley. The more entire side is about thirty feet six inches in height, and was, some years ago, about ten feet higher. The whole structure appears to have been, on the outside, of a conical form; but on the inside, the surrounding wall is quite perpendicular; so that it must have been much thicker at the bottom than at the top. It enclosed a small circular area of thirty-three feet and a half in diameter; and was constructed merely of flat stones neatly placed one upon another, without any cement or mortar. At ten feet from the ground it was found to be seven feet four inches thick; and within this thickness were two surrounding galleries; one quite in the lower part of the tower, about six feet two inches high, and two feet five inches wide at the bottom; but made narrower at the top; and flagged and covered with great flat stones. And the other gallery was placed directly over this, having these flag-stones for its floor, and being only five feet six inches high, and only twenty inches wide at the bottom; but covered at top, in like manner, with other great flat stones.

"This upper gallery, in which a man could barely make his way, went quite round the tower, without any division or partition; but the lower gallery, underneath this, is parted off into separate spaces, by great flag-stones placed upright; which several spaces, or little cells, were in general accessible only by means of holes in the floor or gallery above; so that nothing can be more obvious, than that these cells were intended for the keeping and preserving of stores; whilst the upper gallery cannot but remind us somewhat of the little gallery within the wall of the round tower at Brunless.

"Besides these galleries, there were, on the inside of the circular wall, open to the circular enclosed apartment, four perpendicular rows of small cavities, or, as they have been described by others, four stages or nests of small square open holes, dividing the interior circular wall into four parts, and turning up from the lower part of the tower to the top; each little hole, or nest, in the row, divided from that beneath only by a sort of shelf, or flag-stone, and forming a little cupboard.

"The appearance of this sort of little cupboards, as well as that of the sections of galleries, is similar to those in this tower, as they are seen in the wall of another dun, in the same neighbourhood. And these square cavities seem obviously to have been intended to hold the drinking horns, and other utensils for banqueting in these rude dens."

DUODECIMALS, a term applied to an arithmetical method of ascertaining the number of square feet and square inches in a rectangular space, whose sides are given in feet and inches.

In this series of denominations (beginning with feet) every unit in the preceding denomination makes twelve in that which succeeds it: that is, every foot contains 12 inches, or firsts; every first, 12 seconds; and so on. There will be as many denominations in the product as in both factors taken together.

Feet are either marked with or without an *f;* inches are called *firsts* by the mark thus (′) being placed above; *seconds* by the mark thus (″) being placed above; *thirds* thus (‴), and so on. In multiplying any two single denominations together, the value of the product will be known by adding the indices of the two factors. Thus, suppose $7''$ to be multiplied by $11'''$, then the product is 77^{v}, or 77 fifths, because adding the index ″ of the seven to the index ‴ of the eleven, produces v or fifths.

To multiply duodecimals together.—Write the multiplier under the multiplicand, so that the place of feet may stand under the last place of the multiplicand; begin with the right-hand denomination of the multiplier, and multiply it by every denomination of the multiplicand, throwing the twelves out of every product, and carrying as many units to the next; place the remainders, if any, under the multiplier, so that like parts in the product may be under like parts of the multiplicand; proceed with every successive figure of the multiplier, towards the left, in the same manner, always placing the first figure of the product under the multiplier; then the sum of the products will be the total.

Example 1.

Multiply 6..9′ by 3..6′

$\overset{ft}{6}..9'$
$\quad 3..6'$
3..4..6 = 6..9 × 6
20..3 = 6..9 × 3
Answer 23..7..6

Example 2.

Multiply 6..5′..4″ by 3..6′

$\overset{ft}{6}..5'..4''$
$\quad 3..6$
3..2..8..0 = $\overset{ft}{6}..5'..4''$ × 6
19..4..0 = 6..5..4 × 3
Answer 22..6..8..0

In the first example, there is only one place of duodecimals in each factor; there are, therefore, two places in the product. In the second example, there are two places of duodecimals in the multiplicand, and one in the multiplier, which make together three; there are, therefore, three denominations in the product.

Example 3.

What is the product of $\overset{ft}{4}..3'..2''..8'''..9^{iv}..5^{v}..3^{vi}$ by $3'..0''..5'''..0^{iv}..0^{v}..6^{vi}..2^{vii}$

$\overset{ft}{4}..3'..2''..8'''..9^{iv}..5^{v}..3^{vi}$
0.. 3..0..5..0..0.. 6..2
8..6..5..5..6..10..6
2..1.. 7..4..4..8..7.. 6
1..9..4..1..7.. 11..2..3
1..0..9..8..2..4..3.. 9
1..0..11..5..6..8..2.. 0.. 1..1..2..2..4..6

In this example, because there are no feet in the multiplier, the place is supplied by the cipher. The multiplicand has six places of duodecimals, and the multiplier seven; there are, therefore, thirteen places of duodecimals in the product. The first place of figures is feet, and the succeeding are the duodecimal places; the product is one foot, no inches, eleven seconds, five thirds, &c. But, independently of the consideration of there being as many places of duodecimals in the product as in the multiplier and multiplicand, the method of placing the denominations of the factors gives the correct places of the product, since like parts of the product stand under like parts of the multiplicand; it also shows the affinity, not only between duodecimals, but between decimals and every series of denominations, of which the same number in any place makes one of the next towards the left hand. The consideration is also useful, in discovering readily what kind of product arises by multiplying any two single denominations together.

When the number of feet runs very high in each factor, it will be much better to reduce all the denominations in both into the lowest, then multiply the factors, so reduced, and divide by 12 as often as there are duodecimal places in the product.

Example 4.

Multiply $\overset{ft}{6}..5'..4''$ by $\overset{ft}{3}..6'$ as in Example 1.

6 5..4″	3..6′
12	12
77	42
12	
928	
42	
1856	
3712	
12)38976	
12)3248	
12)270..8	
22..6..8 the same as before.	

Example 5.

Multiply $3^{ft}..6'..4''..6'''..5^{iv}..$by $0^{ft}..0'..5''..3'''$

$5''..3'''$ $3^{ft}..6'..4''..6'''..5^{iv}$

5..3	3..6..4..6..5	
12	12	
63	42	
	12	Proofs by duodecimals.
	508	$3^{ft}..6'..4''..6'''..5^{iv}$
	12	0..0..5..3
	6102	0..10..7..1..7..3
	12	1..5..7..10..8..1
	73229	1..6..6..5..9..8..3
	63	
	219687	
	439374	
	12)4613427	
	12)384452..3	
	12)32037..8	
	12)2669..9	
	12)222..5	
	12)18..6	
	12)1..6	
	0..1..6..6..5..9..8..3	

the product, the same as by duodecimals.

In this example, because there are seven places of duodecimals in the two factors, viz., four in the multiplicand, and three in the multiplier, the product 4613427 is divided seven times successively by 12.

There is another method of duodecimals, almost equally convenient. The rule is as follows: First.—Under the multiplicand, place the corresponding denominations of the multiplier.

Then multiply each denomination, from right to left, of the multiplicand, by each term of the multiplier successively from the left to the right, placing the first denomination of each row, or product, one place nearer to the right, and carrying one from every twelve in the product of any denomination, to that which succeeds it towards the left, up to the place of feet; then the sum of all the like products will be the total.

Example 6.

Multiply $10^{ft}..4'..5''$ by $7^{ft}..8'..6''$

$10^{ft}..$ $4'..$ $5''$ Multiplicand.
7.. 8.. 6 Multiplier.

72.. 6..11
6..10..11..4
5.. 2..2..6

79..11.. 0..6..6

Example 7.

Multiply $23^{ft}..4'..6''..7'''$ by $7^{ft}..8'..5''..10'''$

$23^{ft}..4'..6''..7'''$
7..8..5..10

163..7..10..1
15..7..0..4..8
9..8..10..8..11
1..9..5..9..5..10

180..2..4..10..2..4..10

Proof by the first method.

$23^{ft}..4'..6''..7'''$
7..8..5..10

1..9..5..9..5..10
9..8..10..8..11
15..7..0..4..8
163..7..10..1

180..2..4..10..2..4..10

There is the same number of figures in each operation, but in the last the products are inverted. The first method, which is here used to prove the second, is similar to the common method of multiplication of integers, the first place of figures of every product being placed under the second denomination towards the left.

When feet and inches only are concerned, the reader is referred to the articles CROSS MULTIPLICATION, and PRACTICE.

DWANGS, a term used in Scotland, for the short pieces of timber employed in strutting a floor.

DWARF WALLS, low walls of less height than the story of a building. Sometimes the joists of a ground-floor rest upon dwarf walls; and the enclosures of courts are frequently formed by them with a railing of iron on their top: indeed, any low wall used as a fence, may be termed a dwarf wall.

DWELLING-HOUSE. *See* BUILDING and HOUSE.

DYE, the plain part of a pedestal, contained between the base and cornice, in the form of a square prism, approaching frequently to a cube or dye, whence the name originates.

The dye of a pedestal is generally placed in the same vertical plane with the vertical sides of the plinths of columns; there is, however, an instance in the dye of the pedestals of the columns of the Stoa, or Portico, at Athens, where the dye recedes within the vertical sides of the plinths of the bases. The practice of using pedestals under columns, is bad at the best; but in this instance their employment is still more ridiculous, being contrary to the rules of true taste and philosophy.

DYE, is also used for a cube of stone, placed under the feet of a statue and beneath its pedestal, to raise, and show it to more advantage.

DYE. *See* DADO.

DYNAMOMETER, (*measurer of power*), a term which has been applied to an instrument for measuring force or power. The Dynamometer has been used by engineers for ascertaining the tractive power required in drawing carriages upon roads or vessels, upon canals, and also for measuring the relative force of men and other animals. These effects are usually manifested by the compression or distension of a strong spring, or by a steel-yard upon the principle of a bent lever balance; but in both these constructions the instrument is subject to great vibration, owing to the inequalities in the resistance and in the moving force, which render the indications very uncertain. A very ingenious application of the Dynamometer was made by Sir John Macneill, to the Road indicator, in experiments on the comparative condition of different descriptions of roads.

DYPTERON. *See* Dipteron.

E.

EARS. *See* Crosettes and Ancones.

EAGLE, in architecture, a figure of that bird anciently used as an attribute of Jupiter, in the capitals and friezes of the columns of temples consecrated to that deity.

Also a lettern, or reading-desk, used in churches, from whence the lessons are read. It is so called from its form, which is that of an eagle with outspread wings, on which the book is laid, sometimes represented as trampling under foot a serpent. The material is generally brass, and the image is supported on a stem of similar material, pierced and otherwise enriched. *See* Lettern.

EARTH-TABLE, the course of masonry or other work level with the ground.

EARTHEN FLOORS. *See* Floors.

EATING-ROOM. *See* Dining-Room.

EAVES, (from the Saxon,) the margin or edge of the roof of a house, which overhangs the walls, in order to throw off the water from the face of the masonry or brickwork.

Eaves Lath, or Eaves Board, an arris fillet, or thick feather-edged board, placed at the eaves of a roof, for raising the bottom of the first course of slates above the sloping plane of the side of the roof, so as that the next course may be properly bedded: that is, when the lower ends rest firmly upon those which form the eaves-course. It is sometimes also called *eaves catch.*

EBONY, a species of hard, heavy, and durable wood, which admits of a fine polish or gloss. The most usual colour is black, red, or green; but the best i sa jet black, free from veins and rind, very heavy, astringent, and of an acrid pungent taste. Ebony is wrought into toys, and is much used for mosaic and inlaid work.

ECATÆA, statues erected to the goddess Hecate, for whom the Athenians had a great veneration, believing her to be the overseer and protectress of their families.

ECBATANA, the capital of ancient Media, and the residence of the Median and Persian kings. It was situated in a plain, about twelve stadia from mount Orontes. Diodorus says it was 250 stadia in circuit. The walls were seven in number, built upon a circular plan, rising gradually above each other, by the height of each wall conforming in a great measure to the situation of the ground. In the book of *Judith*, we read that they were 60 cubits in height, and 50 in breadth; that the towers over the gates were 100 cubits in height, and the breadth of the foundation 60 cubits, and that the walls were built of hewn and polished stones, each stone being 6 cubits in length and 3 in breadth. The royal palace and treasury were within the inmost of the seven walls. Diodorus says, the timber of the palace was cedar or cypress; and various parts of it were cased with gold or silver. There are no monuments remaining of this superb palace, where the monarchs of Asia generally passed their summer; and it is rather to be lamented that a disagreement should exist among modern travellers, about the site on which this stately metropolis stood.

The site of Ecbatana has been a matter of dispute; but the dispute has arisen solely because those who have discussed the question, either did not know the evidence on which the question must be decided, or did not understand it. The route of commerce between the low country in the ancient Seleucia, and the modern Bagdad and the high table-land of Iran, is determined by the physical character of the country, and has continued the same from the earliest recorded history of those countries, to the present day. The places marked in the "Itinerary" of Isidore, as lying between Seleucia and Ecbatana, are the places indicated by modern travellers as lying on the route between Bagdad and Hamadan.

ECCENTRICITY, the distance between the foci of an ellipsis; it is otherwise called *ellipticity.*

ECCLESIASTICAL ARCHITECTURE. Under this title it is our intention to inquire into the nature of the places of worship employed by the early Christians, to consider the origin and progress of buildings devoted to this purpose, with a cursory glance at their history, and to describe generally their form, distribution, and structural arrangement.

Information on such subjects is to be sought for amongst the patristic writings, the early ecclesiastical historians, more especially Eusebius, and the early Christian writers generally. Collateral evidence corroborative of the testimony afforded from such sources, is to be found amongst cotemporary heathen authors in their occasional and incidental reference to such subjects. Evidence on this matter from all sources has been carefully collated, and much valuable information gained by the patient and learned research of Bingham, who has included it in his most elaborate work, the *Origines Ecclesiasticæ;* to which we shall have occasion frequently to refer in the following pages.

Of the forms of churches for the first three centuries, during the time of persecution, we know but little; and it is probable that during the very earliest period, when the Christian church was in a normal state, so to speak, whilst she numbered but few advocates, and they poor and of little influence, when "not many wise, not many noble were called;" it is probable, we repeat, that Christians had no fixed form or arrangement of parts in their places of public worship, but that a dwelling-house of some member or even a portion of such house, was set apart for the purpose. It is nearly certain that no structures were built for the especial purpose, during the first division of this period; for not only would they have attracted attention and suspicion, but would have been destroyed together with the worshippers: the earliest Christians were compelled to secrecy and obscurity, at least they did not bring themselves offensively or ostentatiously forwards into notice, although not shrinking from an open avowal of their faith when called upon for it; for be it remembered, they were to be "wise as serpents, and harmless as doves."

In the Sacred Writings, more especially in the "Acts of the Apostles," and in the epistles to the various churches, we not unfrequently meet with the word *church*, or *εκκλησια*, which must in some cases undoubtedly apply to the edifice or room in which it was customary for the Christians to assemble; we know besides that it was a practice with the early Christians of the apostolic times to assemble together in some appointed place for the purpose of worship and devotion. It is evident from the accounts of the evangelists, that the eleven continued together after their Master's crucifixion, whether engaged in prayer and fasting, we cannot say; but they were certainly in one place when the women came and told them of the resurrection. In the evening of the same day, likewise, it is mentioned that they were assembled together in one place, and with closed doors, for fear of the Jews; and eight days afterwards, they were again together with closed doors. These would seem somewhat to invalidate the supposition of their being collected together for prayer, or at least public prayer, for it is mentioned that after the return of the apostles from Bethany, "they were continually in the Temple praising and blessing God." Again on the day of Pentecost, they were all together in one house, and, as it is noticed, with one accord, which expression would seem to express the existence of some object, reason, or purpose of their being together, and what more likely than for common prayer? yet they still attended the public services of the Temple, for it is related that after this, "Peter and John went up together into the Temple at the hour of prayer, being the ninth hour." After the incident which occurs at this time in the Temple, and when Peter and John were released from custody, they returned to their companions, who were assembled together —probably in the same place as before—and after relating the circumstances, it is told us that they prayed and "spake the word of God with boldness." Some time subsequent to these events, it is related of Paul and Barnabas, while at Antioch, that for a whole year they assembled themselves with the church, and taught much people. This was in all probability in a stated place set apart for the purpose. Still stronger is the probability with regard to the house of Mary, where Peter fled after his escape from prison, and where many Christians were gathered together praying; one might suppose that a room in her house had been given by Mary for the purpose of public worship. Lydia probably made a similar gift. But, not to multiply instances, we would particularly allude to a circumstance which occurred while Paul was staying at Troas; for it is related that "upon the first day of the week, when the disciples came together to break bread,"—in other words, to celebrate the eucharist,—"Paul preached unto them, ready to depart on the morrow, and continued his speech until midnight. And there were many lights in the upper chamber, where they were gathered together. Now there sat in a window, a certain young man named Eutychus, being fallen into a deep sleep; and as Paul was long preaching, he sunk down with sleep, and fell down from the third loft, and was taken up dead;" upon which Paul goes down to him, and restores him to life. This is probably the most minute description of the place, time, and mode of worship recorded in the Sacred Writings. It will not escape remark that the room in this instance is said to have been an upper room, and there is reason to believe that it was a practice amongst Christians, to use the upper room, or Hyperōon, for this purpose; it will be remembered that it was an upper room in which the Saviour celebrated the passover and instituted the eucharist, and it may possibly have been for some reason of this kind, rather than from the situation and nature of the place, that the upper room was adopted.

It has been maintained that the early Christians had no places set apart for public worship; but as Bingham combats this argument, it may be as well to let him speak for himself. His remarks are for the most part a summary of the inquiries of the learned Mede, who has treated this particular subject at considerable length:—

"A very singular paradox has been advanced by some learned man," says Bingham, "that for the three first centuries after Christ, (i. e.) before Constantine ascended the throne of the Roman empire, A.D. 306, when he established Christianity, and soon after abolished paganism, the Christians, owing to the cruel persecutions to which they were exposed by the pagans in these centuries, first under the tyrant Nero, A.D. 64; and next under the Roman emperor Domitian, A.D. 94, had no such places of worship as churches. This statement is grounded upon some mistaken passages of Origen, Minutius Felix, and Arnobius, who say that the Christians had no temples, which they take as a denial of their having any churches; which opinion, though advanced with some show of learning by Vedelius, Suicerus, and others, is altogether without foundation, contradicted by the authors which they allege, and by themselves in the arguments they produce. Dr. Mede has given us an elaborate disquisition on the subject, in confutation of this opinion, wherein he has collected the authorities of the ancients, which, for the three first ages, prove the existence of Christian churches.

"We shall briefly, for the sake of those who have not that learned author, give the substance of his proofs, and add some others of our own observation. In the first place, he shows that the ancient authors, St. Austin, St. Basil, St. Jerom, and St. Chrysostom, and those under the name of Sedulius, Œcumenius, Theophylact, in their comments on that passage of St. Paul, (1 Cor. xi. 22,) 'Have ye not houses to eat and drink in? or, despise ye the church of God?' all took the word church there, not for the assembly, but for an assembly-room, or place expressly set apart for sacred devotional purposes. Now the apostles, at stated seasons, were in the habit of meeting together for prayer, and supplication for the prosperity of Christianity, upon mount Zion, at Jerusalem, the Hyperōon, or upper room, so often mentioned in the Acts of the Apostles, (Acts i. 13,) and where they were gathered together when the Holy Ghost came upon them, (Acts ii.) and where our blessed Lord also celebrated his Last Supper, and where he appeared to his disciples on two successive sabbaths after his resurrection, to their great amazement, and at a time when the doors were close shut and barred, for fear of the Jews, (John xx. 19.) Here the seven deacons were elected and ordained, (Acts vi. 3,) and here the first council of the churches was held at Jerusalem, (Acts xv.) This place becoming holy and sacred by these meetings, was afterwards inclosed within a goodly edifice, called the church of mount Zion; and in the time of Cyril, bishop of Jerusalem, it was called the high church of the apostles.

"This was the *οἱκος*, or same house of assembly at Jerusalem, that is mentioned, (Acts ii. 46,) where the apostles met for the breaking of bread, when they had all things in common. Some think the word *κατ οἱκω* is not to be translated from house to house, as in our version, but in the house or room where the Christian assembly was used to meet together. The next argument is drawn from what Eusebius observes of the *θεραπευται* in Egypt, whether Essenes, or Christians, they had their *σεμνεια*, or places appropriated for divine worship, from the days of St. Mark, and that such places are to be understood in all such passages of St. Paul, as "Salute ye the churches" in such and such an house; that is, the congregation which meet in the houses of such pious Christians, who had generally some part of their dwelling, or upper rooms, or housetop, (see Acts x. 9,) remote from noise, set apart for the church to assemble in, or, like that of Lydia's, (Acts xvi. 15.) At Macedonia was such an appropriated room, (see Acts xx.,) where St. Paul, on the first day of the week, preached to an immense multitude, and continued his discourse till midnight, when a young man, named Eutychus, sitting in the window where the lattice was open, being overcome by sleep, fell from the upper story, and was taken up dead, but whom St. Paul again restored to life. That there were devotional places, or oratories, set apart expressly for Christian worship in the first century, I think we have sufficient evidence; whether we call these places churches or not. The following century is, however, more clear, where they are called sometimes by the name of Cœnaculum; at others, by that which we have before mentioned, as Hyperoon. Thus we find Lucian, a pagan, or whoever was the author of the dialogue called Philopatris, about the time of Trajan, one of the pagan emperors, bringing in one Cretias, telling how the Christians carried him into a Hyperōon, the place of their assembly, with a design of making him a proselyte to their religion. He argues further, from the tradition of the church, derived from the ancient author of the Recognitians, under the name of Clemens Romanus, which says, that Theophilus, to whom St. Luke is supposed to have inscribed his Gospel at Antioch, where the name of Christians was first given to the followers of Christ, did convert his house into a church; and the like is reported of the house of Pudens, a Roman senator and martyr, in the Acta Pudentis, that it was turned into a church after his martyrdom. He concludes this first century with the testimony of Clemens Romanus, in his genuine epistle to the Corinthians, who says, that God has ordained well-appropriate places, where at appointed times and seasons he would be solemnly served, so that all things might be done religiously and orderly.

"In the second century, while the persecutions were still rife against the Christians, more cruel acts were passed under Trajan, A. D. 107, and Marcus Aurelius, A. D. 166, against them, by which it became necessary for them to act with firmness, and in compact. Thus Ignatius, in his epistle to the Magnesians, exhorts them to meet together in one place, which he calls *τὸ ναὸν Θεȣ*, the temple of God, and, in his epistle to the Philadelphians, he informs us, that at this time there was one altar in every church, and one apostolic bishop, or head, appointed with his presbytery and deacons. The present Greek copies, indeed, read it a little different from Dr. Mede, leaving out the word church, but the mentioning one altar is sufficient to intimate they had then a stated place for their ecclesiastical or Christian assembly. Tertullian, who lived in the following century, has clearly intimated that the Christians, at this time, had churches, when, complaining against those who followed the trade of idol-making, (for the Gentiles excused themselves, that they did not worship them,)—he says, 'the zeal of faith cannot declaim all the day long upon this point, bewailing that any Christians should come into the house of God from the shop of the enemy, and lift up their hands to God the Father, which were the mothers or makers of idols.' In another place he calls the church *Domus Columbæ*, the house of the dove, meaning either Christ, or his dove-like religion. And again, he expressly distinguishes between the baptistry and the church, which in those days were places separate from each other. In this age, Pius, bishop of Rome, wrote two short epistles to Justus, bishop of Vienne in Gaul; in the first of which is mentioned one Euprepia, a pious matron, who is said to have consigned the title of her house over to the church, in which was to be celebrated Divine offices of worship. And in the other epistle is named one Pastor, a presbyter, who is commended for erecting a titulus, that is, a small Christian church; Clemens Alexandrinus, towards the end of this century, also uses the name Ecclesia, for the place of the assembly, as well as the congregation; for, speaking of the church, he says, 'I call not now the place alone by this name, but the congregation of the elect people, the church;' and so, in his famous homily, *Quis dives Salvetur*, he brings in the Asian bishop, to whom St. John committed the young man to be trained up in the Christian discipline, complaining that the youth was become a villain and a robber, and, instead of following the church, had now betaken himself to the mountains, with a company like himself. By this it is plain, that, in his time, the word Ecclesia was taken for a church, or sacred place, as well as for the Christian assembly themselves, and that such a building as a church must have been known and understood. We have also the Scripture accounts of the seven Apocalyptic churches, in Asia Minor, to whom St. John the Divine, wrote from the isle of Patmos, where he was banished by the emperor Domitian, A. D. 96. These churches were Ephesus, Smyrna, Pergamos, Thyatira, Sardis, Philadelphia, and Laodicea, (Revelation ii. and iii.); some of whose ruins, as travellers inform us, now remain.

"In the third century, the testimonies are both more numerous and certain respecting the churches of the Apostolic Christians, though a succession of Roman emperors had passed edicts against them of a more severe and cruel nature, with the exception of that of Nero's. The persecuting emperors of this century were Septimius Severus, A.D. 203; Maximinus Thrax, A. D. 236; Decius, A. D. 250; Gallus, A. D. 253; Valerianus, A. D. 258; and lastly, Diocletian, A. D. 302.

"We have a testimony, in this age, of the existence of Christian churches, from a heathen author. Lampridius, in the life of Alexander Severus, reports, 'that there happening a dispute between the Christians and victuallers about a certain noted public place, each party challenging it as their own, the emperor's rescript determined it thus, in favour of the Christians: that it was better that God should be worshipped there after any manner, than that it should be given up to the victuallers.' About the middle of this period lived the famous Gregory of Neocæsarea, surnamed Thaumaturgus, who himself built several churches in Neocæsarea, and the adjacent parts of Pontus, as Gregory Nyssen reports in his life. St. Cyprian, about the same time, speaks of the place where the church assembled, under the name of Dominicum, the Lord's house; and, in another, opposes the church and the capitol—the altar of the Lord's house, and the altars of images and idol-gods, to one another; for, speaking against some that had lapsed, and, without due contrition, were for intruding themselves into the church again— 'If this were once permitted,' says he, 'what then remains but that the church should give way to the capitol, and the priests withdraw and take away the altar of the Lord with them, and let the images and idol-gods, with their altars, succeed, and take possession of the sanctuary, where the venerable bench of our clergy sit?' About this time, also, Dionysius, bishop of Alexandria, speaks of the churches as appropriate to the service of God.

"It appears further, from the rescript of Gallienus the emperor, recorded by Eusebius, where he restores the Christians their churches, under the name *τοποι θρησηδισμοι*, worshipping places; and from what has been noted before, out of the letter of Aurelian, which chides the senate for demurring about opening Sibylline books, as if they had been consulting, not in the capitol, but in a Christian church. As also that other rescript of his, in Eusebius, that the request of the council of Antioch ordered Paulus Samosatensis to be turned out of the house of the church. But the testimony of Eusebius goes further beyond all others; for, speaking of the peaceable times which the Christians enjoyed from the persecutions of Valerian to that of Diocletian, he observes, 'that the number of Christians so grew and multiplied in that *fifty years*, that their ancient churches were not large enough to receive them, and therefore they erected, from the foundations, more ample and spacious ones in every city.'

"The only objection against all this, made with any show of probability, is drawn from some of the ancient apologists—Origen, Minutius Felix, Arnobius, and Lactantius, who seem to say, 'that the Christians, in their time, had no temples or altars, nor ought to have any;' but, as Dr. Mede shows at large, this is only spoken against such temples, as the heathens pleaded for in the notion of encloistering the Deity by an idol, otherwise the very authors from whom the objection is drawn, must largely contradict themselves; for Arnobius owns they had their conventicula, houses of assembly, which he complains were barbarously destroyed in the last persecutions. And Lactantius says the same, giving them also the name of the temples of God, which Diocletian ordered to be demolished, at Bithynia. And Origen himself speaks of adorning the Christian churches and altars, in one of his Homilies upon Joshua. Lactantius, in another of his Institutions, speaks of one of the Christian conventicula in a town of Phrygia, which the heathen had burnt, with the whole assembly in it. And in his book *de Mortibus Persecutorum*, he gives a more particular account of the destruction of the churches throughout the heathen world; for he not only mentions the demolishing the stately churches of Nicomedia, in the kingdom of Bithynia, but intimates, that the same fate attended the churches over all the world; however it was, both Eusebius and Lactantius agreed in this one point, that there were churches before the last persecution.

"As a further proof of the existence of Christian churches in the middle of this century, we have a remarkable story told by Eusebius concerning the martyr Marinus, A.D. 259, in the time of Gallienus Marinus, who, being a candidate for a Roman office at Cæsarea, was informed against as a Christian, by an antagonist, who pleaded that he ought not to have the office, upon that score. The judge, upon examination finding it to be so, gives him three hours to consider whether he would quit his religion or his life. During this space, Theotecnus, bishop of Cæsarea, meets with him, and, taking him by the hand carries him to the church, and sets him by the holy table, then offers him a Bible and a sword, and bids him take his choice. He readily, without demur, lays his hand upon the Bible, whereupon the bishop thus bespake him: 'And here,' says he, 'adhere to God, and in his strength enjoy what thou hast chosen, and go in peace:' with this he immediately returned from the church to the judge, makes his confession, receives his sentence, and dies a martyr.

"Optatus takes notice of forty churches in Rome before the last persecution, which, being taken from the Christians, were afterwards restored to them by order of Maxentius, as St. Austin has more than once informed us. We have also read of some Christian churches in Africa, that were demolished in this persecution; as at Zama and Furni, noticed in the Gesta Purgationis of Cecilian and Felix. Others were taken away; and, in the mean time, till they were restored again, both councils and church-assemblies were held in private houses, as Optatus observes of the council of Cita. And St. Austin after him says, 'It was not to be wondered at, that a few bishops should hold a council in a private house, in the heat of persecution, when the martyrs made no scruple, in the like case, to be baptized in prison, and Christians meet in prison to celebrate the sacrament with the martyrs, as well as in secluded places.' But not to multiply instances of this nature, the very tenor of the imperial edicts, which raised the last persecution, is undeniable evidence, that the Christians, in all parts of the world, had their public churches, to which they resorted so long as they had opportunities to frequent them; for Eusebius says, 'the edicts of the emperors of Rome were sent to all the Roman provinces, even to Britain, commanding the churches of the Christians to be levelled with the ground, and the Bibles to be given up and burnt.' This was the last persecution, when Diocletian boasted that he had annihilated Christianity, and proclaimed the extirpation by exulting inscriptions—*Nomine Christianorum deleto qui templa evertebant;* and, *Superstitione Christi ubique deleta.* But the flame was not extinguished; it was again to break forth, for the mouth of the Lord had spoken it. Diocletian had now become hateful; soon after which he abdicated the throne, and Constantine the Great assumes the imperial sway of the Roman empire."

To these remarks we would add some further ones of Mede, and likewise give, at length, some passages referring to this subject, drawn from the writings of the early fathers who were living during the period we are speaking of.

Basil, speaking of the passage before alluded to, of *Have ye not houses to eat and to drink in?* &c., says, that we ought not to dishonour sacred places or things by the mixture of things of common use; and in answer to the question as to whether the Eucharist may be celebrated in a common house says, that as the word doth not allow that any common vessel or utensil shall be brought into places that are sacred, so likewise doth it forbid that the holy mysteries should be celebrated in a common house; for neither would the Old Testament permit any such thing to be done, nor our Lord, who said, "There is here one greater than the temple;" nor the apostle, saying, "Have ye not houses to eat and to drink in," &c. Whence we may learn, that we ought not to take our common supper in the church, nor should we dishonour the Lord's supper by eating it in a private house. But if one be necessitated to communicate in private, let them choose out the most clean and decent room for such a purpose, and withal see that he do it in the fittest and most seasonable time. St. Chrysostom says, on the same subject, "Behold a further change, that not the poor only, but also the church itself is injured. For, as hereby thou makest the Lord's supper a private supper, so thou dealest no better with the place, in that thou usest the church as a private and ordinary house." So again, Theodoret, "If ye come together to feast it, do this in your own houses, for to do thus in the church is a manifest contempt, a plain dishonour done to the church. For how can it but seem a thing wholly indecorous and absurd for you to fare deliciously in the temple of God, where the Lord himself is present, who hath prepared for us a common table, when at the same time those Christians that are poor are hungry, and out of countenance by reason of their poverty?" The author of the commentaries upon the epistles, alluding to the same text, says, "Ye despise the church of God, making it a place for common feasts and banquetings," and in the same track follow Theophylact and Œcumenius.

With regard to the nature of the earliest churches, and more especially to the Hyperōon, Mede says, "For the first it is not to be imagined they were such goodly and stately structures as the church had after the empire became Christian, and we now, by God's blessing, enjoy; but such as the state and condition of the times would permit, at the first some capable and convenient room within the walls or dwelling of some pious disciple, dedicated by the religious bounty of the owner to the use of the church, and that usually an Ἀνώγεον, or Ὑπερωον, an upper room, such as the Latins call *Cœnaculum*, being, according to their manner of building, as the most large and capacious of any other, so likewise the most retired and freest from disturbance, and next to heaven, as having no other room above it. For such uppermost places we find they were wont then to make choice of, even for private devotions, as may be gathered from what we read of St. Peter, (Acts x. 9,) that he went up to the housetop to pray; for so δῶμα signifies *ex usu Hellenistarum*, and is accordingly here rendered by the vulgar Latin, *in superiora*.

"Such an Hyperöon as we speak of, was that remembered by the name of *Cœnaculum Sion*, where, after our Saviour was ascended, the apostles and disciples assembled together daily in prayer and supplication, and where, being thus assembled, the Holy Ghost came down upon them in cloven tongues of fire at the feast of Pentecost. Concerning which there hath been a tradition in the church, that this was the same room wherein our blessed Saviour, the night before his passion, celebrated the Passover with his disciples, and instituted the mystical Supper of his Body and Blood for the sacred rite of the gospel; the same place where, on the day of his resurrection, he came and stood in the midst of his disciples, the doors being shut, and, having showed them his hands and his feet, said '*Peace be unto you*,' &c; the place where, eight days, or the Sunday after, he appeared in the same manner again unto them, being together, to satisfy the incredulity of Thomas, who the first time was not with the rest; the place where James the brother of our Lord was created by the apostles, bishop of Jerusalem; the place where the seven deacons were elected and ordained; the place where the apostles and elders of the church at Jerusalem held that council, and pattern of all councils, for decision of that question—whether the Gentiles which believed were to be circumcised or not; and for certain, the place of this *Cœnaculum* was afterwards enclosed with a goodly church, known by the name of the church of Sion, upon the top of which it stood; insomuch that St. Jerome, in his *Epitaphio Paulæ*, made bold to apply that of the Psalm to it,'Her foundations are upon the holy hills; the Lord loveth the gates of Sion more than all the dwellings of Jacob.' How soon this erection was made, I know not; but I believe it was much more ancient than those other churches erected in other places of that city by Constantine and his mother, because neither Eusebius, Socrates, Theodoret, nor Sozomen, make any mention of the foundation thereof, as they do of the rest. It is called by S. Cyril, who was bishop of the place, *the upper church of the apostles*; and says he, 'The Holy Ghost descended upon the apostles in the likeness of fiery tongues, here in Jerusalem, *in the upper church of the apostles*.'

"If this tradition be true, it should seem by it that this *Cœnaculum*, from the time our blessed Saviour first hallowed it by the celebration of his mystical Supper, was thenceforth devoted to be a place of prayer and holy assemblies. This is the more easy to be believed, if the house were the possession of some disciple at least, if not kindred also to our Saviour according to the flesh, which both reason persuades, and tradition likewise confirmeth it to have been.

"And if this were so, why may not I think that this *Cœnaculum Sion*, or upper room of Sion, was that οἶκος whereof we read, concerning the first Christian society at Jerusalem, that 'they continued daily in the Temple, and, breaking bread (κατ' οἶκον) in the house, ate their meat with gladness and singleness of heart?' the meaning being, that when they had performed their devotions daily in the temple at the accustomed times of prayer there, they used to resort immediately to the *Cœnaculum*, and there having celebrated the mystical banquet of the Holy Eucharist, afterwards took their ordinary and necessary repast with gladness and singleness of heart. For so κατ' οἶκον may be rendered; for ἐν οἴκῳ, and not *domatim* or *per domos*, *house by house*, as we translate it, and so both the Syriac and Arabic render it, and the New Testament elsewhere uses it."

It would seem from this last passage, that Mede sees no difficulty in reconciling the attendance of the apostles on the public service of the Jewish Temple, with the supposition that they likewise celebrated a common worship in their own chapels or consecrated places; and if we look into the matter, this double service will not appear extraordinary, for as yet they adhered to their Master's practice of worshipping at the Temple, while at the same time there were many peculiar and distinctive services in their new religion, which they could not perform in the Temple. For instance, the celebration of the Holy Eucharist was an essential no less than a peculiar rite, which they would not have been allowed, even supposing them willing, to have celebrated in the Temple; they were necessitated therefore to fulfil this command in their own places of worship. This seems to have formed a continuation and completion of the Temple service.

"Such as these, I suppose," continues Mede, "were the places at first set apart for holy meetings, much like to our private chapels now in great men's houses, though not for so general a use.

"In process of time, as the multitude of believers increased, some wealthy and devout Christian gave his whole house or mansion, either while he lived, if he could spare it, or bequeathed it at his death, unto the saints, to be set apart and accommodated for sacred assemblies and religious uses.

"At length, as the multitude of believers still more increased, and the Church grew more able, they built them structures of purpose, partly in the cemeteries of martyrs, partly in other public places; even as the Jews—whose religion was no more the empire's than theirs—had, nevertheless, their synagogues in all cities and places where they lived among the Gentiles."

The following quotations from writers of the period will give some insight into the general use and nature of distinct places of worship in their days. In the second century, Ignatius speaking to the Magnesians, says, in the passage alluded to above, "All of you meet together for prayer in one place, let there be one common prayer, one mind, one hope in love, in the immaculate faith in Jesus Christ, than which nothing is better. All of you as one man run together to the temple of God, as to one altar, to one Jesus Christ, the High Priest of the unbegotten God."

In the third century Hippolytus, describing the state of the world at the coming of antichrist, says, "the temples of God shall be as common and ordinary houses; churches shall be utterly demolished everywhere; the Scriptures shall be despised:" thus showing the esteem in which churches were then held.

Gregory of Neocæsarea, surnamed Thaumaturgus, who lived in the middle of the third century, describing the five degrees or admission of penitents according to the discipline of his time, says, 1st. *Weeping* (the first degree of penance) was without the porch of the oratory, where the mournful sinners stood, and begged of all the faithful as they went in to pray for them. 2d. *Hearing* (the second degree) was within the Porch, in the place called *Narthex*, the place where these penitent sinners (being now under the *ferula* or censure of the church) might stand near to the catechumens, and hear the Scripture read and expounded, but were to go out before them. 3d. *Prostration or lying along on the Church-pavement*. These *prostrate* ones were admitted some what further into the church, and went out with the catechumens. 4th. *Standing or staying with the People or*

Congregation. These *Consistentes* did not go out with the *Catechumens*, but after they and the other penitents had left, remained, and joined in prayer with the faithful. 5th. *Participation of the Sacraments.*" This is a somewhat remarkable passage, to which we shall have occasion again to refer.

In the rescript of Galienus the churches of the Christians are mentioned as Τοποι θρησκευσιμοι or Places of Worship. Gregory Nyssen, speaking of the success of Gregory of Neocæsarea, relates, "How that, becoming all things to all men, he had in a short time gained a great number of converts through the assistance of the Divine Spirit, and that hereupon he had a strong desire to set upon the building of a temple or place for sacred assemblies; wherein he was the more encouraged by the general forwardness he observed among the converts to contribute both their moneys and their best assistance to so good a work. This is that temple which is to be seen even at this day." Eusebius, speaking of the long peace which the Church enjoyed before the persecution of Diocletian, says, "How shall any one be able to express those infinite multitudes of Christians assembling in every city, those famous meetings of theirs in their oratories or churches? and therefore they, not being content with those smaller churches which before they had, (those their ancient edifices not being large enough to receive so great a number,) took care to erect from the very foundation fairer and more spacious ones in every city."

Soon after this dreadful persecution Constantine succeeded to the government, and having been fully convinced of the truth of the Christian faith, with hearty and unremitting zeal set about its establishment, nor to any thing did he give more constant attention than to the erection and adornment of churches. Before, however, entering upon a description and examination of these edifices, it may be as well to say a few words respecting a subject which has not been agreed upon amongst the learned; it is this, whether the early Christians made use of heathen temples for the performance of their public services. Bingham enters into the subject at some length, from whom we quote the following:—

"At first, when the reformation from heathenism was in its infancy, no idol-temples were made use of as churches, but were either permitted to the heathen for some time, or else shut up or demolished. Till the twenty-fifth year of Constantine, A.D. 333, the temples were in a great measure tolerated, but in that year he published his laws commanding temples, altars, and images to be destroyed, which laws are sometimes referred to in the Theodosian code. And pursuant to these laws, a great many temples were defaced in all parts of the world, and their revenues confiscated, as appears not only from the Christian writers, St. Jerome and Eusebius, and others, but also from the complaints of the heathen writers, Eunapius, Libanius, and Julian. In some of the following reigns also the same method was taken to shut up or to deface the temples, as is evident from the account which Ruffin gives of the general destruction of them in Egypt by the order of Valentinian. But in the next reign, in the time of Theodosius, another method was taken with some of them. For as Gothofred observes, out of the Chronicon Alexandrinum:—'Theodosius turned the famous temple of Heliopolis, called Balanium, into a Christian church, (εποιησεαντο εκκλησιαν χριστιανων.) And about the same time Socrates tells us, 'That when Valens had banished the two Macarii, the heads of the Egyptian monks, into a pagan island, they converted all the inhabitants, and turned their temple into the form of a church.' The like was done by the famous temple of the Dea Celestis at Carthage, by Aurelius, the bishop, in the time of Honorius, A.D. 399, which the author of the book, *de prædictionibus*, under the name of Prosper, tells, with this remarkable circumstance, 'that it had been dedicated before by one Aurelius, a heathen high-priest, with this inscription, *Aurelius pontifex dedicavit*, which our author says was left in the frontispiece, to be read by all the people, because, by God's providence, it was fulfilled again in Aurelius the bishop, for whom it served as well as the former Aurelius, when he had once dedicated it to the use and service of the Christian religion, and set his chair in the place of the goddess. Not long after this, Honorius published two laws in the Western empire, forbidding the destruction of any more temples in cities, because they might serve for ornament, or public use, being once purged of all unlawful furniture—idols and altars, which he ordered to be destroyed wherever they were found.

"These laws, as Gothofred rightly observes, seem to have been published at the instance of the African fathers, who, as appears from one of the canons of the African code, petitioned the emperor, that such temples as were in the country only, and private places not serving for any ornament, might be destroyed. Arcadius published such another law for the Eastern empire, which relates only to the destruction of temples in country-places, and not in cities, where now there was no such danger of superstition, since they might be converted to a better use. And upon this ground the author, under the name of Prosper, commends Honorius for his piety and devotion, because he gave all the temples, with their adjacent places, to the church, only requiring the idols to be destroyed. 'Tis true, indeed, after this we find a law of Theodosius Junior commanding all temples to be destroyed; but, as Gothofred seems rightly to interpret it, "the word *destroying*, in that law, is to be understood only of despoiling them of their superstition, because it follows in the same law, that they were to be expiated by placing the sign of the cross upon them, which was a token of their being turned into churches. And his observation may be confirmed further from what Evagrius reports of Theodosius—that he turned the Tycæum, or Temple of Fortune at Antioch, into a church called by the name of Ignatius. The like was done by a great temple at Tanis in Egypt, as Valesius has observed out of the Itinerary of Antonius the martyr.

"Cluver also, in his description of Italy, takes notice of a place in the Jerusalem Itinerary, called Sacraria, betwixt Fulginum and Spoletum, near the head of the river Clitumnus, which he thinks was no other than the temple of Jupiter Clitumnus, though another learned antiquary makes it somewhat doubtful as to the present church now standing there. However, we have seen instances enough of this practice, and Bede tells us, that 'Gregory the Great gave Austin the monk instructions of the same nature about the temples here among the Saxons in Britain,—that if they were well built they should not be destroyed, but only be converted from the worship of devils to the service of the true God.' And so he observes it was done at Rome, where, not long after, Boniface the Fourth turned the heathen temple, called the Pantheon, into the church of All Saints, in the time of the emperor Phocas. Sometimes the temples were pulled down, and the materials were given to the church, out of which new edifices were erected for the service of religion, as Sozomen and Ruffin particularly observe of the temples of Bacchus and Serapis at Alexandria. I have already shown out of Antonius, that the Roman halls or basilicæ were likewise turned into churches. The like is reported of some Jewish synagogues by the author of the Chronicon Alexandrinum, who takes notice particularly of a synagogue of the Samaritans, in a place called Gargarida, which Zeno the emperor converted into a large Christian church.

"And though it is not agreed by learned men whether the temples said to be built by Hadrian were intended for the worship of himself, or the worship of Christ; for Casaubon and Pagi think he designed them for himself, whilst Huetius defends Lampridius, his relation, who says, "He designed them for the honour of Christ;" yet it is certain, that after they had been used to other purposes, they were at last, some of them, turned into Christian churches: for Epiphanius says, 'There was a great temple at Tiberias, called the Hadrianum, which the Jews made use of for a bath; but Josephus Comes, the converted Jew, in the time of Constantine, turned it into a church.' And the like was done by another of them by Athanasius at Alexandria, having before been the hall or place of Licinius, as the same Epiphanius informs us. So that now, partly by the munificence of the emperors, and partly by their orders for converting heathen temples into churches, and partly by the great zeal and liberality of private Christians in times of peace, churches became another thing from what they were in former ages, that is, more noble and stately edifices, more rich and beautiful."

Thus far Bingham, who seems to conclude from the above quotations of the early writers, that to convert heathen temples into Christian churches was not an uncommon practice: a writer, however, in the Quarterly Review, in a critique on the publications of Knight and Bunsen, on Ecclesiastical Antiquities, arrives at a very different conclusion; and as he has evidently given more than ordinary attention to the subject, it may not be amiss to refer to his remarks, in this place:—

"The antipathy," says he, "borne by the early Christians to the fine arts, debased by the pollutions of heathen idolatry, can neither be denied nor concealed; and the same causes which prevented the cultivation of the arts, ensured the degradation and subversion of their proudest and most splendid monuments. Excluding for the present the consideration of other agencies, the first paragraph in the rise of Christian architecture, must narrate the fall of the structures devoted to the superstition, which it was the end of the gospel to obliterate and destroy.

"The heathen temples were doomed to inevitable ruin. Laws had been promulgated by Theodosius for their preservation; conducive to the decoration of the city, they might be perhaps rendered useful for the purposes of civil society. Some may have been thus respited, though not rescued, until the decayed remains crumbled to the ground; they were never respected or honoured by public opinion, and could rarely be adapted to the objects pointed out by the imperial law, without such alterations as in most cases amounted to destruction. Others were accidentally preserved in desolate or secluded situations, in the forest or the marsh, or the mountain-glen, or on the shore, whence the inhabitants have been extirpated, or chased away. Such are the columns of Pæstum: the heavens are yet as bright as when the garlands hung down from the ruined architrave; the sea as azure as when the waves were ploughed by the painted prows; the crushed herbs beneath your feet, still send up their rich perfume. To the senses, the works of art are still as noble, the works of nature as sweet and gay; but the whole scene mourns under the curse inflicted upon scoffing, lascivious, corrupted Hellas. Language, people, race—their very name has disappeared. The wasting pestilence still hovers, and will ever hover, marking the vengeance which has fallen on the deserted shore.

"Few temples were ever adapted for the purposes of Christian worship; fewest of all in the capital of the Christian world. 'Of the Christian hierarchy,' says Gibbon, 'the bishops of Rome were commonly the most prudent and the least fanatic; nor can any positive charge be opposed to the meritorious act of saving and converting the majestic structure of the Pantheon.' In casting the account of the merits and demerits of the Christian hierarchy, such a pontiff as Gregory the Great would have been ill inclined to accept the encomium. In the *gergo* of Gibbon, 'fanaticism' is piety, and 'prudence' unbelief. The 'meritorious act,' thankful as we may be for the result, was a single item, by no means influencing the general balance of praise or dispraise; it was the solitary performance of Boniface IV.; it was an act from which no consequences resulted. With the exception of the Pantheon, we fail to detect any real example in Rome, of a temple which can be said to owe its *preservation*, in the *proper sense* of the term, to the Christian clergy. They had no thought of the kind—they took no pleasure in such antiquities. They sought no credit for such care. Antiquaries, with eager zeal, have collected about ten examples in which this preservation is asserted. Even in the cases which are least dubious, no further merit can be claimed for the hierarchy than the accidental preservation of a portico, a cella, or a wall, an encumbrance which it was troublesome to remove—a fragment which saved some expense, built up, concealed, marred, or deformed by the new erection to which it was unwillingly conjoined.

"It could not be otherwise. In the early Christians, any participation in our modern worship of heathen art, would have been false and unnatural. All the opinions, all the habits, all the feelings, all the conscience, of the early Christians strove against the preservation of the memorials of heathenism. Neither beauty nor convenience, if they had possessed the latter requisite, would, save in some few special cases, like that of the Pantheon, plead for the preservation of the relics of classical antiquity. They considered the idols as accursed. No object which had in anywise been connected with the worship of idols, or could be supposed to have been employed in their service, was to be used without exorcism. Thus, in the ritual of the church of Durham, there is a form of prayer for hallowing the vase found in the Roman encampment, which could not be employed for any Christian use until subjected to such purification. Nor was this belief confined to the rude Northumbrian peasant, or to a barbarous age. Let us place ourselves before the portal of St. Peter's, fresh from the workmen's hands. Four months have been employed in removing the huge obelisk of Sesostris from the ruins of Nero's Circus to the front of the great Basilica. Eight hundred workmen, toiling at creaking winch and groaning capstan, heave up the mass; whilst the breathless crowd watch the slow rising of the gigantic beam. It stops; when the one cry, '*aqua alle funi*,' which subjects the individual who suggests the happy expedient, to the pain of death, enables the maestro to complete his task; amidst the thunder of the cannon, the 'guglia' stands firm and erect upon its basement. But is the work complete? No: the trophy of the victory of Christianity over heathenism cannot yet be received as such, until all connection with its former slavery to the fiend has been destroyed. In solemn procession, the supreme pontiff exorcises the magnificent work, so long dedicated to the foul superstition of Misraim, and devotes it to the honour of the Cross, performing the rites which were deemed to expel the evil spirit. Those who may not share in the belief which dictated these ceremonies, must, nevertheless, respect the sentiments contained in the simple majestic language, commemorating the consecration of the spoils of heathenism to the service of the Cross. 'Ecce Crux Domini—Christus vincit—Christus regnat—Christus imperat—Christus ab omni malo plebem suam defendat—Vicit Leo de tribu Juda.'

"Thus did Pope Sixtus record his triumph. Yet there was a greater triumph felt by the zeal which taught the early Christians to glory in casting down the altars and the high places devoted to sin; deeming—we will not presume to judge whether rightly or wrongly—that such a testimony to the truth was imperatively enjoined upon them. By their deeds they contemned the temporizing policy of the emperors. They sought the actual and visible victory of literally erecting the temple of the Lord upon the ruins of the habitation of the demon. The statues were broken, to be buried in the foundations; hence few sculptures have ever been found at Rome, which did not, like the Venus of the Medici, show by their defacement and fractures, the aversion of which they had been the objects. Amongst the great congregation of the faithful, the distaste, the horrors excited by paganism —its structures, monuments, glories, charms—were unconquerable and paramount. Idols might have been removed, and the building consecrated by the rites, which, according to the primitive belief, would drive away the demon; yet no lustration could entirely heal the leprosy of the walls. The language of the Virgin Martyr was echoed in every heart:—

> 'Your gods, your temples, brothel-houses rather;
> Or wicked actions of the worst of men,
> Pursued and practised. Your religious rites!
> Oh! call them rather juggling mysteries,
> The baits and nets of hell. . . . . .
> Your Venus whom you worship, was a harlot—
> Flora, the foundress of the public stews,
> And has for that her sacrifice.
> Your Jupiter, a loose adulterer,
> Incestuous with his sister. Read but those
> That have canonized them. You will find them worse
> Than in chaste language I can speak them to you.'

"Whatever had been touched by paganism, seemed, and can we say unjustly? to be reeking with impurity."

On this subject we incline towards the opinions of the reviewer, notwithstanding the evidence adduced by Bingham; at the same time we do not mean to deny the occasional application of pagan temples to Christian uses under peculiar circumstances, as in the case of Austin and the Saxons at a later date, yet we do think the instances of such application were comparatively few, and formed the exception rather than the rule. For not only were the feelings of the early Christians enlisted against every thing connected with the worship of the heathen deities,—or devils, as St. Paul calls them,—but the form also of pagan temples was totally unsuitable for churches. Temples were little more than cells for the reception of the idol and priests, the people stood outside. The services of the Christian church required a very different arrangement; here you required accommodation for worshippers within the walls, as the very name *εκκλησια*, *assembly*, implies; there is here a communion or organized congregation. Christians came together not merely to behold as it were a spectacle, but to pray together, and to hear the Gospel read to them. "The Christian temple," says Professor Willis, "was a heathen temple turned inside out;" in the heathen temples the colonnade was outside, in the Christian church it was necessary to transpose it to the inside, to obtain greater internal space, as we see was the case in their later structures. Taking all this into consideration, we think there is some reason to decide that the examples of the adaptation of temples to the purpose of Christian worship, formed but exceptions. The very term *temple* was never used by the earlier writers, when speaking of the *church;* the terms were distinctive of the religion to which they belonged, the former when used, implying always heathen temples. The term employed in contra-distinction to this is *εκκλησια*, which, from being the name of the assembly, soon came to be applied to the place in which they met; this word is very common. Another appellation is *κυριακον*, *Dominicum, or Domus Dei*, which is met with in Eusebius and two or three councils; *Domus Columbæ* used by Tertullian, is a similar term. Other terms found in Eusebius, Socrates, Sozomen, and others, are *προσευκτηρια* and *οικοι ευτηριοι*; but one very frequent in the writers of the fourth and fifth centuries, though scarcely seen before, is Basilicæ. The word *temple* was seldom or never used in this sense during the first three centuries.

The earliest descriptions of early churches, now extant, are to be found in the writings of Eusebius, who gives somewhat lengthened accounts of the Holy Sepulchre at Jerusalem, and of the church of Paulinus at Tyre, which we proceed to notice. The descriptions are not very lucid; they show us how richly churches were adorned, and throw some little light upon their structure and arrangement, although the account is in many places confused; still it gives us some idea of the buildings, and, by comparison of this with other accounts, and with the remains of what are supposed to be earlier churches, we are enabled to decide pretty nearly their original form and distribution. He commences with a description of the Holy Sepulchre.

The Empress Helena, after a long search, succeeds in discovering the place of the Holy Sepulchre; which had been covered over by the pagans, and polluted by their rites, the place having been dedicated by them to Venus, a statue of which goddess was erected over the Sepulchre. Constantine having destroyed all the remains of heathenism, and having had the place purified from such abominations, proceeds to consider the erection of a suitable church upon the spot, and sends directions to Macarius, bishop of Jerusalem, upon the subject, a portion of which, as given by Eusebius, we transfer to these pages.

"Moreover, I would persuade you to that which is clear and evident, namely, that we ought to take especial care that this place, which we have purified and cleansed from superstitious idols, and which God and good men, from primitive times accounted sacred and holy, and which was afterwards so esteemed for the attestation and confirmation it gave to our belief in Christ's passion, should be honoured by erecting a church thereat. It is meet therefore that your wisdom should so dispose of this work, and prudently provide all things necessary thereto, that the beauty of the temple may excel all other churches, and the several parts of it may exceed the chief churches in other cities. Know therefore that we commit the care of erecting, building, and curiously adorning the walls thereof, to our friend Dracilianus and the president of your province. For out of our gracious bounty we have commanded them that they should have recourse to your wisdom to know what artificers and workmen shall be necessary to the building thereof, and accordingly shall straightway provide them, and send them thither. And when you have cast and contrived what marble pillars, or other marble works, will be necessary, either to adorn it, or make it more durable, look that you certify us by your letters, that when we understand what shall be necessary, we may provide accordingly. For this, which is the most special place of all the world, ought to be adorned with all kinds of work of cost and curiosity.

"I would have you certify me whether the roof of the sanctuary should be arched, or built in some other form; but if it be built archwise, it may be conveniently gilded. It remains therefore that your holiness should speedily signify unto those whom we have appointed to be overseers of the work, both what artificers and labourers will be necessary and what charge it will require; and also to certify us not only concerning the pillars and other marble work, but also concerning the wood-work of the roof, if you think fit that it should be built in that form."

Then follows a glowing description of the building when completed, from which we extract the following:—

"First of all, then, he adorned the sacred cave itself, as the chief part of the whole work, and the hallowed monument of which the angel radiant with light had once declared to all that regeneration which was first manifested in the Saviour's person. This monument, therefore, first of all, as the chief part of the whole, the emperor's zealous magnificence beautified with rare columns, and properly enriched with the most splendid decorations of every kind. The next object of his attention was a space of ground of great extent, and open to the pure air of heaven. This he adorned with a pavement of finely-polished stone, and enclosed it on three sides with porticos of great length. For at the side opposite the sepulchre, which was the eastern side, the church itself was erected, a noble work rising to a vast height, and of great extent both in length and breadth. The interior of this structure was floored with marble slabs of various colours, whilst the external surface of the walls, which shone with polished stones exactly fitted together, exhibited a degree of splendour in no respect inferior to that of marble. With regard to the roof, it was covered on the outside with lead, as a protection against the rains of winter. But the inner part of the roof, which was finished with sculptured fretwork, extended in a series of connected compartments, like a vast sea, over the whole church; and being overlaid throughout with the purest gold, caused the entire building to glitter as it were with rays of light.

"Besides this, were two porticos on each side, with upper and lower ranges of pillars corresponding in length with the church itself, and these also had their roofs ornamented with gold. Of these porticos, those which were exterior to the church were supported by columns of immense size, while those within these rested on piers of stone beautifully adorned on the surface. Three gates placed exactly east were intended to receive those who entered the church.

"Opposite these gates, the crowning part of all was the hemisphere, which rose to the very summit of the church. This was encircled by twelve columns, (according to the number of the apostles of our Saviour,) having their capitals embellished with silver bowls of great size, which the emperor himself presented as a splendid offering to his God.

"In the next place he enclosed the atrium, which occupied the space leading to the entrances in front of the church. This comprehended first the court, then the porticos on each side, and lastly the gates of the court. After these, in the midst of the open market-place, the entrance-gates of the whole work which were of exquisite workmanship, afforded to passers-by, on the outside, a view of the interior, which could not fail to inspire astonishment.

"This temple, then, the emperor erected as a conspicuous monument of the Saviour's resurrection, and embellished it throughout on an imperial scale of magnificence. He further enriched it with numberless offerings of inexpressible beauty, consisting of gold, silver, and precious stones in various forms; the skilful and elaborate arrangement of which, in regard to their magnitude, number, and variety, we have not leisure at present to describe particularly."

The following is our author's description of the church of Paulinus at Tyre, in his letter to that bishop:—

"Thus then, embracing a much wider space, he strengthened the outer enclosure with a wall to compass the edifice, that it might be a most secure bulwark to the whole work. Then raising a large and lofty vestibule, he extended it towards the rays of the rising sun; and, on entering the gates, he has not permitted you to enter immediately, with impure and unwashed feet, within the sanctuary, but leaving an extensive space between the temple and the vestibule, he has decorated and enclosed it with four surrounding porticos, presenting a quadrangular space, with pillars rising on every side. Between these he carried round the frame-latticed railing, rising to a proportionate and suitable height; leaving, however, the middle space open, so that the heavens can be seen, and present the splendid sky irradiated by the beams of the sun. Here, too, he has placed the symbols of the sacred purification, by providing fountains built opposite the temple, which, by the abundant effusion of its waters, affords the means of cleansing, to those that proceed to the inner parts of the sanctuary. And this is the first place that receives those that enter, and which, at the same time, presents to those that need the first introduction, both a splendid and convenient station.

"After passing this, he has made open entrances to the temple, with many other inner vestibules, by placing again three gates on one side towards the rising sun. Of these he constructed the middle one, far exceeding those on each side in height and breadth, embellishing it, at the same time, with exceedingly splendid brazen plates bound with iron, and decorated with sculpture, superadding them, as guards and attendants to a queen. In the same way, after disposing the number of the vestibules, also with the porticos on each side of the whole temple, he constructed above these different openings to the building, for the purpose of admitting more light, and these lights or windows he also decorated with various kinds of ornamental sculpture.

"But the royal temple itself he has furnished with more splendid and rich materials, applying a generous liberality in his expenses. And here it appears to me to be superfluous to describe the dimensions, the length and breadth of the edifice, the splendid elegance, the grandeur that surpasses description, and the dazzling aspect of the works; for when he had thus completed the temple, he adorned it with lofty thrones in honour of those who preside, and also with seats decently arranged in order throughout the whole, and at last he placed the holy altar in the middle. And that this again might be inaccessible to the multitude, he enclosed it with frame-lattice work, accurately wrought with ingenious sculpture, presenting a beautiful appearance to the beholders. And not even the pavement was neglected by him, for this too he splendidly adorned with marble, and then proceeded to the rest and to the parts outside the temple. He provided spacious exhedræ and oëci on each side, united and attached to the church, and communicating with the entrance to the middle of the temple."

Of the above structures, the former is still in existence; not indeed the identical building, but, as there seems reason to believe, a building similar in general form and arrangement. The text of Eusebius is difficult and obscure, and conveys but an indefinite idea of the edifice. Strange to say, we have a plan and description, which may be relied upon as genuine, in our own isles.

At Iona flourished abbot Adamnan, so distinguished by his participation in the great paschal controversy, A. D. 705; and he supplies the architectural antiquary with the knowledge so much desired. We owe the information to a singular contingency. After a long pilgrimage and continued residence in the Holy Land, a Gaulish bishop, named Arculphus, driven to the Hebrides, became the guest of the Culdee monastery. Here he related his perils, describing the holy places he had visited; and the "*Sebellus de Locis Sanctis*" contains his narrative.

Rarely has any work been transmitted with more peculiarity and authenticity. Adamnan wrote upon his tablets, from the actual dictation of the stranger; the notes so taken became the book we now possess. The Holy Sepulchre, as might be anticipated, was the main object of Adamnan's curiosity; and in addition to the verbal description, Arculphus drew a plan of the buildings upon the tables with his own hand. This plan Adamnan copied in his manuscript; he speaks of his drawing with extreme humility, calling it a vile figuration; but, as will be seen by comparing it with the plan of San Stefano Rotondo, it affords valuable information. The church was wholly of stone, of "wonderful rotundity," supported by twelve columns; having, as it would seem, three aisles; it was entered by four doors; and the sepulchre itself was illuminated by twelve lamps, burning day and night in honour of the twelve apostles. Since Adamnan speaks of three walls, we must suppose that the interior circle marks the columns, and the lines were probably staircases, leading to an upper church or gallery. When Aculphus saw the Holy Sepulchre, it had been somewhat damaged by the Persians, and it was subsequently ruined by the Arabs; yet, as the existing church still retains the original shape, we do not doubt but that it was rebuilt upon the original foundations.

Other churches were built by Constantine, at Jerusalem, Antioch, Nicomedia, Mambre, Heliopolis, Rome, and Constantinople, but few remain to the present day, few, at least, that have not been materially altered. Perhaps the most perfect specimen remaining is the church of S. Constantia; the burial-place of the daughter of Constantine; it is circular in plan, and divided by concentric rows of pillars, from which spring arches to support the roof. The model from which it was constructed was evidently identical with that of the Holy Sepulchre, even were it not that structure itself. It is the opinion of some, that the form of circular churches was derived from that of heathen temples of the same kind, such as those of Vesta, or Minerva Medica; this, however, does not seem to be the case, for although they are both circular in plan, they are of entirely different construction and arrangement. The temple has its columns on the exterior, supporting an entablature, while the church has its detached columns arranged in concentric circles within, connected by arches springing from the capitals, forming one or more aisles; the arrangement, it will be acknowledged, is totally dissimilar, and the mere outline cannot have much weight in the consideration.

But some have gone still further, and claimed the very structures themselves for heathen temples: the building mentioned above is supposed by such to be an ancient temple of Bacchus; but as Mr. Knight, in his beautiful work on this subject, says, "This opinion is principally founded on the mosaics with which the ceiling of the aisles is adorned, and which represents vine-leaves and grapes. But the vine is a Christian emblem, and is so frequently introduced in the decoration of Christian places of worship, that little weight can be attached to this circumstance. The architecture of this building is in conformity with the style of the time of Constantine, and not in conformity with that of a much earlier date." The fact is, the circular is the most natural form for sepulchral chapels, where the chief object is a tomb, placed in the centre. Other similar chapels are still in existence, of which, probably, the most remarkable, is that of S. Stephen. Baptisteries were likewise frequently of the same form, as is that of S. John Lateran, but more frequently octagonal, and sometimes octagonal within and circular without. All such buildings seem to have been simply baptisteries or sepulchral chapels; the form is totally unfitted for the requirements of the Christian liturgy, nor do they seem to have been employed for such purpose, with the exception, perhaps, of the church of the Holy Sepulchre, and this was not purely circular, but had parts of different plan attached to it, something like to the Temple Church, London. The form is very suitable for a baptistery. *See* Round Churches.

The more usual plan of Christian churches is that of a parallelogram, which form is said to have been derived from the heathen courts of justice; but ere entering upon the consideration of this matter, it will be well to give some description of the parts and arrangement of the early Christian churches, as collected from the descriptions of Eusebius above given, and from the writings of other authors who allude to the subject.

From such authorities, it would seem that churches of this period consisted not merely of a building for public service, but also of *exhedræ* or out-buildings, employed for the secular as well as religious concerns of the church; such as schools, libraries, houses of residence for the clergy, &c.; the whole being surrounded and enclosed by an outer wall. This arrangement is very similar to that of our existing cathedrals. That all within this outer wall was considered as belonging to the church, and consecrated ground, is evident from the fact of its being acknowledged as a sanctuary in after times. The position of the church within this enclosure, was generally east and west, having the altar toward the east; but this custom was not always observed, as we meet with many exceptions. That such a custom did prevail in spite of such exceptions, we have the authority of several writers. Socrates, noticing an example of the contrary practice, says, that the church at Antioch stood in a different position to other churches, for that the altar did not look towards the east, but to the west; and a similar observation is made by Paulinus Nolanus, respecting one of his own churches, and he gives the reason for his departure from the usual custom, namely, that the structure was made to look towards another, in memory of the Saint in whose name the latter was dedicated. The Apostolical Constitutions direct that churches should be built toward the east, but Walafridas Strabo says, "The ancients were not nicely curious which way their churches stood, but yet the most usual custom was for Christians to pray toward the east, and therefore the greater proportion of churches were built with respect to that custom."

Allowing this custom to have prevailed then, we shall have our first or outer entrance in the west wall of the enclosure, and this is called by Eusebius the προπυλον μεγα and προτη εισοδη. Through this vestibule, admittance was obtained into a large quadrangle or open area, surrounded by cloisters, which is called by Eusebius, *αιθριον* and *αυλη*, and by the Latins, *atrium;* the cloisters being distinguished in the former case by the name of *στοαι*, and consisting of a covered way, the roof supported by pillars or an open arcade. The object of this court seems to have been to receive the penitents of the first order, or mourners, who were not permitted to enter the main body of the church; in after times it was used for a place of burial, but then only for persons of distinction; kings thinking it a great honour to be buried within the gates. This place was sometimes named *impluvium*. In the centre of the open area was a fountain or large basin of water, in which it was customary for the Christians to wash their hands and face, and perhaps their feet, ere they entered the church, such practice being a symbol of the purity of heart which should attend them there. Tertullian speaks of the absurdity of going to prayer with washed hands and a polluted soul. A similar custom still prevails in the Romish church, borrowed doubtless from primitive practice, although differing in the intention and object for which it is observed. The fountain is called indifferently, φιαλη φρεαρ, *nymphæum*, *cantharus*, and *leontarium*, the latter term supposed to have been applied from the spouts being sometimes in the form of lions' heads. Socrates, speaking of the skirmish between the Catholics and the Macedonian heretics, says, "Such a slaughter was made, that the court (*αυλη*) was filled with blood, insomuch that the fountain (*φρεαρ*) was overflowed therewith, and ran through the adjoining cloisters (*στοαι*) even into the street." Examples of the atrium in its primitive shape are yet preserved in the churches of San Clemente, San Lorenzo, San Paolo, San Georgio in Velabro, Sta Maria in Trastevere; remodelled in San Giovanni Laterano, and Sta Maria Maggiore, and rebuilt in modern shape in St. Peter's. At San Ambrogio, Milan, the atrium is fully as large as the nave.

Entrance was obtained from the atrium into the *pronaos* or *narthex*, through three gates, of which the central one was frequently the largest and most important. The narthex formed the first division in the body of the church, and was used as the station for the catechumens, and such of the penitents as came under the title *ακουομενοι*, or hearers, so called from the circumstance of their being allowed to listen to the lessons and sermon, to which privilege also Jews, heathens, heretics, and schismatics were admitted, in this part of the church. Here also, somewhat in advance, stood the *substrati*, or third class of penitents, so called from the custom of prostrating themselves before the bishop, after sermon was ended, to receive his benediction. There were frequently more narthecces than one in a church, that of Sta Sophia is said to have had no less than four.

We have now arrived at the *ναος*, or nave, the principal division of the church, in which the body of the faithful, those who were under no censure, and in full communion with the church were congregated. This part was separated from the narthex by rails of wood, and was entered by gates which are distinguished by writers as *πυλαι καλαι*, or *βασιλικαι*, the beautiful or royal gates, so named perhaps from the circumstance of kings laying aside their crowns at this place, ere they proceeded further into the church. Leo Grammaticus notices it as a flagrant want of reverence in the emperor Michael, that "when he came to the royal gates, he did not lay aside his crown, as kings were used to do."

It was a practice with the early Christians to separate the sexes in public service, one portion of the church being allotted to the males, and another to the females. The author of the Apostolical Constitution speaks of this separation as usual in his time, for he says, "Let the doorkeepers stand at the gate of the men, and the deaconesses at the gate of the women;" and S. Cyril says, "Let men be with men, and women with women, in the church." Socrates also remarks of Helena, that "she always submitted to the laws of the church in this respect, praying with the women in the women's place." In some cases, the women were placed on the north side of the church, but probably this was not an universal practice; in the Greek church the galleries were reserved for the women. Besides this, there was a further subdivision, distinct positions being allotted to virgins, widows, and matrons. In the Apostolical Constitutions, the virgins, widows, and aged women were placed in the highest rank, and the matrons behind them. In this manner were the communicants disposed in the nave, but besides them the fourth or last order of penitents were admitted into this part of the church; they were called *Consistentes*, and were allowed to remain during the celebration of the Eucharist, although not to participate.

At the farther end of the nave, was the choir, which was divided from it by a low wall or wooden partition; here were located the singers, and here also the gospel and epistles were read from the *ambo*, or pulpit. This was an elevated desk, ascended by several steps, which S. Cyprian calls *pulpitum* and *tribunal ecclesiæ*, and which was elsewhere called *βημα γνωστων*. Bona cites Prudentius to prove that the bishops and priests made their sermons from this pulpit, but this seems to be a mistake, for the bishops anciently addressed the congregation from the steps of the altar, as is evident from Valesius. S. Chrysostom, it appears, did preach from the ambo, but only in order that he might be the more audible to the people; such was not the usual custom. A very perfect example of the form and arrangement of the choir still remains in the church of San Clemente.

We now arrive at the last division, which answered to the holy of holies of the Jewish temple, being appropriated to the priests and the celebration of the most sacred offices of the church. Eusebius calls this place *αγιασμα*; and it is elsewhere named *αγιον*, or the sanctuary. The Latins call it *sacrarium*. The term *θυσιαστηριον*, which is more particularly applied to the altar, is sometimes used to denote the whole sanctuary, as is evident from the decrees of the council of Laodicea, which forbid lay persons entering the *θυσιαστηριον*. A more common appellation is that of *βημα*, which is so employed from the circumstance of this part of the church being elevated above the nave by a series of steps. A further separation was effected by means of rails, or lattice-work, named *cancelli*; whence our term *chancel*. In his description of the church of Paulinus, Eusebius states the office of these cancelli to be the rendering the sanctuary inaccessible to the multitude; and the council of Trullo directs, "that no layman whatsoever be permitted to enter the place of the altar, excepting only the emperor, when he makes his oblation to the Creator, according to ancient custom." A similar order of the council of Laodicea has been given above. From this practice, the sanctuary obtained the epithet *αδυτα*, *αναβατα*, *inapproachable*. This part of the church was usually of a semicircular plan, around the circumference of which, in close proximity to the wall, were ranged the seats for the bishop and clergy. The throne of the bishop was in the centre, immediately behind the altar, and raised to a greater elevation than those of the presbyters, which were ranged on either side of him. Gregory Nazianzen speaks of himself, as bishop setting upon a high throne, with the presbyters, on lower benches, on either side.

The altar was situate in the centre of the chancel, in front of the bishop's throne, so as to allow of a passage all round it; it was named indifferently *ara*, *altare*, *θυσιαστηριον* and *βωμος*; the latter, however, qualified by the addition of *αναιμακτον*. The most ancient altars were of wood, as we learn from several passages in the Fathers: amongst others, S. Austin, speaking o an outrage by the Donatists against a Catholic bishop, says, "They beat him cruelly with clubs, and such like weapons, and at last with the broken pieces of the wood of the altar." Optatus, again, speaking of the Donatists, says, "They brake the altars in such pieces as would afford them plenty of wood to make new; but where there was a scarcity of wood, they contented themselves with scraping them, by way of pretended expiation." When stone altars began to be employed, is very uncertain; all that can be determined upon this point is, that the material was in use for such purpose in the time of Gregory Nyssen, but how long before we cannot tell. Gregory, speaking of the sacred character of the church and its furniture, says, "This altar whereat we stand is by nature only common stone, nothing different from other stones, whereof our walls are made and our pavements formed; but after it is consecrated and dedicated to the service of God it becomes a holy table, an immaculate altar which may not promiscuously be touched by all, but only by the priests in the time of divine service." In the next century, a decree was passed at the council of Epone, that no altars should be consecrated, but such as were of stone. The Pontificals speak of silver altars dedicated by Constantine. The early wooden altars were similar in shape to tables, but when stone was employed for this purpose they assumed a somewhat different appearance, consisting either of slabs supported by a central pier, or of a structure built up similar to a sarcophagus, or tomb.

The altar was covered by a canopy, supported by pillars, frequently twelve in number, in allusion to the number of the apostles, and having their capitals adorned with silver bowls. The canopy which was spherical, was surmounted with a cross and the space between the pillars hung with veils, which served to conceal the altar. These are, perhaps, the veils alluded to by Chrysostom, where, speaking of the consecration of the elements, he says, "When you see the veils withdrawn, then think you see heaven opened, and the angels descending from above." Curtains, however, were used in other parts of the church, before the doors, and at the entrance to the sanctuary, which were sometimes richly adorned with gold, as was that given by Chosroes to the church at Antioch. Epiphanius relates his tearing to pieces a veil suspended before the doors of the church, because it had a picture on it; and Athanasius, speaking of the enormities of the Arians, says, "They took the bishop's throne, and the seats of the presbyters, and the table which was of wood, and the veils of the church, and whatever else they could, and carried them out and burned them." Sometimes a silver dove was suspended over the altar. The canopy was turned *ciborium*, or *πυργος*. In later times, crosses were set upon the altar, but the time of their introduction is not known: Sozomen and Evagrius are among the first who allude to the practice. The altar was covered with a linen cloth, as is evidenced by Optatus, who, in allusion to the extravagant pretensions of the Donatists in purifying everything that had been touched by the Catholics, says "that if anything was polluted, it must be the covering, and not the tables;" and adds, that they pretended to wash these palls. Sometimes such coverings were of richer stuff, for Palladius has reference to some Roman ladies, who bequeathed their silks to make coverings for the altar. The sacred vessels were of various materials. We learn from Irenæus, Epiphanius, and Jerome, that chalices were made of glass in their time; but there can be no doubt that silver and gold were frequently employed for this purpose; for it is related of Laurentius, who was martyred in the time of Valerian, that he would not deliver up the plate in which they were used to celebrate the sacred mysteries; and in an inventory delivered up at the same period, by Paul, bishop of Cirta, we find mention made of two gold cups, six silver cups, and various other vessels of the same materials.

In many churches, besides the altar, was a side-table, in a recess, on one side of the *bema*, where the offerings of bread and wine were received, and which is called by various names, *παρατραπεζα*, *prothesis*, *paratorium*, *oblationarium*, and *corban*. In the recess on the opposite side of the bema, was the *Scenophylacium*, which was a sort of vestry in which the priests robed, and where the deacons brought the vestments and vessels from the Diaconicum, previous to service. It was likewise called the *Diaconicum Bematis*, to distinguish it from the larger building of the same name and uses outside the church.

Under the general term *exhedræ*, are comprehended all the buildings that were contained within the outermost enclosure, but without the walls of the church, properly so called: these were many in number consisting of schools, residences for the priests, &c.; but we shall here only take notice of the more important.

The *Baptistery*, during the first five centuries, formed a separate building outside the church, as we gather from Eusebius, Paulinus of Nola, and Gregory of Tours. It was a large and capacious edifice, containing several apartments, some perhaps for the catechumens, and was not unfrequently octagonal in plan. It was necessary that these buildings should be somewhat extensive, for the sacrament of baptism was but seldom celebrated, the two seasons set apart for the purpose being Easter and Pentecost; so that a large number of persons were congregated together at the same time; and there is reason to suppose that there was but one baptistery to each city, however numerous the churches may have been. In the centre of this building was the font, which was large enough for immersion.

The *Secretarium*, or *Diaconicum*, was a building in which all the property belonging to the church, such as vestments, vessels, offerings, &c., were deposited when not in use, and whence they were carried into the church when required. It was called diaconicum from the fact of the deacons having charge of all matters contained therein.

Another outbuilding was the *Library*, as we learn from Eusebius, who tells us that he was greatly indebted to that founded by Alexander, bishop of Jerusalem, in procuring materials for the compilation of his history; and Julius Africanus is said to have founded another at Cæsarea. The largest library was probably that belonging to the church of Sta Sophia, Constantinople, which is said to have contained one hundred thousand books, and was burned down by the firing of the city in a proper tumult. That *Schools* were attached to the church, we may know from what Socrates says of Julian, "that, in his youth, he frequented the church, where, in those days, the schools were kept."

Amongst the exhedræ are likewise reckoned the *mitatorium*, *gazophylacium* and *pastophoria* but of these we know little or nothing.

As regards the decoration of the interior of the church, we may gather, that the walls were sometimes coated with marble, and most frequently adorned with inscriptions of passages of Scripture, or other religious writings appropriately disposed. Thus S. Ambrose speaks of the text, "There is a difference between a wife and a virgin," &c., being written on the walls near the virgins' seats; Paulinus mentions several passages applied to the same purpose, as do also Sidonius and Apollinaris. The roofs were enriched with mosaic, or what is called lacunary or panel-work, and in this case gilding and colour were employed; in the church of Sta Sophia is an instance of the former practice, and in that of Constantine at Jerusalem, an example of the latter, where the roof was panelled, and covered with gold. S. Jerome likewise speaks of lacunary golden roofs, walls adorned with marble, pillars with capitals of shining gold, gates inlaid with ivory and silver, and altars set with precious stones and gold. Such was the arrangement and decoration of an early Christian church.

We have already considered the question relative to the conversion of heathen temples to the purposes of Christian worship; but there is yet another building in use amongst the pagans, which lays claim to the same honour, and with some greater show of probability, it is the *basilica*. The Roman basilica was the hall of public justice, the court in which, during the early history of that nation, the kings sat to hear and decide the causes of their subjects; it was, in fact, at that period a royal palace situate in the Forum, whence the name. The word, however, is Greek, and was first applied to the portico in the Athenian Ceramicus immediately beneath the Pnyx; the custom, as well as the building, was borrowed by the Romans. Such edifices varied in form in different instances, but not to any very great extent, the same disposition seems to have been universally observed and was as follows:—

The plan was an oblong, terminated at one, or sometimes both ends, with a semi-circle; the semi-circle was occasionally omitted, and sometimes there were two or three of different dimensions. Internally the breadth was divided into three—rarely into five—by two or four rows of columns running down the length of the church; at the extreme end was the semi-circular apse, in the midst of which was the seat of the prætor, whence he administered justice; this was the tribunal. On either side of the prætor, but lower down, were the benches for his assessors, the centumviri, and other officers, and all these were separated from the other part of the building by an enclosure of lattice-work, to which was given the name of *cancelli*. Outside of this screen was a place allotted to the notaries and advocates, the remainder of the building being occupied by the people.

We have here a three-aisled structure, the divisions being formed by two central rows of columns and two outer walls, the columns frequently supporting a gallery in the outer divisions. The central portion was generally lighted from windows or openings in a wall raised above the columns, thus forming a sort of clere-story. This roof was invariably of wood, and did not always cover the whole building. For a further description *see* BASILICA.

Some writers suppose that several such buildings were delivered by Constantine into the hands of the Christians, and were employed by them as churches, or places of public worship. Some go so far as to assert, that they were the prototype of the succeeding churches, not only in form but in the division and disposition of the parts. The writer we have had occasion to quote in a previous part of this article speaks thus:—

"Had the basilica, such as we have described it, been planned for the express reception of a Christian congregation, it scarcely could have received a more convenient or appropriate form—none more happily combining magnificence with utility—none more consonant to the ideas which then prevailed. The general shape of the church as prescribed by the Apostolical Constitutions, was to be an oblong like unto a ship, that is, to the vessel of the ark. Does not the outline of the ground-plot of the basilica entirely meet the suggestion? and the terms *nave*, *nef* or *vaisseau*, applied to the main portion of the edifice, show how enduringly the idea prevailed in subsequent ages. The apse in which the prætor administered justice, surrounded by the centumviri and other judges offered a dignified tribunal for the bishop and his clergy; the dark chambers below suggested the subterraneous chapel, in which might be deposited the remains of saint or martyr. The enclosures, the *cancelli* for the notaries and advocates, might receive the singers of the choir. The lengthened aisles would furnish space for the congregation of the faithful: the galleries seclude the women; and the porch fronting some of the basilicas, or the uncovered portion which, if separated from the rest by a wall, would constitute a court, was prepared for those who had been separated from the rest of the congregation by their sins, or were not yet allowed to participate in the sacraments. Hence we find from one of those incidental notices which often are more instructive than the set narrative of history, that the basilica had been given up, bodily, for the purpose of Christian worship. A poet, but also a rhetor, addressing an emperor, tells him that these structures, heretofore wont to be filled up with men of business, were now thronged with votaries praying for his safety; '*Basilica olim negotiis plena, nunc votis pro tua salute susceptis.*' This occupation of the Roman basilicæ was, nevertheless, only transitory. They did not become the abiding-places of the faith. Why was this privilege denied them? In situation they were most convenient, placed in the centre of business and population; their plan and form so convenient as to invite the purposes of worship. Unpolluted by the idol or sacrifice, they were free from the recollections rendering the heathen temple odious. With the smallest proportionate expense or labour, the basilicæ of the Forum might have been rendered the most stately and dignified of sanctuaries. Yet they fell! Only one example can be found of a secular basilica actually converted into a Christian church—and that example, memorable as it is, does not exist in Rome. As if for the purpose of constantly demonstrating to mankind the visible triumph of the spiritual kingdom, every stage in the early development of the empire of Christianity seemed destined to efface the honours of heathen sovereignty. The Christian basilica, though entirely modelled upon the heathen basilica, and constructed with the spoils of the basilica, was therefore fated to be its ruin and destruction.

"A single cause suffices—a cause of which we now can scarcely appreciate the potency. Veneration for the graves of the martyrs, as an almost irresistible motive, attracted the Christian basilica away equally from the precinct of the secular basilica as from the site of the heathen temple. By determining the locality assigned to the Christian edifice, this feeling necessarily determined the neglect, ruin, and destruction of the proud monuments of senators and Cæsars. The demolition of earlier structures, for the purpose of furnishing materials, had already been long practised. Thus the interior of the Coliseum displays the friezes and fragments, mixed up in confusion, amidst the masonry of the beautiful yet appalling circuit of its walls. These, perhaps, may have resulted from the removal of other buildings previously existing on the site; but under Constantine similar demolitions proceeded, as it should seem, equally from the desire of sparing expense, and the increasing inability to execute works of art. The splendid Forum of Trajan, which had excited Constantine's admiration, fell at his command, and furnished by its spoils the decorations of the arch of the first Christian emperor. Abandoned for more hallowed ground, the civil basilicas were destroyed, and the columns which supported them transported to the new sites, where they arose in lengthened perspective and barbaric splendour. By their very aspect, such of the Christian churches as retain their original features, show the haste and unskilfulness with which they are reared; one capital cut through and deprived of the lower range of the acanthus, to fit it into the required space; another projecting over the shaft; a third shrinking within; a fourth, the leaves blocked, and prepared for the touch—never to be given—of the chisel that was to have imparted Corinthian elegance;—the columns themselves of unequal circumference or unequal height, deprived of their due proportions, or rudely stilted to attain the necessary elevation. The richest materials are mixed with others of inferior quality; pavonazzo and verd antique, the products of the quarries of Syene or of Paros, and the homely Travestine, are intermingled without choice or discrimination."

This writer is of opinion that the heathen basilicas were not actually converted into Christian temples; there are many, however, who hold the contrary, amongst whom is Mr. Hope, who cites, as examples of such adaptation, the Sessorian basilica, and that in the palace of the Lateran, which he says were given to the church by Constantine. The strongest argument on this side, is, we think, the triumphant declaration of Ausonius, that the ancient halls of justice were filled with Christian worshippers; the above-mentioned reviewer alludes to this passage in the following words : —

"We have already seen that no one of the Christian basilicæ at Rome, resulted from any adaptation of the civil structures of heathenism to religious purposes. The columns fell, to rise in new localities. Rome furnishes no example of a basilica preserved by its application to Christian worship. No confirmation is given in the ancient capital to the orator's assertions, exulting, in the presence of Gratian, at the crowds which filled the ancient halls of justice, then, as he boasts, resounding with hymn and praise; yet we can point out one city in which his assertions are not a rhetorical phrase, but a truth. Do we seek for the verification of the words of the poet-rhetor, 'Basilica, olim negotus plena, nunc votis pro tua salute susceptis?' Here we find that which at Rome we search for in vain. Here alone can we behold the one example of a basilica consecrated as a Christian church, in which you enter, and see the Corinthian capitals just displaying their graceful foliage, mutilated and yet distinct—through the rude wall which encircles them—whilst the shaft of another, displaced and broken, lies in gigantic bulk before the portal of the edifice. This indeed is the very city in which the poet-rhetor was speaking—for he is Ausonius—and the city is Treves. The ancient capital of the Roman empire beyond the Alps, furnished the model for the structures, which, far more than those of Rome herself, assisted in the development of Christian architecture."

We cannot think this a satisfactory method of getting over the difficulty; Ausonius seems to speak of such facts as well and universally known; he is describing the general effect of Christianity, and glorying in its success; his are sweeping assertions, not applicable to merely individual instances, but to general custom. Besides, if the Christians at Treves converted basilicas into churches, why should they not do the same elsewhere? and especially in the metropolis, where there was a larger proportion of such buildings, and greater need of churches.

While saying this, we do not mean to deny that there was a strong repugnance amongst the early Christians to everything that had been connected with paganism, and that the application of the basilica was rather a matter of necessity than of choice. When Constantine legalized Christianity, the Christians numbered somewhat considerably, and no doubt increased rapidly upon that event; many who previously favoured that religion, but were fearful of the consequences of an avowal, now openly professing it. Churches were needed more than ever, and they had not skill wherewith to erect them; what could be done? where were churches to be found, while new ones were building? were there any existing buildings that could be adapted to such a purpose? The pagan temples were not fitted for such uses, even had there been no repugnance to their origin; but the basilicas would answer the purpose well, as far as their construction was concerned, nor were there equal objections to them on the score of their previous employment. What more likely than that they should be used at least for a time, until new structures could be erected?

The counter-argument arising from the absence of any examples of such adaptation of the civil basilica, may be accounted for without much difficulty: they were destroyed, to afford materials for new structures in other sites. The principal cause of their destruction or removal, is to be sought in the veneration of the Christians for the graves of the martyrs. On this subject, Mr. Knight says :—

"From the custom which had originated in the catacombs —from the habit which the primitive Christians had acquired of visiting the graves of the martyrs; it became a matter of necessity to associate the church with the tomb, and to provide a place of worship below ground, as well as above. This, in several instances, was accomplished at Rome by placing the church immediately above a part of the catacombs, as at San Lorenzo and Santa Agnese; or, as at St. Peter's, by placing the altar immediately above the spot to which the mortal remains of the apostles had been removed.

"The practice of associating the churches with the graves of martyrs, was the cause of their being frequently placed in situations which had little reference to public convenience; namely, without the walls of the cities to which they belonged; for, as executions usually took place without the walls, and as the martyrs were often buried, or supposed to have been buried, where they were put to death, the wish of that age could not be accomplished without frequently placing the churches in remote and insulated situations. Thus it was that Constantine placed the church of St. Peter adjacent to the circus of Nero, though the city of Rome was, at that time, at some distance from the Vatican Hill. Theodosius, for similar reasons, placed the church of St. Paul at an equal distance from the city on the opposite side. At that time, a liability, which afterwards exposed insulated churches and their frequenters to much peril, did not exist. At that time, the interior of the empire was still inviolate, and those who built the churches never imagined that the day might come, when their descendants could not go out of the walls without being liable to attacks, and when the churches themselves would be exposed to insult and injury. Little did Constantine imagine, that men of a newer religion than his own would ever reach and deface the cathedral which he had planted within sight of the metropolis of the world."

The existence of such a feeling amongst the early Christians, coupled with the circumstance of the tombs of martyrs being usually without the walls, and the prevalent custom of employing the materials of old buildings for the construction of new, will account, as we think, satisfactorily for the want of more tangible evidence of the conversion of the heathen basilica to Christian uses.

While we contend thus far, we do not wish to ally ourselves with those who maintain, that the arrangement of churches was derived from that of the civil basilica: there is no doubt a similarity of distribution and a certain analogy between the purposes which each division in either building served; still, there are strong grounds for believing that such disposition in the churches arose from the natural requirements of the religion, rather than from any extraneous influence. The description of the several orders of penitents, and of their positions in the church, as above given, is sufficient proof of such being the case, for that was written during times of persecution, before Constantine had ascended the throne; the division into parts, therefore, was determined long ere any basilicas were given up for Christian worship. It is not improbable, however, that the form of later churches was derived from that of the basilica; for it must needs be, that either some existing form was copied, or an entirely new idea originated. That the latter was the case is very improbable, from the nature of things, almost all novelties having emanated, in some degree or other, from things previously existing: but, besides this, such an occurrence was more especially improbable at the period alluded to, when art was falling to decay, and its influence was not strong enough even to retain previous acquirements, much less to originate new. The main features in the churches erected immediately after the establishment of Christianity, with the exception of Constantine's circular buildings, were those of the civil basilica: there were some few alterations and additions, it is true, to adapt the form to the requirements of the church; but these were at first not very considerable, although extended farther in after times. Of these were the atrium and out-buildings; and, in later times, transepts. With regard to the latter, it has been argued by some, that they are to be found in the civil structures; at least, in the internal arrangement; but this we think almost too nice a similarity. There was, indeed, a cross-passage at the end of the nave, so to speak, but we can scarcely set it down as the prototype of the transept. The cross-form originated in Christian symbolism; nor does it appear even in churches of the earliest date. The Apostolical Constitutions allude to churches as being in the form of a ship, and such seems to have been the actual shape of the first buildings. The cross-plan was a gradual development. At first, we find the cross a prominent feature in the internal decoration, as at St. Clement's, where the paving of the nave is arranged in that form; and afterwards forming an essential office in the construction, as in the Byzantine churches, and the later basilicas. We are of opinion, then, that, at the onset, civil basilicas were employed for Christian worship, though rather as a matter of necessity than choice; that the division and disposition of parts observable in the early churches was not derived from the basilica; but that their form and construction was so derived; and that hence was developed the form of churches in after ages.

As regards the styles of architecture employed, the earliest constructions can scarcely be said to belong to any style; they were composed of the ruins of heathen structures, promiscuously heaped together; columns from one building, entablature from another; or even one column from one building, and the next from a second; and not unfrequently the shaft or base of one column with the capital of another: columns of different heights and proportions were huddled into the same row, and the difference of level made up either by stilting or cutting short. The Byzantine churches, with their square plans and spherical roofs, are the first buildings which can be said to possess any style, and these were chiefly confined to Asia Minor, having little influence in Italy until the sixth century. (See, Byzantine Architecture.) Shortly after this, the Lombards established themselves in Italy; and although they brought with them no architecture of their own, they gave a somewhat novel character to the buildings erected by them, the difference being principallly in detail. This style prevailed in the north of Italy up to the end of the twelfth century, at the commencement of which some marked alterations were introduced. (See, Lombardic Architecture.) To this succeeded that most perfect form of Ecclesiastical Architecture, pre-eminently termed the Christian style, which has prevailed, with some interruptions, ever since; we need scarcely add, we allude to the Gothic, or pointed, which for its solemn grandeur, as well as for its perfect construction, is, of all, the most appropriate for a Christian temple.

We have now arrived at the conclusion of this interesting subject, and for any further information must refer to such articles as Church, Cathedral, Gothic, and Saxon Architecture, &c.

ECHINUS (from εχινος, a word denoting the prickly cover of a chesnut) a convex moulding in the form of a conic section, generally carved into ornaments representing truncated spheroids, or eggs, with the upper ends cut off, the upper part of the axis projecting, and the lower part receding. Each truncated spheroid is surrounded with a border, of an elliptic figure, in close contact, showing something more than a semi-ellipsis, the shorter axis being horizontal.

The projecting edge of the border is in the surface of the moulding, previously wrought, as is also the curvature of the upper part of the spheroid. Every two adjacent borders contain a space equal to the thickness of the border at the top, and gradually receding towards the bottom. In each recess, or space, is an anchor, or tongue; the front edge of which comes in contact with the surface of the original moulding, and is in a vertical line cutting the surface of the moulding at right angles.

In Grecian architecture, the front of each border, and also the front of each tongue, or anchor, is wrought to an angle, the section of which inclines equally to the surface. The bottom of the spaces on each side of the tongue, on the under side, is nearly in the same surface as the recess on the sides of the eggs.

In Roman architecture, the general contour is the segment or quarter of a circle, and the fronts of the surrounding borders are not brought to an angle, but remain as part of the moulding, either plain or with a hollow sunk between the edges, leaving a fillet next to each edge.

Its situation in an order, is in the entablature or capital, but never in the base.

In the original Doric order, the ovolo, which crowns the cornice, and that of the capital, are never carved. In the Ionic and Corinthian entablatures, it may either be carved or not, but in the antiques it is generally carved. The ovolo in the capitals of these orders, is, however, always carved into the ornaments we are describing. The French call this moulding, *quart de rond;* the English, *quarter-round*, or *boulting;* the Italians, *ovolo;* the Latins, *ovum*, from its being usually carved with the figures of eggs; and the French, for the same reason, sometimes call it *œuf.*

ECHO, (from the Greek, ηχος, *sound*, of the verb, ηχεω, *I sound*.) the reverberation of sound, occasioned by the particular construction of a vault or wall, the section of which is most commonly of an elliptical or parabolical figure. The method of making artificial echoes, is taught by the Jesuit Blancani, in his *Echometria*, at the end of his book *On the Sphere*.

We are informed by Vitruvius, that in various parts of Greece and Italy, there were brazen vessels, ingeniously arranged under the seats of the theatres, to render the sound of the actors' voices more clear, and make a kind of echo; by which means the prodigious multitude of persons present at their spectacles were enabled to hear with ease and pleasure.

The distribution of sound in public edifices, so that the echoes may be most advantageously brought to strengthen the original sound, is a subject practically deserving much attention. In Sir J. Herschel's Treatise on Sound, the reader will find some sensible observations on the errors of architects in this respect. The inattention of the latter to the effect of the reverberation of sound, was curiously exemplified in the cathedral of Girgenti, where the confessional was placed in a focus conjugate to another and unenclosed part of the church; by which unlucky error the echo was instrumental in informing a husband of the infidelity of his spouse. In many of our public buildings, though professedly erected for purposes where the proper distribution of sound is of paramount importance, it is no uncommon occurrence, that one part of the audience possesses a monopoly, while the remainder witness the ceremony or performance in dumb show.

Sounds are reflected by certain configurations of bodies, like the reflection of light from polished surfaces; so that if a person situated before one of these bodies utter a word, he will in a short time after hear the echo, or repetition of the sound. The vibratory motion of the air, which constitutes sound, is reflected by hard bodies, and, in certain cases, even by fluids. Thus the sides of a hill, houses, rocks, banks of earth, the large trunks of trees, the surface of water, especially at the bottom of a well, and sometimes even the clouds, have been found capable of reflecting sounds. The configuration of the surface of these bodies, is much more concerned in the production of the echo than their substance. A smooth surface reflects sounds much better than a rough one. A convex surface is a very bad reflector of sound; a flat one reflects very well; but a small degree of concavity, particularly when the sounding body is in or near the focus of concavity, renders the surface a much better reflector, and the echo is heard considerably louder.

Thus, in an elliptical apartment, if the sounding body be placed in one focus, the sound will be heard much louder by a person situated in the other focus of the ellipsis, that in any other part of the room. In this case, the effect is so powerful, that even when the middle part of the room is wanting, the sound expressed in one focus will be heard by a person situated in the other, but hardly at all by those who stand in the intermediate space.

Without attempting to explain the manner in which the vibrating air impinges upon, and is sent back by, the reflecting body, which would lead us too far into the science of acoustics, we shall briefly notice the following ascertained facts.

If a person standing before a high wall, a bank, a rock, &c., at a certain distance, and uttering a word with a pretty strong voice, or producing by a hammer, stone, &c., any short, sharp sound, hear a repetition of that word or sound, he will find that the time elapsed between his uttering the word, or striking with the hammer, and hearing of the echo, is equal to the time that a sound is known to employ in going through an extension of twice the distance between him and the reflecting wall, rock, &c.; for the vibratory motion of the air must proceed from the sounding person to the wall, &c., and back again from the latter to the former. Now, sound is known to travel at the rate of about 1,125 feet in a second of time; therefore, if the person who expresses the word, or any sound whatever, stand at the distance of 1,125 feet from the echoing wall, &c., two seconds of time must elapse between his uttering the sound and his hearing the echo. If the distance be equal to 4,500 feet, then eight seconds of time must elapse between the uttering of the sound, and the arrival of the echo; and so on. But the same original sound and the echo may be heard by persons at different distances, both from the original sounding-place, and from the reflecting body. The effect, however, will not be exactly uniform, for those who are nearer to the reflecting body, will hear the echo sooner than persons more remote. A situation may be easily found, from which they will hear both the original sound and the echo at the same instant, and as both sounds coalesce, they will only appear as one loud sound, without the echo.

But though several persons, in different situations, may hear the echo of the same sound, yet the echo will be heard better in one particular direction than in any other; now if two straight lines be drawn from the middle of a reflecting surface, one to the place from which the original sound proceeds, and the other to the above-mentioned best direction, those two lines will be found to make equal angles with the surface. Hence it appears, that in the reflection of sound, the angle of incidence is equal to the angle of reflection. Therefore, if a person wishes to hear the echo of his own voice in the best possible manner, he must stand in a direction perpendicular to the reflecting surface. And this shows, that though sound proceeds from an original sounding body, or from a reflecting surface, in every direction; yet a greater quantity of it proceeds in some particular direction than in any other, which is probably owing to the original impulse being given to the air more forcibly in one direction than in another, or from want of perfect freedom in the aërial fluid.

Several phenomena may be easily explained upon the above-mentioned property of sound: for instance, several reflecting surfaces are frequently so situated with respect to distance and direction, that a sound proceeding from a certain point is reflected by one surface first, then by a second, soon after by a third, and so on, but by all in one direction; in which case a multiplied tautological echo is produced; that is to say, the same word is heard repeated several times successively in the same tone and accent; the expression of one Ho! will appear like a peal of laughter; a musical instrument, properly played, will produce an agreeable repetition of as many instruments of the same sort, imitating each other.

According to the various distances of the speaker, a reflecting object will return the echo of several, or of a few syllables, for all the syllables must be uttered before the echo of the first syllable reaches the ear; otherwise it will make a confusion. The farther the reflecting object is, the greater number of syllables will the echo repeat; but the sound will be enfeebled nearly in the same proportion, till at last the syllables cannot be heard distinctly. When the reflecting object is too near, the repetition of the sound arrives at the ear whilst the perception of the original sound still continues, in which case, an indistinct sounding noise is heard. This effect may especially be observed in empty rooms, passages, &c., because, in such places, several reflections from the wall to the hearer, as also from one wall to the other, and then to the hearer, clash with each other, and increase the indistinctness.

From what has been said, it will be easily conceived, that with respect to echoes, a vast variety of effects may be produced, by varying the form, the distance, and the number of reflecting surfaces; and hence we hear of various surprising echoes being met with at different places.

In Woodstock Park, near Oxford, there is a famous echo, which repeats seventeen syllables in the daytime, and twenty at night, when the air is somewhat more dense. On the north side of Shipley Church, in Sussex, there is another remarkable echo, which, in favourable circumstances, repeats twenty-one syllables. At Rosneath, near Glasgow, in Scotland, is an echo, that repeats three times, completely and distinctly, a tune played with a trumpet.

Whispering-places, are those where a whisper, or other small noise, is conveyed from one part to another, at a great distance. They depend upon this principle, that the voice, being applied to one end of an arch, easily passes by a repetition of reflections to the other.

Hence sound is conveyed from one side of a whispering-gallery to the opposite one, without being perceived by those who stand in the middle. The form of a whispering-gallery is that of a sphere, or the segment of a sphere. The principle of whispering being that of continued reflection. If a person whisper softly against a wall, the rays which proceed from his mouth issue in all directions against the wall; we shall only take the rays which emanate from the whisperer's mouth (which we shall suppose to be a point) in a horizontal plane, then it is evident, that they will proceed to the right and to the left, and each particle of sound, as we may call it, for want of a more specific name, will cut off equal segments of the circle which forms the section of the wall; or, in other words, will pass along equal chords; and there will be an infinite number of such reflections; each particle describing chords different from those described by another, and an indefinite number of these will divide the semi-circumference into parts all equal to each other, in the same system of chords; therefore, all the describing particles of sound passing along the equal chords, will meet upon the other extremity of the diameter opposite the whisperer, and thus form a loud whispering noise. It is evident, that polished surfaces are the most favourable for this purpose. Accordingly, all the contrivance requisite in whispering-places is, that near the person who whispers, there may be a smooth arched wall, either cylindric or cylindroidic; though a body with circular sections will do, but not so well.

The most considerable whispering place in England, is the whispering gallery in the dome of St. Paul's Cathedral, London, where the ticking of a watch may be heard from side to side, and a very easy whisper be sent all round the dome. The famous whispering-gallery in Gloucester Cathedral, is no other than a gallery above the east end of the choir, leading from one side thereof to the other. It consists of five angles, and six sides, the middlemost of which is a naked window; yet two whisperers hear each other at the distance of twenty-five yards.

ECHOMETRY, the art of constructing vaults to produce echoes.

ECPHORA, or Ecphoran (from ἐκ, *out*, and φερω, *I bear*,) the projecture, or distance between the extremity of a member, or moulding, and the naked of the column, or other part it projects from.

Some authors, however, account the ecphora, or projecture, from the axis of the column, and define it to be a right line intercepted between the axis and the outermost surface of a member, or moulding. The word is used by Vitruvius, in Chapter III., book iii., in the explanation of columns and their ornaments. See Projecture.

ECTYPE (from the Greek): *αρχετυπον*, denotes the original, or model; *εντυπον*, the copy or image, moulded or struck *in creux;* and *εκτυπον*, the image *in relievo*, or embossed.

EDDYSTONE LIGHTHOUSE, a celebrated building erected upon a cluster of very dangerous rocks, situated in the English Channel, in latitude 50° 3′ N., and longitude 40° 21′ W. These rocks are about fourteen miles from Plymouth Sound, and, lying nearly in the track of vessels going up or down channel, have been the cause of many shipwrecks. To guard against these disasters, it was deemed necessary to erect a lighthouse; but to effect this in a complete and permanent manner, so as to resist storms and afford light, was a task of extreme difficulty.

The Eddystone rocks are so peculiarly exposed to the swell of the ocean from the south and west, that the heavy seas break upon them with uncontrolled fury. Sometimes, after a storm, when the sea is apparently quite smooth, and its surface unruffled by the slightest breeze, the ground-swell, or under-current, meets the slope of the rocks, and the sea beats tremendously upon them, and even rises above the light-house, overtopping it for the moment, as with a canopy of frothy wave. Notwithstanding this awful swell, Mr. Henry Winstanley undertook, in the year 1696, to build a light-house on the principal rock, for the rest are under water; and in 1700 he completed it. So confident was this ingenious mechanic of the stability of his edifice, that he declared his wish to be in it during the most tremendous storm that could arise. This wish he unfortunately obtained, for he perished in it, during the dreadful storm which destroyed it, November 27, 1703. Another light-house, of a different construction, was erected of wood, on this rock, by Mr. John Rudyerd, in 1709; which being consumed by fire in 1755, a third, of stone, was begun by the justly celebrated Mr. John Smeaton, April 2, 1757, and finished August 24, 1759, which has hitherto withstood the attacks of the most violent storms. The following account of this building, taken from Mr. Smeaton's "Narrative," must be read with interest, as a noble instance of the triumph of skill, science, and perseverance over obstacles of the most formidable character:—

Mr. Smeaton begins his account with a general description of the Eddystone rocks, the course of the tides, their situation, component matter, and the proper season for visiting them. He then takes an ample view of Mr. Winstanley's edifice, to whom he ascribes great praise for having undertaken and achieved what had been generally deemed impracticable; and after deploring that gentleman's disaster, goes on to describe the second lighthouse, built by Mr. Rudyerd, as a most complete edifice of the kind, being of timber, in the course of which he details the best methods of fixing iron chains, and securing timber-work to rocks, which we shall give in his own words.

"As nothing would stand upon the sloping surface of the rock without artificial means to stay it, Mr. Rudyerd judiciously concluded, that if the rock were reduced to level bearings, the heavy bodies to be placed upon it, would then have no tendency to slide; and this would be the case, even though but imperfectly executed; for the sliding tendency being taken away from those parts that were reduced to a level, the whole would be much more securely retained by the iron bolts or branches, than if, for the retention of the whole, they had depended entirely upon the iron-work; as manifestly appears to have been the case with the building of Mr. Winstanley. According to Mr. Rudyerd's print, the inclined surface of the rock was intended to have been reduced to a set of regular steps, which would have been attended with the same good effect, as if the whole could have been reduced to one level; but in reality, from the hardness of the rock, the shortness and uncertainty of the intervals in which this part of the work must have been performed; and the great tendency of the laminæ whereof the rock is composed to rise in spawls, according to the inclined surface, when worked upon by tools, urged with sufficient force to make an impression; this part of the work, that is, the stepping of the rock, had been but imperfectly performed, though in a degree that sufficed.

"The holes made to receive the iron branches, appear to have been drilled into the rock by jumpers, making holes of about $2\frac{1}{4}$ inches diameter; the extremities of the two holes forming the breadth for the branch, at the surface of the rock, were about $7\frac{1}{2}$ inches; and these holes were directed so that at their bottoms they should be separated somewhat better than an inch more, that is, so as to be full $8\frac{1}{2}$ inches. In the intermediate space, a third hole was bored between the two former; and then if the three holes were broken into one, by square-faced pummels, this would make the holes sufficiently smooth and regular. By this means he obtained holes of a dove-tail shape, being $2\frac{1}{4}$ inches wide, $7\frac{1}{2}$ broad at top, $8\frac{1}{2}$ at bottom, and 15 and 16 inches deep; and as these could not be made all alike, every branch was forged to fit its respective hole. The main pieces of each branch, were about $4\frac{1}{2}$ inches broad at the surface of the rock, and $6\frac{1}{2}$ at the bottom; and this being first put down into the hole, the space left for a key would be 3 inches at top, and 2 inches at bottom, which would admit it to be driven in so as to render the whole firm, and the main branch fixed like a dove-tail or lewis.

"The holes being each finished, and fitted with their respective branches, and cleared of water, a considerable quantity of melted tallow was poured into each hole: the branch and key being then heated to about a blue heat, and put down into the tallow, and the key firmly driven, all the space unfilled by the iron, would become full of tallow, and the overplus made to run over: when this was done, all remaining hot, a quantity of coarse pewter, being made red-hot in a ladle, and run into the chinks, as being the heaviest body, would drive out the superfluous melted tallow: and so effectually had this operation succeeded, that in those branches which were cut out in 1756, and had remained fast, the whole cavity had continued so thoroughly full, that not only the pewter, but even, in general, the tallow, remained apparently fresh: and when the pewter was melted from the irons, the scale appeared upon the iron, as if it had come from the smith's forge, without the least rust upon it.

"All the iron branches, which are shown, as I found them, in Plate I, having been fixed in the manner above-mentioned, they next proceeded to lay a course of squared oak balks, lengthwise upon the lowest step, and of a size to reach up to the level of the step above. Then a set of short balks were laid crosswise of the former, and upon the next step compoundedly, so as to make good up to the surface of the third step. The third stratum was therefore again laid lengthwise, and the fourth crosswise, &c., till a basement of solid wood was raised, two complete courses higher than the highest part of the rock; the whole being fitted together, and to the rock, as close as possible, and the balks, in all their intersections with each other, trenailed together. They were also fitted to the iron branches where they happened to fall in; for the branches do not seem to have been placed with any complete regularity or order, but rather where the strength and firmness of the rock pointed out the properest places for fixing them; they were, however, to appearance disposed so as to form a double circle, one about a foot within the circumference of the basement, and the other about three feet within the former; besides which, there were two large branches fixed near the centre, for taking hold of the two sides of a large upright piece of timber, which was called *the mast;* by which two branches it was strongly fixed down; and being set perpendicular, it served as a centre for guiding all the rest of the succeeding work.

"The branches were perforated, in their respective upper parts, some with three, and some with four holes; so that, in every pair (collectively called *a branch*) there would be at a medium seven holes; and as there were at least thirty-six original branches, there would be 252 holes, which were about seven-eighths of an inch in diameter; and, consequently, were capable of receiving as many large-bearded spikes, or jag-bolts, which being driven through the branches into the solid timber, would undoubtedly hold the whole mass firmly down; and the great multiplicity of trenails in the intersections, would confine all the strata closely and compactly together.

"I cannot omit here to remark, that though the instrument we now call *the lewis*, is of an old date, yet, so far as appears, this particular application of that idea, which Mr. Rudyerd employed in fixing his iron branches firmly to the rock, was made use of for the first time in this work: for though Mr. Winstanley mentions his having made twelve holes, and fixed twelve great irons in the rock, in his first year's work, yet he gives no intimation of any particular mode of fixing them, but the common way with lead; and the stump of one of the great irons of Mr. Winstanley's, that was cut out in the course of the work of the summer of 1756, was fixed in that manner; but we remarked, that the low end of this bar or stanchion, was a little club-ended, and that the hole was somewhat under-cut; so that, when the lead was poured in, the whole together would make a sort of dovetail engraftment: however, when these irons, by great agitations, became loose, and the lead yielded in a certain degree, they would be liable to be drawn out; as the orifice by which they entered must have been large enough to receive the iron club. Mr. Rudyerd's method, therefore, of keying and securing, must be considered as a material accession to the practical part of engineery; as it furnishes a secure method of fixing ring-bolts and eye-bolts, stanchions, &c., not only into rocks of any known hardness; but into piers, moles, &c., that have already been constructed, for the safe mooring of ships; or fixing additional works, whether of stone or wood.

"In this way, by building *stratum super stratum*, of solid squared oak timber, which was of the best quality, Mr. Rudyerd was enabled to make a solid basement of what height he thought proper: but in addition to the above methods, he judiciously laid hold of the great principle of engineery, that weight is the most naturally and effectually resisted by weight. He considered, that all his joints being pervious to water, and that though a great part of the ground-joint of the whole mass was in contact with the rock, yet many parts of it could not be accurately so; and therefore, that whatever parts of the ground-joint were not in perfect contact, so as to exclude the water therefrom, though the separation was only by the thickness of a piece of post-paper, yet if capable of receiving water in a fluid state, the action of a wave upon it edgewise, would, upon the principles of hydrostatics, produce an equal effect towards lifting it upwards, as if it acted immediately upon so much area of the bottom as was not in close contact.

"The more effectually therefore to counteract every tendency of the seas to move the building in any direction, he determined to interpose strata of Cornish moor-stone between those of wood; and accordingly having raised his foundation solid, two courses above the top of the rock, he then put on five courses, of one foot thick each, of the moor-stone. These courses were as well jointed as the workmen of the country could do it, to introduce as much weight as possible into the space to contain them: they were, however, laid without any cement; but it appears that iron cramps were used, to retain the stones of each course together, and also upright ones to confine down the outside stones.

"When five feet of moor-stone were laid on, which, according to the dimensions, would weigh 120 tons; he then interposed a couple of courses of solid timber, as before; the use of which was plainly for the more effectual and ready fastening of the outside uprights to the solid, by means of jag-bolts, or screw-bolts; and that these bolts might the more effectually hold in the wood, in every part of the circle (which could not be the case with timbers lying parallel to each other, because in two points of the circle, opposite to each other, the timbers would present their ends towards the bolt) he encompassed those two courses with circular, or what are technically called *compass timbers*, properly scarfed together, and breaking joint one course upon the other. We must not, however, suppose, that these courses were composed wholly of circular timbers to the centre, but that the circles of compass timbers on the outside, were filled up with parallel pieces within; and that the compass timbers were, in the most favourable points, jag-bolted to the interior parallel pieces.

"The two uppermost courses, after clearing the rock, and before the five moor-stone courses came on, were furnished with compass timbers, as well as some others below.

"The two courses of wood above the moor-stone courses terminated the entire solid of the basement; for a well-hole was begun to be left upon these courses for stairs in the centre, of 6 feet 9 inches in the square; and hereupon was fixed the entry door, or rather, one course lower, making a step up, just within the door; in consequence of this, the entire solid terminated about 9 feet above the higher side of the base, and 19 feet above the lower side thereof.

"In Mr. Winstanley's house, the entry was from the rock into an internal staircase, formed in the casing upon the south-east side; he therefore needed only a few external steps. But Mr. Rudyerd's entry door, being full eight feet above the highest part of the rock, would consequently need a ladder. This he made of iron, of great strength; and being open, whenever the seas broke upon this side of the house, they readily found their passage through, without making any violent agitation upon it.

"The two compass courses terminating the entire solid, having been established, as already mentioned, he again proceeded with five moor-stone courses; nearly the same as the former; allowing for the necessary difference resulting from there now being a central well-hole for the stairs, and a passage from the entry door, as described, to the well-hole: this passage was 2 feet 11 inches wide, and, as it appears, took up the whole height of the five courses. The weight of these five courses, according to the dimensions, amounted to 86 tons.

"He then again proceeded with two compass courses, covering the door-head and passage, so as now to leave no other vacuity than the well-hole; and upon these he laid four moor-stone courses, the weight of which amounted to sixty-seven tons. He then proceeded with two compass courses, and after that, with beds of timber, cross and cross, and compass courses interposing; and, last of all, with one compass course, upon which he laid a floor over all, of oak plank three inches thick, which made the floor of the store-room.

"The height of this floor above the bottom of the well, was near 18 feet; above the foot of the mast, 33 feet; above the rock on the higher side, 27 feet; and above the foot of the building on the lower side, 37 feet. In all this height, no cavity of any kind was intended for any purpose of depositing stores, &c. From the rock to the bottom of the well, all was solid, as we have shown; but as the building increased in height, and consequently was more out of the heavy stroke of the sea, a less degree of strength and solidity would be equivalent to the former, and therefore admit of the convenience of a staircase within the building, with a passage into it: which last, being made upon the east side, would be withdrawn from the heavy shock of the seas from the south-west quarter, and the rock being there highest, the ascent by the iron stair upon the outside, would be the least; the whole therefore, to the height of the store-room floor, as above-mentioned, having been made with all possible solidity, was denominated *the solid.*

"The height of Mr. Rudyerd's store-room floor was fixed as high as the floor of Mr. Winstanley's state-room, which was over his store-room; and as many were doubtless still living who had seen and examined Mr. Winstanley's light-house, during the four years that it stood in a finished state; and as in that time there would be an opportunity of knowing, from experience, to what height the unbroken water of the waves mounted in bad weather, we may very well suppose that Mr. Rudyerd regulated the height of his solid from that information.

"We have already seen, that the two compass courses of wood, which capped the first bed of moor-stone, and terminated the entire solid, were forcibly screwed down by ten large iron bars, or bolts, to the beds of timber below the moor-stone, and these by the trenails and branches to the rock. We must suppose this precaution to have been taken to prevent any derangement from the heavy strokes of the sea in storms and hard gales, which were liable to happen in the very finest part of the season, before there was any proper opportunity of connecting the upper part of the work with the lower, by means of the upright timbers that were to form the outside case; because, till the work was brought to that height, there could be no proper means of beginning to fix them; and as we do not find any traces or mention of binding the upper courses with the lower, after the staircase was set forward, we must suppose that the outside casing had been then begun from the rock, and carried on progressively, so as to become a bond of the upright kind; for, all such timbers as were high enough having been screwed fast to the compass courses, would be thereby secured to the lower courses; otherwise, from what I have myself experienced of the situation, I should have expected, that whenever the two courses of compass timber were put upon the second bed of moor-stone, if a hard gale should have come on at south-west, it would not only have lifted up and carried away the timber beds, but possibly would have deranged the moor-stone courses, notwithstanding the upright cramps to the outside stones.

"The solid being in this manner completed, the upper part of the building, comprehending four rooms, one above another, was chiefly formed by the outside upright timbers; having one kirb or circle of compass timber at each floor, to which the upright timbers were screwed and connected, and upon which the floor timbers were rested. The uprights were also jag-bolted and trenailed to one another, and, in this manner, the work was carried on to the height of 34 feet above the store-room floor, and there terminated by a planking of three inches thick, which composed the roof of the main column, as well as served for the floor of the lantern, and of the balcony round it.

"Thus the main column of this building consisted of one simple figure, being an elegant frustum of a cone, unbroken by any projecting ornament, or anything whereon the violence of the storms could lay hold; being, exclusive of its sloping foundation, 22 feet 8 inches upon its largest circular base, 61 feet high above that circular base, and 14 feet 3 inches in diameter at the top; so that the circular base was somewhat greater than one-third of the total height, and the diameter at top was somewhat less than two-thirds of the base at the greatest circle.

"The junction of the upright timbers upon each other was by means of *scarfs*, as they are technically called in ship-building and carpentry; that is, the joining of timbers end to end by over-lapping. The timbers were of different lengths, from 10 to 20 feet, and so suited, that no two joinings or scarfs of the uprights might fall together. The number of uprights composing the circle was the same from top to bottom; and their number being seventy-one, the breadth at the bottom would be 1 foot nearly; their thickness there was 9 inches; and, as they diminished in breadth towards the top, they also diminished in thickness. The whole of the outside seams were well caulked with oakum, in the same manner as in ships; and the whole payed over with pitch; consequently, upon a near view, the seams running straight from top to bottom in some measure resembled the flutings of columns; which, in so simple a figure, could not fail to catch the attention of the beholder, and prove an agreeable engagement of the eye.

"The whole of the building was, indeed, a piece of shipwrightry: for it is plain, from the preceding account, that the interposed beds of moor-stone had nothing to do with the frame of the building, it being entire and complete exclusive thereof: the beds of moor-stone could therefore only be considered in the nature of ballast, and amounted, from what has been before stated, in the whole, to the weight of above two hundred and seventy tons.

"All the windows, shutters, and doors, were composed of double plank, cross and cross, and clinked together; which falling into a rebate when shut, their outside formed a part of the general surface, like the port-holes in a ship's side; without making any unevenness or projection in the surface. There were, however, two projecting parts terminating this frustrum; one at the top, and the other at the joining with the rock; the utility of which seems to render them indispensable. They had each a projection of about 9 inches. The top projection, which is in the nature of a cornice, consisted of a simple bevel, and the use of it was very great; for in times of storms and hard gales of wind, when, according to the accounts of Mr. Winstanley's building, the broken sea rises to a far greater height than the whole structure, it would be likely to break the windows of the lantern, unless there was something to throw it off, as their use does not admit of any defence by shutters. Therefore Mr. Rudyerd applied this simple cornice, judging it sufficient to have the effect of throwing off the sea in times of storms; and yet not so much projection as that the sea, at the height of 71 feet above the foot of the building, could have power enough to derange it.

"The bottom projection, which has been called *the kant*, and which fills up the angle formed between the uprights and the sloping surface of the rock, so as to guard the foot of the uprights from that violence of action which the waves naturally exert when driven into a corner, was certainly a very useful application; but I am inclined to think it was not there upon the first completion.

"Upon the flat room of the main column, as a platform, Mr. Rudyerd fixed his lantern, which was an octagon of 10 feet 6 inches diameter externally. The mean height of the window-frames of the lantern above the balcony floor, was nearly 9 feet; so that the elevation of the centre of the light above the highest side of the base was 70 feet; that is, lower than the centre of Mr. Winstanley's second lantern by 7 feet; but higher than that of his first by 24 feet. The width of Mr. Rudyerd's lantern was, however, nearly the same as that of Mr. Winstanley's second; but, instead of the towering ornaments of iron work, and a vane that rose above the top of the cupola no less than 21 feet, Mr. Rudyerd judiciously contented himself with finishing his building with a round ball, of 2 feet 3 inches diameter, which terminated at 3 feet above the top of his cupola. The whole height of Mr. Rudyerd's lantern, including the ball, was no more than 21 feet above his balcony floor; whereas that of Mr. Winstanley's including the iron ornaments, was above 40.

"The whole height, then, of Mr. Rudyerd's light-house, from the lowest side to the top of the ball, was 92 feet, upon a base of 23 feet 4 inches, taken at a medium between the highest and lowest part of the rock that it covered.

"I have endeavoured to describe this building with all possible minuteness, because it affords a great and very useful lesson to future engineers. We are sure that a building such as Mr. Winstanley's was not capable of resisting the utmost fury of the sea, because, in four years after its completion, it was totally demolished thereby: but Mr. Rudyerd's building having sustained the repeated attacks of that element, in all its fury, for upwards of forty-six years after its completion; and then being destroyed, not by water, but by fire; we must conclude, it was of a construction capable of withstanding the greatest violence of the sea in that situation. And by withstanding it there, this light-house proves the practicability of a similar erection in any like exposure in the known world.

"I have seen a paper in the hands of one of the present proprietors, upon which were put down the quantities of materials said to have been expended in the construction of this building: viz., 500 tons of stone, 1,200 tons of timber, 80 tons of iron, and 35 tons of lead; and of trenails, screws, and rack-bolts, 2,500 each."

Mr. Smeaton then proceeds to detail the means by which the erection of the new lighthouse fell into his hands, his several interviews with the proprietors, and various other preliminary occurrences, among which the following remarks on the difference in structure of stone and wood, and on the bond of the stones to the rock and to each other, are particularly worthy of notice.

"In reflecting upon the late structure, it appeared most evidently, that had it not been for the moor-stone courses, inlaid into the frame of the building, and acting therein like the ballast of a ship, it had long ago been overset, notwithstanding all the branches and iron-work contrived to retain it: and that, in reality, the violent agitation, rocking, or vibration, which the late building was described to be subject to, must have been owing to the narrowness of the base on which it rested; and which, the quantity of vibration it had been constantly subject to, had rendered, in regard to its seat, in some degree rounding, like the rockers of a cradle. It seemed therefore a primary point of improvement, to procure, if possible, an enlargement of the base, which, from the models before me, appeared to be practicable. It also seemed equally desirable, not to increase the size of the present building in its waist; by which I mean that part of the building between the top of the rock and the top of the solid. If therefore I still kept strictly to the conical form, a necessary consequence would be, that the diameter of every part being proportionably increased by an enlargement of the base, the action of the sea upon the building would be greater in the same proportion; but as the strength increases in proportion to the increased weight of the materials, the total absolute strength to resist that action of the sea, would be greater by a proportional enlargement of every part, but would require a greater quantity of materials; on the other hand, if we could enlarge the base, and at the same time rather diminish than increase the size of the waist and upper works; as great a strength and stiffness would arise from a larger base, accompanied with a less resistance to the acting power, though consisting of a less quantity of materials, as if a similar conical figure had been preserved.

"On this occasion, the natural figure of the waist or bole of a large spreading oak, presented itself to my imagination. Let us for a moment consider this tree: suppose at 12 or 15 feet above its base, it branches out in every direction, and forms a large bushy top, as we often observe. This top, when full of leaves, is subject to a very great impulse from the agitation of violent winds; yet, partly by its elasticity, and partly by the natural strength arising from its figure, it resists them all, even for ages, till the gradual decay of the material diminishes the coherence of the parts, and they suffer piecemeal by the violence; but it is very rare that we hear of such a tree being torn up by the roots. Let us now consider its particular figure.—Connected with its roots, which lie hid below ground, it rises from the surface thereof with a large swelling base, which at the height of one diameter is generally reduced by an elegant curve, concave to the eye, to a diameter less by at least one-third, and sometimes to half of its original base. From thence its taper diminishing more slowly, its sides, by degrees, come into a perpendicular, and for some height form a cylinder. After that, a preparation of more circumference becomes necessary, for the strong insertion and establishment of the principal boughs, which produces a swelling of its diameter. Now, we can hardly doubt but that every section of the tree is nearly of an equal strength in proportion to what it has to resist: and were we to lop off its principal boughs, and expose it in that state to a rapid current of water, we should find it as much capable of resisting the action of the heavier fluid, when divested of the greatest part of its clothing, as it was that of the lighter, when all its spreading ornaments were exposed to the fury of the wind: and hence we may derive an idea of what the proper shape of a column of the greatest stability ought to be, to resist the action of external violence, when the quantity of matter is given whereof it is to be composed.

"In *Plate* V. *Figure* 1, is a sketch, representing the idea which I formed of this subject. It is farther observable, in the insertions of the boughs of trees into the bole, or of the branches into the boughs, (which is generally at an oblique angle) that those insertions are made by a swelling curve, of the same nature as that wherewith the tree rises out of the ground; and that the greatest rake or sweep of this curve is that which fills up the obtuse angle; while the acute angle is filled up with a much quicker curve, or sweep of a less radius: and *Figure* 2, of the same Plate, represents my conception of this matter. In this view of the subject, I immediately rough-turned a piece of wood, with a small degree of tapering above; and leaving matter enough below, I fitted it to the oblique surface of a block of wood, somewhat resembling the sloping surface of the Eddystone rock; and soon found, that by reconciling curves, I could adopt every part of the base upon the rock to the regularly turned tapering body, and so as to make a figure not ungraceful; and at the same time carrying the idea of great firmness aud solidity.

"The next thing was to consider how the blocks of stone could be bonded to the rock, and to one another, in so firm a manner, as that, not only the whole together, but every individual piece, when connected with what preceded, should be proof against the greatest violence of the sea.

"Cramping, as generally performed, amounts to no more than a bond upon the upper surface of a course of stone, without having any direct power to hold a stone down, in case of its being lifted upward by an action greater than its own weight; as might be expected frequently to happen at the Eddystone, whenever the mortar of the ground-bed it was set upon was washed out of the joint, when attacked by the sea before it had time to harden; and though upright cramps, to confine the stones down to the course below, might in some degree answer this end, yet, as this must be done to each individual stone, the quantity of iron, and the great trouble and loss of time that would necessarily attend this method, would in reality render it impracticable; for it appeared, that Mr. Winstanley had found the fixing twelve great irons, and Mr. Rudyerd thirty-five, attended with such a consumption of time (which arose, in a great measure, from the difficulty of getting and keeping the holes dry, so as to admit of the pouring in of melted lead) that any method which required still much more, in putting the work together upon the rock, would inevitably, and to a very great degree, procrastinate the completion of the building. It therefore seemed of the utmost consequence to avoid this, even by any quantity of time and moderate expense, that might be necessary for its performance on shore; provided it prevented hinderance of business upon the rock; because of time upon the rock, there was likely to be a great scarcity, but on the shore a very sufficient plenty. This made me turn my thoughts to what could be done in the way of dovetailing. In speaking however, of this as a term of art, I must observe, that it had been principally applied to works of carpentry; its application in the masonry way had been but very slight and sparing; for in regard to the small pieces of stone that had been let in with a double dovetail, across the joint of larger pieces, and generally to save iron, it was a kind of work even more objectionable than cramping; for though it would not require melted lead, yet being only a superficial bond, and consisting of far more brittle materials than iron, it was not likely to answer our end at all. Somewhat more to my purpose, I had occasionally observed, in many places in the streets of London, that, in fixing the kirbs of the walking-paths, the long pieces, or stretchers, were retained between two headers, or bond pieces; whose heads being cut dovetail-wise, adapted themselves to, and confined in, the strechers; which expedient, though chiefly intended to save iron and lead, nevertheless appeared to me capable of more firmness than any superficial fastening could be; as the tye was as good at the bottom as at the top, which was the very thing I wanted; and therefore if the tail of the header was made to have an adequate bond with the interior parts, the work would in itself be perfect. What I mean will be rendered obvious by the inspection of *Figure* 3, in *Plate* V. Something of this kind I also remembered to have seen in Belidor's description of the stone floor of the great sluice at Cherbourg, where the tails of the upright headers are cut into dovetails, for their insertion into the mass of rough masonry below. From these beginnings I was readily led to think, that if the blocks themselves were, both inside and out, all formed into large dovetails, they might be managed so as mutually to lock one another together; being primarily engrafted into the rock: and in the round and entire courses, above the top of the rock, they might all proceed from, and be locked to, one large centre stone. After some trials in the rough, I produced a complete design, of which *Figure* 5, *Plate* V., is the exact copy; the dotted lines representing the course next above or below, which in the original was drawn from the same centre, on the other side of the paper; so that looking on each side separately, each course was seen distinctly; or, looking through the paper, the relation of the two courses, showing how they mutually broke joint upon one another, was clearly pointed out: and this method of representation was pursued throughout; but not being practicable in copper-plate work, I am under the necessity of introducing the method by dotted lines, though attended with some degree of confusion of the main design.

"It is obvious, that in this method of dovetailing, while the slope of the rock was making good; by cutting the steps (formed by Mr. Rudyerd) also into dovetails, it might be said, that the foundation-stones of every course were engrafted into, or rather rooted in, the rock; which would not only keep all the stones in one course together, but prevent the courses themselves (as one stone) from moving or sliding upon each other. But after losing hold of the rock, by getting above it; then, though every stone in the same course would be bonded in the strongest manner with every other, and might be considered as consisting of a single stone, which would weigh a considerable number of tons, and would be farther retained to the floor below by the cement, so that, when completed, the sea would have no action upon it but edgeways; yet, as a force, if sufficiently great, might move it, notwithstanding its weight, and the small hold of the sea upon it, and break the cement before time had given it that hardness which it might be expected to acquire afterwards; I had formed more expedients than one for fixing the courses to one another, so as absolutely to prevent their shifting; but I shall not trouble my reader with a recital of those expedients at present, as they will more properly come in along with the reasons of my choice, in the detail of the actual proceedings."

Mr. Smeaton made his first voyage to the Eddystone on the 2d of April, 1756, but was prevented from landing by the weather; but on the 5th of the same month he was more successful, and staid upon the rock about two hours and a half, during which time he observed, "such traces of the situations of the irons fixed by Mr. Winstanley, as that it would not be difficult to make out his plan, and the position of the edifice; from whence it appeared very probable that Mr. Winstanley's building was overset all together; and that it had torn up a portion of the rock itself with it, as far as the irons had been fastened in it." He also "perceived that Mr. Rudyerd's iron branches, as then called, were much smaller and shorter than he had described them to be at the bottom of his print; that many of them were loose, and some broken and bent: and that, in regard to the steps, described to be cut upon the rock, there were only five of them, of which the traces were remaining: so that there was but one flat or tread of a step above the centre of the house; and the upper part of the surface of the rock above that, was a sloping plain, as it had been at first. Three steps, of the five now remaining, seemed to have been but faintly cut, and the uppermost but one was so imperfect, that he supposed a large spawl or splinter had come from it; and this appeared the more probable, as the uppermost step was so shaken, that another large spawl might have been easily raised from it, by a slight action of a wedge. Above the uppermost step the rock seemed to be of a softer nature, was cracked in many places, and probably had received some damage from the fire. None of the steps appeared to have been cut with much regularity, either as to level or square; but to have all the marks of hurry upon them. In the centre of the house a slight footing was cut for the mast, suitable to a square of 18 inches, with large iron branches, answerable to two of its sides, and a small hole bored in the centre, of about 1¼ inch diameter, being 6 inches deep. By consulting Plate I., many of the above matters will be made apparent to the eye.

"I then," says Mr. Smeaton, "proceeded to try the degree in which the rock was workable, and found that from a flat surface, indifferently taken, I could, with a pick, sink a hollow at the rate of five cubic inches per minute; and could cut or drill a hole with a jumper of 1¼ inch diameter, at the rate of one inch deep in five minutes. I also tried a method of forcing two holes into one, by a square flat-faced bruiser, or pummel; so that, if there should be occasion, I might be able to make a continued groove; or let in an iron branch, in the manner of Mr. Rudyerd, and I had the satisfaction to find that the whole succeeded to my wishes."

In the choice of materials, Mr. Smeaton was determined in favour of moor-stone or granite, for the outside work, and Portland stone for the inside. The latter was not eligible for the outer surface, on account of its liability to be destroyed by a marine insect; and the moor-stone was too hard and expensive in the working to admit of its being used throughout the building.

By the 15th of May, Mr. Smeaton had made ten voyages of observation to the Eddystone, and then returned to London, where having settled with the proprietors, he received his commission to proceed on the work. He then went back to Plymouth, and, on the 3d of August, landed with the first company of workmen on the rock, where he began to fix the centre and lines of the work. After describing the difficulties under which he laboured from the uncertainty of the weather, and the necessity in which the workmen were placed, of returning to shore every tide, till a vessel fit for their reception could be properly moored off the rock, Mr. S. observes upon his preference of the use of picks and wedges for operating upon the rock, that "it might seem, at first sight, that a greater dispatch would have been by the use of gunpowder, in blasting the rock, in the same manner as is usual in mines, and in procuring limestone from the marble rocks in the neighbourhood of Plymouth: but though this is a very ready method of working hard and close rocks, in proportion to the dispatch that could be made by picks and wedges; yet, as a rock always yields to gunpowder in the weakest part, and it is not always easy to know which part is weakest; it might often have happened, if that method had been pursued, that, instead of forming a dovetail recess, such as was required, the very points of confinement would have been lost. Besides, the great and sudden concussion of gunpowder might possibly loosen some parts that it was more suitable to the general scheme should remain fast. For these reasons, I had previously determined to make no use of gunpowder for this purpose.

"On the 7th of September," says Mr. Smeaton, "I sent to Portland the draughts for the six foundation courses, that were to be employed in bringing the rock to a level; which, with the draughts for eight that I had before dispatched, completed the order for the whole quantity of Portland stone to be used in the solid up to the entry door; being all that we could expect to set in place the next season. The rock was not indeed yet ready for completing the exact moulds for those stones that were to fit into the dovetails made in it; but, by ordering the stones large enough, and being scappelled something near their proper form, it would prevent loss of time in waiting to get the true figure from the rock, as well as unnecessary waste.

"Nothing happened to prevent the companies from working every tide from the 27th of August, till the 14th of September, in which time they had worked one hundred and seventy-seven hours upon the rock. In this interval, having procured a carpenter to be applied to that purpose, I began to make the moulds for the exact cutting of the stones to their intended shapes. This was done by laying down, in chalk-lines upon the floor of a chamber, the proposed size and figure of each stone, being a portion of the plan at large of the intended course; and the carpenter having prepared a quantity of battens, or slips of deal board, about three inches broad, and one inch thick, shot straight upon the edges by a plane; those battens being cut to lengths, and their edges adapted to the lines upon the floor, and properly fitted together, became the exact representatives of the pieces of stone whose figure was to be marked from them, when their beds were wrought to the intended parallel distance.

"It is obvious that there was no necessity for making moulds for a whole course after the work became regular; as was the seventh course, after the six foundation courses brought the rock to a level; it was sufficient to make one mould to each circle of stones, beginning with the centre stone; but as the six foundation courses were adapted to the particular irregularities of the rock, and consequently could not be strictly regular, it was necessary that a separate mould should be made for every separate stone composing that part of the work.

"During this interval, I visited the rock, and on arriving there the 8th of September, was informed by Mr. Jessop, that the preceding evening, there being a very strong tide, and no wind, a West-Indiaman, homeward bound, and a man-of-war's tender, were in great danger of driving upon the north-east rock; but that he timely perceiving their danger, though they themselves were not aware of it, ordered out the seamen and hands, who towed them off.

"On this visit, I staid two days; for as the working company had begun to take down the upper part of the rock, it was necessary to concert, and put in practice, the proper means of doing that, without damage to what was destined to remain. I have already mentioned my resolution of not using gunpowder; yet it was necessary, for the sake of dispatch, to employ some means more expeditious than the slow way of crumbling off the matter by the blunt points of picks. It has been already noticed, that the laminæ composing the rock were parallel to the inclined surface; and it was very probable that the chasm into which Mr. Winstanley's chain had been so fast jambed, that it never could be disengaged, extended farther into the rock than the visible disunion of the parts: this made me resolve to try a method sometimes used in this country, for the division of hard stones, called *the key and feather*, in order to cross-cut this upper stratum of the rock. The construction and operation of the key and feather is as follows:—A right line is marked upon the surface of the rock or stone to be cut, in the direction in which it is intended to be divided. Holes are then drilled by a jumper, at the distance of six or eight inches, and about one inch and a quarter in diameter, to the depth of about eight or nine inches; the distances, however, of the holes, and their diameters, as well as their depth, are to be greater or less, according to the strength of the stone, in the estimation of the artist directing the work. The above dimensions were what we used on this occasion. The key is a long tapering wedge, of somewhat less breadth than the diameter of the holes, and so as to go easily into them; the length being three or four inches more than the depth of the holes. The feathers are pieces of iron, also of a wedge-like shape; the side to be applied to the key being flat, but the other side a segment of a circle, answerable to that of the holes; so that the two flat sides of two feathers being applied to the two flat sides of the key, and the thick end of the feathers to the thin end of the key, they all together compose a cylindric, or rather oval kind of body; which in this position of parts is too big to go into the holes by at least one-eighth of an inch; that is, in the direction of a diameter passing through the three parts; but, in the other direction, is no broader than to go with ease into the holes. A key and a pair of feathers is made use of in each hole; and the feathers being first dropped in, with the thick ends downward, the keys are then entered between them; the flat sides of all the keys and the feathers being set parallel to that line in which the holes are disposed; the keys are then driven by a sledge-hammer, proceeding from one to another, and being forced gradually, as in splitting of moor-stone, the strongest stones are unable to resist their joint effort; and the stone is split according to the direction of the original line, as effectually, and much more regularly and certainly, than could be done with gunpowder, and without any concussion of the parts. Had our rock been entirely solid, this way of working might not have been applicable, on account of the crack's going too deep; but here, when it arrived at the joint where the chain was lodged, the split part became entirely disengaged from the rest; and in this way we were enabled to bring off the quantity of several cubic feet at a time: and thus the chain was released, after a confinement of above fifty years. The impossibility of disengaging it before now appeared very evident; for the pressure had been so great by the rock's closing upon it, as before suggested, that the links in their intersections were pressed into each other, as completely as if they had been made of lead; though the bolt-iron composing thec hain had been at least five-eighths of an inch in diameter.

"On Thursday, the 16th, I again went off to the rock, and found the work in the following situation. The lowest new step (the most difficult to work upon, because the lowest) with its dovetails quite completed. The second step rough-bedded, and all its dovetails scappelled out. The third step (being the lowest in Mr. Rudyerd's work) smooth-bedded, and all the dovetails roughed out. The fourth in the like state. The fifth rough-bedded, and dovetails scappelled out: and the sixth smooth-bedded, and all the dovetails roughed out. Lastly, the top of the rock, the greatest part of the bulk whereof had been previously taken down by the key-and-feather method, as low as it could be done with propriety, was now to be reduced to a level with the upper surface of the sixth step; the top of that step being necessarily to form a part of the bed for the seventh, or first regular course; so that what now remained, was to bring the top of the rock to a regular floor by picks: and from what now appeared, (as all the upper parts, that had been damaged by the fire, were cut off,) the new building was likely to rest upon a basis even more solid than the former had done.

"On Thursday, the 30th, I traced the outlines upon the upper part of the rock for the border of the seventh course, all within which was to be sunk to the level of the top of the sixth, and all without to be left standing, as a border for defence of the ground-joint of the work with the rock; and measuring the height of the top step above the bed of the first, I found it to be eight feet four inches: which would now be the difference of level between the west or lowest side of the new building, and the east or highest."

The setting in of the equinoctial winds prevented much farther progress in the work for this season; but on the 7th of November, the weather being somewhat moderate, Mr. Smeaton went off in the Eddystone boat, with battens, and the carpenter, to mould off the dovetails from the rock, when he found "four or five of the dovetails in the upper step wanting some amendment, that would employ as many men at each, for about four or five hours. The greatest part of the top of the rock was now brought to a regular floor, but some part of the north-east side wanted bringing down to a level." And here the operations for the year ended; for, on the 15th of the month, the workmen left the rock, having been able to make only thirty-eight hours and a half since the 2nd of October.

Mr. Smeaton occupies the interval between this period and the next working season with describing the regulations of his mason's yard, the size of the stones, &c., among which the following remarks may be useful to the reader.

"From the beginning I always laid it down as a fundamental maxim, that on account of the precariousness of weather to suit our purposes, (and without its being favourable, I think it has already sufficiently appeared, that nothing is to be done upon the Eddystone,) if we could save one hour's work upon the rock, by that of a week in our work-yard, this would always prove a valuable purchase; and that therefore everything ought to be done by way of preparation, which could tend to the putting our work together with expedition and certainty, in the ultimate fixing of it in its proper place; and for this purpose, it was necessary to make use of as large and heavy pieces of stone as, in such a situation as the Eddystone, were likely to be capable of being managed without running too great a risk.

"The common run of modern buildings, even of the largest size, are composed of pieces in general not exceeding five or six hundred-weight, except where columns, architraves, cornices, and other parts are to be formed, that indispensably require large single pieces; because stones of this size and bulk are capable of being handled without the use of tackles, or purchases, unless where they are to be raised perpendicularly: yet it appeared to me, that this choice of general magnitude resulted only from the workmen's not having commonly attained all that expertness in the management of the mechanic powers that they might have; in consequence of which, they avoid, wherever they can, the necessity of employing them. This arises not from the real nature of the thing, when properly understood; for a stone of a ton weight is, when hoisted by a proper tackle, and power of labourers, as soon and as easily set in its place, as one of a quarter of that weight; and, in reality, needs much less hewing than is necessary for the preparation of four stones to fill up the same space; nor need this reasoning stop at stones of a ton weight, but it might proceed even to as large sizes as are said to be found in the ruins of Balbec, if there were not inconveniences of other kinds to set on the opposite side of the question, as well as the want of quarries in this kingdom to produce stones of that magnitude.

"The size of the stones that could be used in the Eddystone lighthouse seemed limited by the practicability of landing them upon the rock: for as nothing but small vessels, that were easily manageable, could possibly deliver their cargoes alongside of the rock, with any reasonable prospect of safety; so no small vessels could deliver very large stones, because the sudden rising and falling of the vessels in the gut amounted frequently to the difference of three or four feet, even in moderate weather, when it was very practicable for a vessel to lie there; so that in case, after a stone was raised from the floor of the vessel, her gunnel should take a swing, so as to hitch under the stone, one of such a magnitude as we are now supposing, on the vessel's rising, must infallibly sink her; and hence it appeared, that much of the safety in delivering the cargoes would depend upon having the single pieces not to exceed such weight as could be expeditiously hoisted, and got out of the way of the vessel, by a moderate number of hands, and by such sort of tackles as could be removed from the rock to the store-vessel each tide: and on a full view of the whole matter, it appeared to me very practicable to land such pieces of stone upon the rock, as in general did not much exceed a ton-weight; though occasionally particular pieces might amount to two tons.

"The general size of our building stones being thus determined upon at a ton-weight, those would have been far too heavy to be expeditiously transferred and managed, even in the work-yard, unless our machinery rendered that easy, which would otherwise be difficult, without too great an expense of labour: and as the moving and transferring the pieces of stone in the work-yard would be greatly increased in quantity, by the very mode of attaining a certainty in putting the work together upon the rock; this consideration made it still the more necessary to be able to load upon a carriage, and move the different pieces from one part of the yard to the other, with as much facility (comparatively speaking) as if they had been so many bricks: for, that we might arrive at perfect certainty in putting the work ultimately together in its place upon the rock, it did not appear to be enough, that the stones should all be hewn as exactly as possible to moulds that fitted each other; but it was farther necessary, that the stones in every course should be tried together in their real situation in respect to each other, and so exactly marked, that every stone, after the course was taken asunder, could be replaced in the identical position in which it lay upon the platform, within the fortieth part of an inch. Nor was this alone sufficient; for every course must not only be tried singly together upon the platform, and marked, but it must have the course next above it put upon it, and marked in the same manner, that every two contiguous courses might fit each other on the outside, and prevent an irregularity in the outline: and this indeed, in effect, amounted to the platforming of every course twice: so that, in this way of working, every stone must be no less than six times upon the carriage:—1st. When brought into the yard from the ship, to carry it to the place of deposition, till wanted to be worked.—2ndly. When taken up and carried to the shed to be worked.—3rdly. After being wrought, to be returned to its place of deposition.—4thly. When taken up to be carried to the platform.—5thly. When finished on the platform, to be returned to its place of deposition.—6thly. When taken up to be carried to the jetty, to be loaded on board a vessel to go to sea.

"It might, at first sight, appear superfluous to try the courses together upon each other, as the under and upper sides of all the courses were planes: and, in case the work could have been put together upon the rock in the same way that common masonry generally is done, it would have been so: that is, if we could have begun our courses by setting the outside pieces first, then it would have been very practicable to have regulated the inside pieces thereto; but as our hope of expedition depended upon certainty in every part of our progress, this required us to be in a condition to resist a storm at every step: the outside stones therefore, unconnected with the inner ones, would have scarce any fastening besides their own weight, and would be subject to the most immediate and greatest shock of the sea; and, after completing the outward circle, the inner space would be liable to become a receptacle for water: the necessity therefore of fixing the centre stone first, as least exposed to the stroke of the sea, and of having sure means of attaching all the rest to it, and to one another, rendered it indispensable that the whole of the two courses should be tried together; that if any defect appeared at the outside, by an accumulation of errors from the centre, it might be rectified upon the platform.

"The moor-stone, though very hard with respect to its component parts, yet being of a friable nature, is extremely difficult to work to an arris (or sharp corner,) or even to be preserved, when so wrought by great labour and patience: that is, with sharp tools, and small blows; it therefore soon appeared to me, that we should make very rough and coarse work of it, if the finishing of the pieces were left to the workmen of the country where produced: for, though carefully wrought there in their place, yet in loading and unloading from their carriages, and again putting on board, and unloading from the vessels, the arrises would be very subject to damage. Therefore, to have as much done in the country as possible, and to save weight in carriage (leaving the finishing part to be done at home) rough moulds were sent for each size and species of stone, which were to be worked by them to a given parallel thickness, and with length and breadth enough, when so bedded, (as it is called) to be cut round all the sides to the true figure of the finishing mould: but they were to reduce them as near the size as they could safely do it by the hammer; and, that they might not leave an unnecessary waste, they were to be paid no more for either stone or carriage, than what the mould measured upon the thickness given; and if they were wanting of substance sufficient to make the figure complete, it should be at our option to reject them when they came home."

Our author next proceeds to detail his experiments on cements; but as they constitute no part of the building process, the reader is referred to the articles CEMENT and MORTAR, where the subject is duly considered.

On the 5th of June, 1757, the operations on the rock were recommenced, and by the 10th all the preliminary matters were settled; so that "on Saturday, the 11th of June, the first course of stone was put on board the Eddystone boat, (*see Plate* III. *Figure* 1.) with all the necessary stores, tools, and utensils. We landed at eight on Sunday morning, the 12th of June, and before noon had got the first stone into its place, being that upon which the date of the year 1757 is inscribed, in deep characters; and the tide coming upon us, we secured it with chains to the old stanchions, and then quitted the rock till the evening tide, when it was fitted, bedded in mortar, trenailed down, and completely fixed; and all the outward joints coated over with plaster-of-paris, to prevent the immediate wash of the sea upon the mortar. This stone, according to its dimensions, weighed two tons and a quarter. The weather serving at intervals, it was in the evening of Monday, the 13th, that the first course, consisting of four stones, was finished; and which, as they all presented some part of their faces to the sea, were all of moor-stone.

"The next day, Tuesday the 14th, the second course (*see Plate* III. *Figure* 2,) arrived; and some of it was immediately landed, proceeded with, and in part set the same tide: the loose pieces being chained together by strong chains, made on purpose for this use, and those ultimately to the stancheons, or to lewises in the holes of the work Course I. that had already been fixed. The sea was uncommonly smooth when we got upon the rock, this evening's tide, but while we were proceeding with our work, within the space of an hour and a half, the wind sprung up at north-east, and blew so fresh, that the Weston, lying to deliver the remainder of her cargo, had some difficulty in getting out of the gut; and, had it not been for the transport buoy, to which she had a fastening by a rope, it would probably have proved impracticable to have got her out again. And we soon saw it was necessary to get everything in the best posture time and circumstances would admit, in order to quit the rock with safety to ourselves, and security to what we must necessarily leave behind us.

"The pieces that were fixed and trenailed down, were supposed to be proof against whatever might happen; but the loose pieces, and those that were simply lowered down into their dovetail recesses, were considered as needing some additional security, to prevent their being carried away by the violence of the sea. Of the thirteen pieces of which Course II. consisted, five only were landed: No. 1 was completely set; No. 2 and 3 were lowered into their places, and secured by chains; and No. 4 and 5, which lay at the top of the rock, were chained together, and also to the slide-ladder, which was very strongly lashed down to the eye-bolts, purposely fixed on the rock for that intent.

"In the evening (of June 15,) we made a short tide upon the rock, and had the satisfaction to find that no material damage had happened to anything; we therefore proceeded with our work, and completely fixed No. 2 of Course II. On the morning of Friday the 17th we again landed for a short time; and, nothwithstanding we did not meet with anything amiss on our return to the rock on Wednesday evening, after the hard gale of wind, yet this morning we found a part of the rock in the border of our work, that secured a corner of No. 3, was gone: we therefore, to secure that stone to its neighbour, applied an iron cramp, of which we had some in readiness in case of accident. We were prevented landing in the evening, by a fresh wind and rain at north-west, but landed again on Saturday morning's tide, the 18th. However, we had not been long there before a great swell arose from the south-west; and though there had been no wind apparently to occasion it, yet it came upon us so fast, that we were obliged to quit the rock before we could get our work into so satisfactory a posture of defence as I wished. It was, however, as follows: No. 1, 2, 3, 4, and 5, were completely fixed as intended; No. 6 and 7, were fitted, and lowered upon their mortar-beds; No. 8, was simply got into its place, with a weight of lead of five hundred weight upon it; which, in all such trials as had hitherto been made thereof, had lain quietly. Not having time to get the stone, No. 9, into its place, we chained it upon the top of the rock to the slide-ladder, as we had done before on Tuesday. In this condition we left the rock, having staid till we were all wet from head to foot.

"The storm continued till Tuesday morning: about noon of that day," says Mr. Smeaton, "the wind and sea having become still more moderate, I judged it practicable to row ahead against it, so as to get to the westward of the rock, and reconnoitre our damages: accordingly, taking four oars in the light yawl, it being then near low water, I observed, when the sea fell away from the rocks, (every sea then breaking bodily over it,) that No. 9, and the slide-ladder to which it was chained, were both gone; that the two pieces of moor-stone, No. 5 and 6, which had only been let down upon their mortar-beds, without farther fastening, were also gone; that No. 3 had broke its cramp, and was gone; and that the five hundred weight of lead, that had been laid upon the most projecting part of the piece, No. 8, had, by the force of the sea acting edgewise upon it, been driven to the eastward, till it was stopped by the rise of the third step, against which it seemed abutted; so that having thereby quitted the piece, No. 8, upon which it was laid, that was gone also: we therefore, as it appeared, had lost five pieces of stone; the loss of which was, in the first instance, alleviated by finding that the first course appeared so thoroughly united with the rock, that its surface began to look black, with dark-coloured moss fixing upon it, and giving it the same hue as the rock itself: also, that our shears and windlass were all standing, without the least derangement.

"I did not wait for the subsiding of the winds and seas, so as to enable us to land, and look out whether or no we could recover any of the lost pieces; I immediately made for Plymouth in the light yawl, and landed at Mill Bay, at five o'clock on Tuesday evening, the 21st; and, having collected the moulds of the stones we had lost, and chosen proper spare blocks, I set a couple of men to work upon each piece of stone, day and night, till finished. This disaster, though it furnished a few reflections, yet they were not of the unpleasant kind; for, as every part of the stonework that was completed according to its original intention, appeared to have remained fixed, it demonstrated the practicability of the method chosen; and at the same time shewed the preference of wedging to cramping, as the cramp had failed: and also the utility of trenails, as a security till the mortar was become hard.

"At four o'clock on Monday morning the 27th, the weather serving, I went out with Richardson and company, in the Eddystone boat; we got to the buss at ten, and found the Weston at the transport buoy, but could not land till the afternoon's tide, being a complete week since we had been last upon the rock. We first replaced the ladder, and afterwards proceeded, without more than usual interruptions, till the 30th in the evening, when we closed and completed the Course No. II., and began upon Course III. The execution of these two courses had taken us up from the 12th to the 30th inclusive, and though they consisted of no more than seventeen pieces of stone in the whole, yet I found myself no ways disheartened; for, in establishing these two courses, I considered the most difficult and arduous part of the work to be already accomplished, as these two courses brought us up to the same level where my predecessor Mr. Rudyerd had begun.

"Friday, July the 1st, we were able to land. I observed, that during the last tide, the swell had washed some of the pointing out of the exterior joints, and also some of the grouting out of the upright joints; but as a heavy sea seemed likely to come on with the tide of flood, I judged it to be to no purpose to repair the cement while a violent swell continued; I therefore employed the company in cutting off the iron stancheons belonging to the former building, as they now began to be in our way, and as the hold we got of them ceased to be of use, in proportion as we got more fastening from the lewis holes of our own work.

"The weather having become more favourable, on Sunday morning, the 3d of July, I went on board, accompanied by Mr. Jessop and his party, to whom, as they had never had the opportunity of setting a stone, it behoved me to attend. We, however, not only met with a repulse this day, but could not make any farther attempt to go out till Tuesday, the 5th; and then the wind, though gentle, being contrary, had not the company on board the buss come with their two yawls and towed us thither, in all probability the day would have been spent in fruitless attempts. Our difficulty was considerably increased by the coming on of so thick a fog, that, all our efforts united, we had much ado to regain the buss. Richardson told me they had had such bad weather, that the slide-ladder had again broke its lashings and driven away; that they had, however, got all the irons cut off close to the rock; but that the last tide, though there was only a breeze at south-west, the swell was so great, and came on so suddenly, as to put them in great danger of being washed off from the top of the rock, before they could quit it.

"At two o'clock this day we landed, and Jessop's company set six pieces of stone, and effectually repaired the cement; and next day a proportionable dispatch was made, though the weather was not very mild.

"On Monday, the 11th, I again went out; Course III. consisting of twenty-five pieces, was closed on the following day, and Course IV. begun.

"Thursday, the 14th of July, the company pursued the work of Course IV.; and now, both companies being fully instructed in the method of setting the basement courses, I returned to Plymouth; from whence I proposed to visit each company as often as should seem expedient, but always once in each company's turn, if wind and weather should permit.

"Contrary winds, ground-swells, and heavy seas for several days, interrupted the regularity of our proceedings; however, taking such opportunities as we could, the Course IV., consisting of twenty-three pieces of stone, was closed in the morning's tide of the 31st of July, (*see Plate* III.); and in the evening's tide five pieces of Course V. were set. Our work went on regularly for some days together; and, visiting the work upon the 5th of August, I found the Course V. containing twenty-six pieces, closed in, (*see Plate* III.); but that by some inadvertency in proceeding with the interior part, the masons had been obliged to set two of the outside pieces so as to be farther out than they should have been by an inch each. However, as I found the work was sound and firm, I thought it better to cut off the superfluous stone from the outside, than to disturb the work by the violence that must have been used in unsetting the pieces; I therefore determined to let them stand as they were, till the cement was become so hard as to support the edges of the stone while the faces were working afresh; and which, from the mortar of our first and second course, we found was likely to be the case before the close of the season. One of the dovetails had also given way in driving a trenail, owing to a flaw in the stone; for the remedying whereof we applied a cramp.

"The 8th of August, at noon, the weather being exceeding fine, with a low neap tide, I took the opportunity of drawing a meridian line upon the platform of Course VI. the sea never going over the work during the whole tide, which was the first time it had not washed over all, since we began to build: we therefore took this favourable opportunity of carefully making good all our pointings and groutings, wherever the water had washed during the bad weather that had succeeded the last departure of the Eddystone boat; and which was the case with it, in places where it had not had time to set before a rough tide came on; but I observed, with much satisfaction, that whatever, not only of the original work, but of the repaired pointing, had once stood a rough tide without giving way, the same place never after failed. I also observed, that as in mending the pointings we had in some places made trial of Dutch tarras as well as puzzolana, interchangeably, the puzzolana, for hard service, was evidently superior to the tarras: and some particular joints had proved so difficult, that I was obliged to try other expedients; the best of which was to chop oakum very small, and beat it up along with the mortar. This was our last resource, and it never failed us.

"Upon the 11th, I again went out in the vessel that contained the remaining pieces of Course VI.: those I saw fixed; and that course, consisting of thirty-two pieces, closed in the same evening. (*See Plate* VI.) This completing our six basement courses, brought our work upon the same level to which we had, the preceding season, reduced the top of the rock; and upon this, as a common base, the rest of the structure was to be raised by regular entire courses. The time this part of the work (consisting of one hundred and twenty-three pieces of stone) had taken up, was from the 12th of June to the 11th of August inclusive, being a space of sixty-one days. We now considered our greatest difficulties to be successfully surmounted, as every succeeding course had given us more and more time, as well as more and more room; and this will appear from our proceedings; for it has already been noticed, that the two first courses, consisting of nineteen pieces of stone only, had cost us seventeen days.

"Having now got the work to this desirable situation, I apprehend it will be agreeable to my reader to be more particularly acquainted with the method in which the stones were set and fixed. I have intimated, that when each separate piece, of which a course was to consist, was separately wrought, they were all to be brought to their exact places with respect to each other, upon the platform in the work-yard, and so marked, that, after being numbered and taken to pieces, they could again be restored to the same relative position. This was done upon the complete circular courses by drawing lines from the centre to the circumference, passing through the middle of each set of stones; and likewise concentric circles through the middle of each tier or circle of stones, so as to indicate to the eye their relative position to each other: but to render the marks not easily delible, where those lines crossed the joints, a nick was cut and sunk into the surface of the two adjacent stones; for doing which, a piece of thin plate-iron was employed, with sand, upon the principle that stones are sawn; so that not only the sight, but feeling, could be employed in bringing them together again exactly; for the same or a similar plate being applied to the nick, the least irregularity of its position would be discoverable. In a similar manner the stones of the base courses were marked by lines drawn parallel to the length of the steps, and others perpendicular to the same, the crossings being sawn in, as before described. There was, however, a nicety in this part of the work, that required particular attention, and that was in forming a provision for setting the four radical stones, that occupy the four radical dovetails into which each step was formed, as may be observed in the several figures of *Plate* III. Those stones were formed, from the work of the rock's being actually moulded off, and from the manner, already described, of bringing those moulds to agree after they were brought home from the rock, those stones were laid upon the platform thereby, and then marked with lines upon their own substance, in the manner just mentioned: and as the distances of each of those stones were then ascertained by gauge-rods of white fir-wood, while upon the platform; it must be expected, as each step was reduced to a level plain, as the platform was, that when laid upon the rock in their due positions and distances, by the gauge-rods, they would nearly fit the dovetails that had been cut in the rock to receive them; and where there was the least want of fitness, as might possibly happen with bodies of so rigid a nature, either the stone or the rock was cut, till each stone would come into its exact relative position, and then all the rest would follow one another by their marks, in the same manner as they had done upon the platform.

"It is necessary to be noticed, that the waist of each piece of stone had two grooves cut, from the top to the bottom of the course, of an inch in depth, and three inches in width: applicable to those grooves were prepared a number of oak wedges, somewhat less than three inches in breadth, than one inch thick at the head, nearly three-eighths thick at the point, and six inches long. The disposition of these grooves is shown in the courses of *Plate* III. where the little black parallelogram figures, placed along the lines describing the joints of the courses, represent the tops of the grooves, and their place on the right hand or left of the joint line show in which stone the groove is cut. It is also to be noted, that where the flank side of a stone was not more in length than a foot, or fourteen inches, one groove was generally deemed sufficient; but those of eighteen inches or upwards had, generally, in themselves or the adjoining stone, a couple of grooves.

"The mortar was prepared for use by being beat in a very strong wooden bucket, made for the purpose; each mortar-beater had his own bucket, which he placed upon any level part of the work, and with a kind of rammer, or wooden pestle, first beat the lime alone, about a quarter of a peck at a time, to which, when formed into a complete, but rather thin paste, with sea-water, he then gradually added the other ingredient, keeping it constantly in a degree of toughness by continuance of beating. When a stone had been fitted and ready for setting, he whose mortar had been longest in beating came first, and the rest in order: the mason took the mortar out of the bucket; and, if any was spared, he still kept on beating; if the whole was exhausted, he began upon a fresh batch. The stones were first tried, and heaved into and out of their recesses, by a light movable triangle, which being furnished with a light double tackle, the greatest number of all the pieces could be purchased by the simple application of the hand; and this made our stones to be readily manageable by such machinery as could commodiously be moved and carried backward and forward in the yawls every tide. To the first stone, and some few others, we took the great tackle, that we might hoist and lower them with certainty and ease; but there were not in the whole above a dozen stones that required it.

"The stone to be set being hung in the tackle, and its bed of mortar spread, was then lowered into its place, and beat down with a heavy wooden maul, and levelled with a spirit level: and the stone being brought accurately to its marks, it was then considered as set in its place. The business now was to retain it exactly in that position, notwithstanding the utmost violence of the sea might come upon it before the mortar was hard enough to resist it. The carpenter now dropped into each groove two of the wedges already described, one upon its head, and the other with its point downward, so that the two wedges in each groove would then lie heads and points. With a bar of iron of about two inches and a half broad, three-quarters of an inch thick, and two feet and a half long, the ends being square, he could easily (as with a rammer) drive down one wedge upon the other, very gently at first, so that the opposite pairs of wedges being equally tightened, they would equally resist each other, and the stone would therefore keep its place; and in this manner those wedges might be driven even more tight than there was occasion for; as the wood being dry, it would by swelling become tighter; and it was possible that by too much driving, and the swelling of the wedges, the stones might be broken; and farther, that a moderate fastening might be effectual, a couple of wedges were also, in like manner, pitched at the top of each groove, the dormant wedge, or that with the point upward, being held in the hand, while the drift wedge, or that with its point downward, was driven with a hammer; the whole of what remained above the upper surface of the stone was then cut off with a saw or chisel; and generally a couple of thin wedges were driven very moderately at the butt-end of the stone; whose tendency being to force it out of its dovetail, they would, by moderate driving, only tend to preserve the whole mass steady together; in opposition to the violent agitation that might arise from the sea.

"After a stone was thus fixed, we never, in fact, had an instance of its having been stirred by any action of the sea whatever; but, considering the unmeasured violence thereof, the farther security by trenails will not seem altogether unnecessary, when we reflect, that after a stone was thus fixed in its place by wedges, a great sea coming upon it, (often in less than half an hour) was capable of washing out all the mortar from the bed underneath it, notwithstanding every defence we could give it by plaster or otherwise; and that when the bed of mortar was destroyed, the sea acting edgewise upon the joint, would exert the same power to lift it up, that the same sea would exert to overset it, in case its broad base was turned upright to oppose it; and as the wedges only fixed and secured the several pieces of which each course consisted, to each other, and had no tendency to keep the whole course from lifting together, in case the whole should lose its mortar bed; it seemed therefore highly necessary to have some means of preventing the lifting the whole of a course together, till the solidity and continuity of the mortar should totally take away that tendency. Adverting now to what was said, that a couple of holes, to receive oak trenails of one inch and three quarters in diameter, were bored in the work-yard through the external or projecting end of every piece of stone: we must now suppose these stones set in their places, and fixed by wedges; then one of the tinners, with a jumper, began to continue the hole into the stone of the course below, and bored it to about eight or nine inches deep: but this hole was bored of a less size, by one-eighth of an inch in diameter, than the hole through the stone above; in consequence, the trenails, having been previously dressed with a plane till they would drive somewhat freely through the upper hole, would drive stiffly into the under one, and generally would become so fast as to drive no farther before their leading end got down to the bottom; and if so, they were sufficiently fast: but as they sometimes happened to drive more freely than at others, the following method was used to render them fast, for a certainty, when they got to the bottom. The leading end of every trenail was split with a saw, for about a couple of inches, and into this split was introduced a wedge, about one-eighth of an inch less in breadth than the diameter of the trenail; it was a full quarter of an inch in thickness at the head, and sharpened to an edge; when therefore the head of the wedge touched the bottom of the hole, the trenail being forcibly driven thereupon, would enter upon it, till the whole substance was jambed so fast, that the trenail would drive no farther; and as the wood would afterwards swell in the hole, and fill the little irregularities of boring by the jumper, it became so fast, that, as it seems, they could sooner be pulled in two than the trenails be drawn out again. The trenail (originally made somewhat too long) being then cut off even with the top of the stone, its upper end was wedged cross and cross. There being generally two trenails to each piece of stone, no assignable power, less than what would by main stress pull these trenails in two, could lift one of these stones from their beds when so fixed, exclusive of their natural weight, as all agitation was prevented by the lateral wedges. The stone being thus fixed, a proper quantity of the beat mortar was liquefied, and the joints having been carefully pointed up to the upper surface, the grout so prepared was run in with iron ladles, and was brought to such a consistency as to occupy every void space; and though a considerable part of this was water, yet that being absorbed by the dry stones, and the more consistent parts settled to the bottom, the vacuity being at the top, this was repeatedly refilled till all remained solid: the top was then pointed, and, when necessary, defended by a coat of plaster.

"The several courses, represented in *Plate* III. are shown as they would appear, when completed with the whole of their wedges and trenails: and besides these, there being also generally two lewis holes upon the upper surface of each stone, those served as temporary fixtures for the work of the succeeding course.

"It was the same evening's tide, of the 11th of August, that the basement was completed and the centre stone of Course VII. was landed. Of the preceding courses, each was begun by the stones that engrafted in the dovetail recesses cut in the rock; these stones, therefore, being immovable by any assignable force acting horizontally, rendered those so likewise that depended upon them; but having now brought the whole upon a level, we could not have this advantage any longer; it therefore became necessary to attain a similar advantage by artificial means. For this purpose, the upper surface of Course VI., (*Plate* III. *Figure* 6,) had a hole of one foot square cut through the stone that occupied the centre; and also eight depressions, of one foot square, sunk into that course six inches deep, which were disposed at regular distances round the centre: these cavities were for the reception of eight cubes of marble, in masonry called joggles. As a preparation for setting the centre stone of Course VII., a parallelopiped (which, for shortness sake, I will call the plug) of strong hard marble from the rocks near Plymouth, of one foot square and twenty-two inches in length, was set with mortar in the central cavity, and therein firmly fixed with thin wedges. Course VI. being thirteen inches in height, this marble plug, which reached through, would rise nine inches above it; upon this, the centre stone (see *Plate* IV. *Course* VII.) having a hole through its centre of a foot square, was introduced upon the prominence of the plug, and, being bedded in mortar, was in like manner wedged (with wedges on each side of the plug) and every remaining cavity filled with grout. By this means, no force of the sea, acting horizontally upon the centre stone, less than what was capable of cutting the marble plug in two, was able to move it from its place: and to prevent the stone more effectually from being lifted, in case its bed of mortar happened to be destroyed, it was fixed down in the manner above described, by four trenails; which being placed near to the corners of the large square of that stone, they not only effectually prevented the stone from lifting, but aided the centre plug in preventing the stone from moving angularly, or twisting, which it might otherwise have done, notwithstanding its weight, which was two tons nearly.

"After setting the first centre stone of Course VII. we immediately proceeded to set the four stones that surround it, and which were united thereto, by four dovetails, projecting from the four sides of the centre stone. These stones being fixed in their dovetails by a pair of wedges on each side at bottom and top, as has already been mentioned, and held down by a couple of trenails to each surrounding stone, and still farther steadied by joint wedges at the head of the dovetails, and also in the mitre, or diagonal joints between each surrounding piece; the whole formed a circular kind of stone of ten feet diameter, and above seven tons weight: and which being held down by a centre plug and twelve trenails, became in effect one single stone; whose circumference was sufficient to admit of eight dovetail recesses to be formed therein, so as to be capable of retaining in their places a circle of eight pieces of stone, of about twelve hundred weight each, in the same manner, and upon the same principle, that the radical pieces of stono were engrafted into the dovetail recesses of the rock; and which being in like manner wedged and trenailed, we proceeded with circular tiers of stone, in the manner shown in *Plate* IV. *Figure* 1. It is, however, to be remarked, that the mode of applying the wedges and trenails being sufficiently explained in the several figures of *Plate* III. and also in *Plate* IV. *Figure* 1, to avoid a repetition of small work, the several succeeding figures simply show the general shapes and disposition of the different pieces composing a course, and other incidental larger matters wholly omitting the particular application of the wedges and trenails; yet it is to be observed, that they were everywhere equally applied, till we got to the top of the solid.

"My much esteemed master and friend, Mr. Weston, who came from London to be witness of our proceedings, arrived at Plymouth during this interval. I went off with him early on Wednesday morning, the 17th, attended by Mr. Jessop and his company, and landed upon the rock at ten: Richardson and company were then about to begin to set the fifth tier, or circle of stone, which was to contain the eight cubes before described. These cubes were so disposed upon the surface of Course VI. that the cavities cut on the under side of Course VII. to take the upper half of each cube, should constantly fall in the broad part of the stones of the fifth circle; which will appear plain by considering the dotted lines relative to Course VII. upon the surface of Course VI. (see *Plate* III. *Figure* 6.) There could consequently be no application of wedges in the upper course, to the fastening of the circle of stones, (No. 5,) upon their respective cubes: when therefore the stone respectively came upon them, we put as much mortar upon the top of the cube as would in part make good the joint between it and its cavity, but not enough quite to fill it; because, if too full, there was no ready way for the superfluous mortar to escape; but a hole, of the size of those for the trenails, being previously bored through each of these pieces, answerable to the middle of each cube; when the stone was set, wedged and trenailed, then it was very practicable, by dressing a trenail so as to become a ram-rod, to drive as much mortar down the hole as would completely fill every vacancy between the stone and its cube: insomuch that we soon perceived, that if this was attempted before the stone was completely trenailed down, it would very easily raise the stone from its bed, as might indeed be expected from the principle of hydrostatics: but, being done after such completion, it brought the whole to the most solid bearing that could be wished; and, when the cement was hardened, answered the end quite as effectually as if they had been wedged.

"It may here be very properly said, that since those cubes could be of little use in keeping the work firmly together, before the mortar was hardened; and after that had taken place, they could be of no use; because the number of one hundred and eight trenails, of which one of these courses consisted when complete, being supposed sufficient to keep it from lifting and moving out of its place; as the mortar hardened, and every additional course was an addition of its own weight upon the former, if those cubes could have been dispensed with in the first instance, they might have been so ever after. This reasoning I can very well admit to be true; yet, when we have to do with, and to endeavour to control, those powers of nature that are subject to no calculation, I trust it will be deemed prudent not to omit, in such a case, anything that can without difficulty be applied, and that would be likely to add to the security. It may farther be remarked, that as this building was intended to be a mass of stone, held together by the natural and artificial union of its parts, it would have been out of character, that, when completed, it should be beholden to certain parts of wood for its consolidation.

"I have mentioned, that I originally conceived more than one way of preventing the courses from shifting place upon one another. My first conceptions were to form a rise (or a depression) of three inches, bounded by a circle somewhat about the diameter of that in which the joggles are placed; which step, or depression, would have formed a socket, whereby the courses would have been mutually engrafted, not much different from what nature has pointed out in the basaltine columns of the Giant's Causeway; but, considering how much unnecessary trouble and intricacy would be hereby introduced, by one part of the bed of the same stone being liable to be three inches higher than the other, I judged that the end would be very sufficiently answered by the much more plain, easy, and simple method of joggles; especially as, for this purpose, the firmest and toughest kind of stone might be chosen, and the number multiplied at pleasure. One plug in the middle, of a foot square, and eight joggles of a foot cube each, of the hardest marble, disposed in the manner described, seemed to me, along with the additional strength and security arising from the trenails, as also from the infinite number of little indentures upon the surface of the courses, as well as the lewis holes, each being filled with an exuberance of mortar, which, when hard, would in effect become a steady pin; from the cohesion of the mortar as a solid, promising to be no less than that of the stone, together with the incumbent weight of every part of the building above; every joint, thus separately considered, seemed, in point of firmness, so satisfactory to my mind, that if the whole of this proved too little, it was out of my power to conceive what would be enough.

"In the morning and evening's tide of the 17th, we set the whole of the fifth tier, and consequently the whole of the eight cubes were then inlaid. The morning of the 18th we again landed, and in this morning and evening's tide, though rough, we had got set five pieces of Circle VI. and had landed the remaining three; as also one of the largest pieces of moor-stone for the east side (see *Plate* IV. *Figure* 1.) This evening's tide we worked with links, and it began to blow so fresh that we had much ado to keep them in, being obliged to make a fire of them upon the surface of the work. We were under the necessity, at last, to quit the rock with some precipitation, and were very glad to get into our yawls; things being left in the following posture: Two of the pieces, Tier 6, were simply dropped into their places, on the north-west side, while the third piece, being about a ton, and the piece of moor-stone near upon two tons, were chained together, and to the work of Course VII. that was already set; these two loose pieces being upon the top of that course, near the east side; the triangles we lashed down upon the floor of the work, as we had practised several times before. The sea became so rough in the night, that the Weston, at the transport buoy, was obliged to slip and make for a harbour. The bad weather continued to increase till the 28th, when there was a violent storm at south-west.

"The 29th, I perceived with my telescope, from the Hoa, the buss to ride safe, but could not see the shears, or indeed anything else upon the rock distinctly, except the breakers. The day following being more clear, and the sea somewhat subsided, I immediately went on board the Eddystone boat to reconnoitre. The wind being north-west, I passed the rock several times under sail, but there was no possibility of landing. I observed, that not only all the work which had been completely set was entire, but that the two stones mentioned to have been simply lowered into their places, also remained therein, and that the five hundred weight still rested upon the stone whereon it was left. The west face of the building had got so complete a coat of sea-weed, that it was only distinguishable from the rock by its form; but the shears and triangles were entirely gone; the two pieces of stone, that had been chained together and to the work, were also gone; the windlass frame broken and much damaged, and the roll gone; the fender piles and the transport buoy, however, remained in their places.

"It was the 3rd of September before the company could make a landing to do anything upon the rock; so that, since the 18th ult., there had been an interval of fifteen days, in which we had been totally interrupted by bad weather, in the very prime part of the season. However, everything having been expedited on shore, to get refitted for work, this day I went out therewith, and began to set up our new shears, windlass, &c., and with the shears got up the piece of Portland, of Circle 6, which was set, as also the others that had been left loose in their dovetails; but the tide of flood coming on, had deepened the water too much before we could try to get up the other.

"September the 5th, the seventh circle was finished and the eighth begun; and this day the wind being variable, from north-east to north-west, and very moderate, was very remarkable, as being the first time of the people having worked till they were obliged to quit the rock for refreshment: and now everything being reinstated, it was some time before we met with anything but the ordinary interruptions.

"The fineness of the season continued to favour the expediting of our works, insomuch that Course VIII., which was begun upon the 8th, was executed in five days, being entirely completed on the 13th, at the same hour. Everything went regularly on till the 20th; so that, in return for our continued interruption from the stormy weather for fifteen days, our works had an uninterrupted progression for eighteen days, when Course IX. was advanced to the fifth circle."

A series of land-swells from the south-west prevented further proceedings till the 30th September, when Course IX. was completed, "and the masons proceeded to rectify the face of the work, where it was in any degree wanting thereof, that there might be no need hereafter to disturb any part of the coat of weed, which was likely to fix upon it during the winter." This ended the operations for the year 1757.

On the 12th of May, 1758, Mr. Smeaton examined the work, and found it perfectly entire, except a small spawl, which had been washed from the rock itself; the whole did not seem to have suffered a diminution of so much as a grain of sand since the time he left it on the 1st of October of the preceding year: on the contrary, the cement, and even the grouted part, appeared to be as perfectly hard as the Portland stone itself; the whole having become one solid mass, entirely covered with the same coat of sea-weed as the rock, the top of the work excepted. This was washed so clean and white, that the lines upon it appeared more distinct than when they were in the work-yard; the cube-holes and lewis-holes, however, from their being constantly filled with water, were grown over with green weed, like the outside. The fender piles were indeed all gone, but this was a trifling disaster, as they could soon be renewed.

The tenth course was set on the 5th of July, the eleventh on the 18th, the twelfth on the 24th, the thirteenth on the 5th of August, and on the 8th of that month the fourteenth, which completed *the fundamental solid.*

From the top of this course begins that part of the building, also called the *solid,* which includes the passage from the entry door to the well-hole of the stairs as described *Plate* IV. *Figures* 2, 3, 4, from which a more adequate idea can be obtained than any words could convey.

Mr. Smeaton then proceeds to describe his method of regulating the superstructure: As "for the sake of the well-hole, we must necessarily lose our centre-stone, the four stones, which in the former courses were united to it by dovetails, were, as now prepared, to be united to each other by hook-scarf-joints, so as to compose, in effect, one stone: and as, in consequence, we had also lost our centre cubes, it became expedient, that the work might have a uniform texture and strength, that those four stones, making a complete circle for the staircase, should be provided with cubes, to prevent their being shifted by any shock applied horizontally, (see *Figure* 4,) as well as with the trenails to hinder them from lifting. By this means the principle of consolidation would be effectually preserved: but as the top of the fourteenth, or entry-door course, was twelve feet above the top of the rock, that is, twenty feet four inches above the base of the first course, the stroke of the sea must here become less violent, and therefore a less degree of resistance would be equally sufficient. And as the large cubes would too much cut the work, which was here of considerably less area; and as several cubes would be requisite for the well-hole stones, I had determined, above the entry-door course, to increase the number of cubes from eight to sixteen, and to diminish their size from twelve to six inches; but still to be of solid gray marble, and two of them to be introduced into each of the four well-hole stones.

"Upon the 9th of August, I marked out the entry and staircase; and having unloaded the Eddystone boat, which was loaded with the first pieces of Course XV., we immediately proceeded with it; and from this time were blessed with such an uninterrupted continuance of fine weather, that upon the 20th of August, Course XVIII. was completed, which reunites the building into a complete circle, by covering the passage to the staircase: the external face of the stone of that course, which makes the cover or head of the entry-door having the figures 1758, denoting the year in which this part of the work was accomplished, cut in deep characters upon it.

"On the 24th of August, the fine weather, and in consequence the works, were interrupted, Course XX. being then in hand; and it was not till the 24th of September, that, with every possible exertion, Course XXIV. was finished, which completed the solid, and composed the floor of the store-room.

"The 25th and 26th of September, Course XXV., being the first course of the superstructure, was successfully completed in its place; but, as the mode of construction now became entirely different from the former, it is necessary to give an account thereof, as also of the reasons for the change. The building was carried up solid, as high as there was any reason to suppose it exposed to the heavy stroke of the sea; that is, to thirty-five feet four inches above its base, and twenty-seven feet above the top of the rock, or common spring-tide high-water mark. At this height, as it was reduced to sixteen feet eight inches in diameter, it became necessary to make the best use of this space, and make all the room and convenience therein that was possible, consistent with the still necessary strength. The rooms being made of twelve feet four inches diameter, this would leave twenty-six inches for the thickness of the walls. These being made with single blocks in the thickness so that sixteen pieces might compose the circle, would, from its figure, compose a stout wall; yet moor-stone, as has been observed, being a tender kind of stone, in respect to the union of its component parts, any method of dovetailing the blocks together, at this thickness, appeared to me impracticable to any good purpose. What seemed to be the most effectual method of bonding the work together, was that of cramping with iron, which would confine each single piece to its neighbouring piece in the same circle: and if to this be added, that every piece should, at each end of it, lay hold of an inlaid piece, or joggle in the same nature as the cubes, then not only all the pieces in the same course would be united to each other by the cramps, but steadied from moving upon the under course by the joggles, and of consequence would be fastened at thirty-two points: for in each course there being sixteen joggle-stones, as each end of each principal piece, at its base, took hold of half a joggle, there would be thirty-two points of confinement in the circle above; that is, the joggles being made to occupy the middle of the upper bed of each block, in that situation they would cross the joints of the course above. These joggles, as well as the rest, were of sawn marble, and made eight inches long, four inches broad, and three inches thick: each end of each block, therefore, would occupy four inches in length, four in breadth, and one inch and a half in the height of each joggle; and this I judged quite sufficient to keep every course in its place, at the height that this kind of work was begun, and so as to constitute a piece of solid masonry. There was, however, another matter, that it seemed quite material also to attend to; and that was, to render the habitable rooms contained within those shells of walls, perfectly dry and comfortable in all weathers; and this seemed to merit very particular attention; for the seas that are said to rise up against, and in a manner to bury the house, in time of storm, would make effectual trial of every joint.

"The level joints being pressed together by the incumbent weight of the building, would keep firm and sound that cohesion of parts produced by the mortar; so that once being made water-tight, there was no doubt that they would so remain: but with respect to the upright joints, the least degree of shrinking, either of the stone or of the mortar between, tended to open the joint, so that it might always remain leaky, in a greater or a less degree; for we know of no degree of separation of parts, however minute, short of absolute contact, which will stop or prevent the percolation of water. For this purpose I conceived that if flat stones were introduced into each upright joint, so as to be lodged partly in one stone, and partly in its neighbour, (much upon the same idea that Dutch laths were formerly introduced into the joints of chamber floors, to hinder the passage of wet,) the water might be prevented from making its way through the upright joints of the walls.

"The manner in which it was executed was as follows: (see *Plate* IV. *Figure* 6.) At each end of each stone, answerable to the middle between the inside of the wall and the outside, was sunk a groove, two inches and a half wide and three deep, running from the top to the bottom: when, therefore, two contiguous pieces of stone were put together in their places, the two grooves being applied to each other, they would form a rhomb of six inches in length and two inches and a half in breadth, which in this state would be an unoccupied cavity from the top to the bottom of each course; the rest of the joint, where the surfaces of the two stones applied to each other, was made good with mortar in the ordinary way, and brought together by the gentle blows of a beetle. For the groove mentioned, a solid rhomb was prepared, of about two inches thick by five inches broad, and in length a little less than the depth of the cavity, which generally was eighteen or twenty inches; and for the sake of the firmness of those slender pieces of stone, I made choice of the flat paving-stones from Purbeck, which is a laminated marble of great strength and solidity. The joint-stones (which was the name we gave those rhombs) thus prepared, would readily go down the cavities; but, to fix them solid, a quantity of well-tempered mortar was prepared, made more soft than ordinary, by the addition of a little water; a competent quantity being put down to the bottom of the hole, the joint-stone was put down upon it, and, by the simple pressure of the hand, was forced down to the bottom, causing the semifluid mortar to rise up to the top, and completely fill the cavity; and, when forced down in the way described, having in this state a small quantity of superfluous moisture about it, a few very gentle blows, or raps, were given upon the top of it by the handle of a mason's trowel, which producing a small degree of agitation, while the dry stones were absorbing the moisture, contributed (like the beating of mortar) to bring all the parts into their most friendly state of contact, and, in consequence, to their firmest state of union; and this happened in the course of a few minutes, so that no farther agitation could be of any service.

"As the cramps, that were to bind the contiguous pieces together, must cross the joints upon their upper surface, they were of course to be applied after the joint-stones were settled in their places. Precaution was therefore necessary not to apply too much exertion in forcing down the joint-stones: for, however gentle the operation may appear, according as it has been described, yet it was found advisable not to put in the joint stones till an additional piece had been got down upon its joggles, and plain-jointed at each side of the two pieces, whose joint-stone was to be put in; for, by this means, they were the united efforts of all the joggles, and adhesion of the beds of two stones on each side of that where the effort was applied. Without any attention to this, the lateral force arising from merely pressing down a joint-stone was capable of breaking the adhesion of the joint where it was applied.

"The cramping was applied the last thing. The top or flat bars of the cramps were about thirteen inches long, two inches broad, and five-eighths of an inch thick, and were turned down at each end about three inches in length; forming a cylinder of one and one-eighth of an inch in diameter. Jumper-holes were previously bored when upon the platform, and the cramps fitted to their places; the surface of the stone under each cramp being sunk three-fourths of an inch, so that the two stones together would completely receive, or rather bury, the cramps: the joint-stones, as said above, being made so much shorter than the height of the course, as not to interrupt the bedding of the cramp. The places for the cramps being properly fitted and cleared, (as we now were not liable to be driven off the work in a moment, as had formerly been the case,) we took the opportunity, whenever time allowed it, of fixing the cramps of a whole course together. There was no danger of the cramps not fitting; as, besides that all the cramps were forged to fit a guage-bar having a couple of holes at the assigned distance, they were also fitted and marked to their particular places at Mill Bay, while upon the platform. Every cramp being now ultimately tried to its place, it was then put into a kettle of lead, made red hot; and the cramp continued there till it was also reddish. About a spoonful of oil was poured into the two cramp-holes, and the cramp being put into its place, the ebullition of the oil caused by the heat of the iron quickly gave a complete oily surface, not only to the whole cramp, but to the whole unoccupied cavity in the stone; then the hot lead being poured upon it, the unctuous matter caused the metal to run into and occupy the most minute cavity unfilled, and completely to cover each cramp; and they became by this means defended from the salts of the sea, even had they remained uncovered, upon Mr. Rudyerd's principle. Mr. Rudyerd had used coarse pewter. The lead we used was slag lead, which is harder and stiffer than fine lead: and, as we used no cramps, as an essential part of the building, till above the store-room floor, I judged pewter, merely for the sake of stiffness, there to be unnecessary. By cramping, in general, a whole course together, the contraction of the iron in cooling would greatly add to the tightness wherewith every stone was bound to its fellow. Thus according to this mode of fixing, (besides the union of the parts by the mortar itself,) to resist all violence and derangement whilst it was doing, and before the induration of the mortar, every course was retained in its place by sixteen joggles, and each single stone by two half-joggles at its lower bed; they were farther steadied to each other by the joint-stones, and lastly by the cramps, which completely prevented a separation; and this method proved so effectual, that we were not only free from all derangement of the stones when in their places, but I did not find a leaky joint, except one, in the whole building. By a due consideration of *Plate* IV., with the particular references to it, the whole of this process will become perfectly intelligible.

"On Saturday, the 30th of September, Course XXVIII. was completely set; and, being the first course upon which was rested the vaulted floor, which made the ceiling of the store-room and floor of the upper store-room; and, as here again occurred a difference in the mode of fixture, in this, as in all like cases, I attended the performance of the work: and that was the leading-in of the first circular chain, that was lodged in a groove cut round the middle of the upper surface of this course, which this day was satisfactorily performed; and the next day, Sunday, October the 1st, Course XXIX. was set, and its circular chain leaded-in also; which operation, with the reason thereof, it will be proper here to describe: The ordinary way of fixing the several courses by joggles and joint-stones, and also the bonding them together by cramps, has already been described; but those courses, upon which the floors rested and depended, seemed to demand every possible security. It will be seen, in the general section, *Plate* II. that each floor designedly rested upon two courses: it will also appear, by inspection, that the circumference of the floors was not made to rest upon the sloping abutments of an arch, in lines tending toward the centre of the sphere, of which the under side of the floor was a portion, but it rested upon a triple ledge going circularly round the two supporting courses. In consequence of this, had each floor been composed of a single stone, this lying upon the horizontal bearings furnished by these ledges, would, while it remained entire, have no lateral pressure or tendency to thrust out the sides of the encompassing walls: and that in effect, the several pieces, of which the floors were really composed, might have the same property as whole stones, the centre-stone was made large enough to admit of an opening, from floor to floor, or man-hole, to be made through it; and being furnished with dovetails on its four sides like those of the entire solid, it became the means by which all the stones in each floor were connected together; and consequently, the whole would lie upon the ledges like a single stone, without any tendency to spread the walls. But if, by the accident of a heavy body falling, or otherwise, any of those stones should be broken, though this might not destroy its use as a floor, or its properties as an arch; yet the parts would then exert their lateral pressure against the walls: and therefore, as a security against this, it became necessary that the circle of the enclosing walls should be bound together, and the building, as it were, hooped.

"This would be in a great measure brought about by the cramps tying the neighbouring stones together, as already described, for the ordinary courses; but yet this was no absolute security, because the outside stones might break and separate, between cramp and cramp: and I suppose, it was for reasons of this kind, that Sir Christopher Wren, in the construction of the cupola of St. Paul's, did not choose to depend upon cramping the stones together, of the course that served as a common base to the inside dome, and the cone for supporting the lantern; but chose to surround the whole with continued chains of iron. Upon this principle, an endless chain was provided for each of the two floor courses; see *Plate* IV. *Figure* 7. The bars composing the links being one inch and a quarter square, that the most iron might be included in a given space, the corners only were a little canted off; and the double parts being brought near together, the whole was comprehended in a groove, of somewhat less than four inches wide, and as much in depth; into which the chains being introduced and brought to a stretch, the rest of the cavity was filled with lead, of which each took about eleven hundred weight, in the following method. The chains were oiled all over before they came from the shore; and the circumference of the groove was divided into four parts by stops, or dams of clay, to prevent the lead from flowing farther than one quarter at a time. A couple of iron kettles were provided, capable of melting commodiously, when full, six hundred weight of lead each; and that quantity was brought in each to a full red; that is, somewhat hotter than we used for the cramps, as the iron of the chain, as well as the stone, were cold. The whole quantity of lead being brought to a heat that we judged proper, and the quarter-groove being supplied with oil sufficient to besmear the whole surface, two persons, with each a ladle, as briskly as they could, poured the melted metal into the same quarter of the groove; and, as soon as it was full, and the lead began to set, one of the clay dams was removed, and the melted hot metal was poured upon the end of the former mass, till it was perceived to re-melt and unite with the fresh metal. This done, the dam at the other end of the first-run mass was taken down, to prevent its cooling more than was necessary, and the third quarter was treated like the former; the end of the mass rendered solid by cooling, being re-melted by the fresh hot metal: lastly, both the remaining dams being taken down, and the metal at each end having a considerable heat, it was found practicable to dissolve both the ends of the former masses: first applying both ladles to that which had had the greater time to cool, and afterwards to the less: by this means the whole was brought to a solid consistence, and the chain entirely buried in the lead. It is, however, to be remarked, that to preserve proper impressions in the lead, for the joggles of the course above, those impressions were made by confining down bricks in proper places, which, when removed, the proper marble joggles were set with mortar in their places.

"Monday, October 2, we proceeded to set up the centre, composed of sixteen ribs, (see *Plate* VIII. *Figure* 3.) for putting the floor together upon; but the weather continued broken till Saturday, the 7th, on which day the Eddystone boat came out, having on board the roof, or platform, for covering the building, and protecting it from the entrance of the downfall spray; together with the doors, iron work, and timber for fitting up the same for habitation. This afternoon we landed, and went on with the setting of the outward circle of floor-stones, made the holes in the wall for fixing the hinges of the entry and store-room doors. In particular, I caused the middle stone to be laid upon the centre, by way of weight, to keep it steady. Three of the four stones that were to connect with the centre-stone were laid upon the top of the wall, on the north-east side: and the fourth I caused to be hoisted and suspended upon the triangle, in the posture that is shown *Plate* VI. at stage second. So that the triangle, which was all of it completely within the area of the top of the building, would be kept down by the weight of this stone, which was between seven and eight hundred weight. The other three that lay upon the wall, I caused to be carefully drawn within the circumference thereof, so that there might not be the least projecting part for the water to strike against in flying upwards; which I judged quite necessary, though the walls were then upwards of forty-three feet above the foundation-stone, and near thirty-five feet above the top of the rock."

The weather now set in so bad, that no farther operations of consequence took place that season. On the 10th of October, Mr. Smeaton was mortified with a copy of a resolution of the Trinity-Board, declining his proposal of exhibiting a light that winter upon the foundation of the building.

"During my stay in London, in the early part of the year 1759, I received regular accounts of the proceedings at Mill Bay, which were carried on with all the dispatch I could wish; but the weather having continued unfavourable to visiting the works at the Eddystone during the winter, I got no report thereon till I received Mr. Jessop's letter, dated the 27th of March, wherein he informed me that on the 21st of that month, being the first opportunity he could catch after the violent storm which had happened on the 9th preceding, they found not only the solid, but the hollow work perfectly sound and firm; all the mortar having become quite hard; and, in short, every part of the work in the situation in which it was left by the workmen in October: the only derangement was, that the sea had carried away the south fender pile from the rock; and also, from the top of the wall, one of the three stones that I had taken care to draw within the verge of the circumference of the wall, as mentioned. They had found the fourteen pieces of stone set in the circumference of the floor, stuck quite firm to the wall, though two of the pieces requisite to complete the circle were left unset; and that, finding the centre itself quite tight and firm underneath them, they had lowered down the stone suspended on the triangle upon it, and removed from tho wall the other two remaining stones to lie upon the centre; and lastly, that they took down the triangle, and stowed it away in the well-hole for the stairs: but, on farther search, nothing of the buoy that was left upon the mooring chains was to be seen.

"Thursday, the 5th of July, I landed on the rock with the men; they proceeded to set up the shears and windlass, while I inspected the work; and found everything perfectly sound and firm, without the least perceivable alteration since we left it; except that the cement used the first year, now in appearance approached the hardness of the moor-stone; and that used the last year, of the full hardness of Portland. We now proceeded to set the floor. The two remaining pieces of the outmost circle, which were left uncompleted last year, were soon set; and we proceeded to haul up the stones for the next circle (No 4.) from the store-room.

The work now proceeded so rapidly, that the second and third stories were completed in thirteen days. On the 8th of August, Course XLV. or the Cove Course, was completed with its two chains; and the next day, the elliptical centre for the balcony floor was set; and by the 16th, the interior area of the balcony floor was completed, the centre was struck, and the outer circle of stones which finished the cap of the main column, being parts of the corona, or cornice, was begun upon. *See Plate* II. and *Plate* IV. *Figure* 9.

"Friday, August the 17th, the last pieces of the corona were set, and therewith the main column was completed. I now examined the perpendicularity of the whole building, by letting fall a plumb line from the centre of the man-hole in the balcony floor to the centre of the bottom of the well-hole, being forty-nine feet and a half; and found it to fall a small matter to the eastward of the centre of the well-hole; as near as I could determine it, not more than one-eighth of an inch. I then measured the perpendicular heights of the several parts of the building, and found them as follows:

	Ft.	In.
"The six foundation courses to the top of the rock	8	$4\frac{3}{4}$
"The eight courses to the entry door	12	$0\frac{1}{2}$
"The ten courses of the well-hole to the store-room floor	15	$2\frac{1}{4}$
"The height of the four rooms to the balcony floor	34	$4\frac{1}{2}$
"Height of the main column, containing forty-six courses	70	0

"We proceeded this day to set up and lead-in the balcony rails, and completed them; and having brought out a temporary cover for the man-hole of the balcony floor, I this day applied it to use, as follows: a short tub, of about a foot high, was made without a bottom, and the smaller end of it being sized as near as possible to the man-holes of the floors, it was driven into that of the balcony; and, by the time it was driven about four inches, the compliancy of the wood to the stone rendered it quite tight; then the rest of its height, forming a border, and standing about eight inches above the floor, would prevent water from dripping into the rooms through the upper man-hole, or hatchway; and having also provided another tub, about nine inches deep, having a strong bottom in it, and so much more in diameter than the other, that it would, when inverted, cover it; this being applied as a cover, would in the greatest stress of weather defend the building from the entry of water at the top."

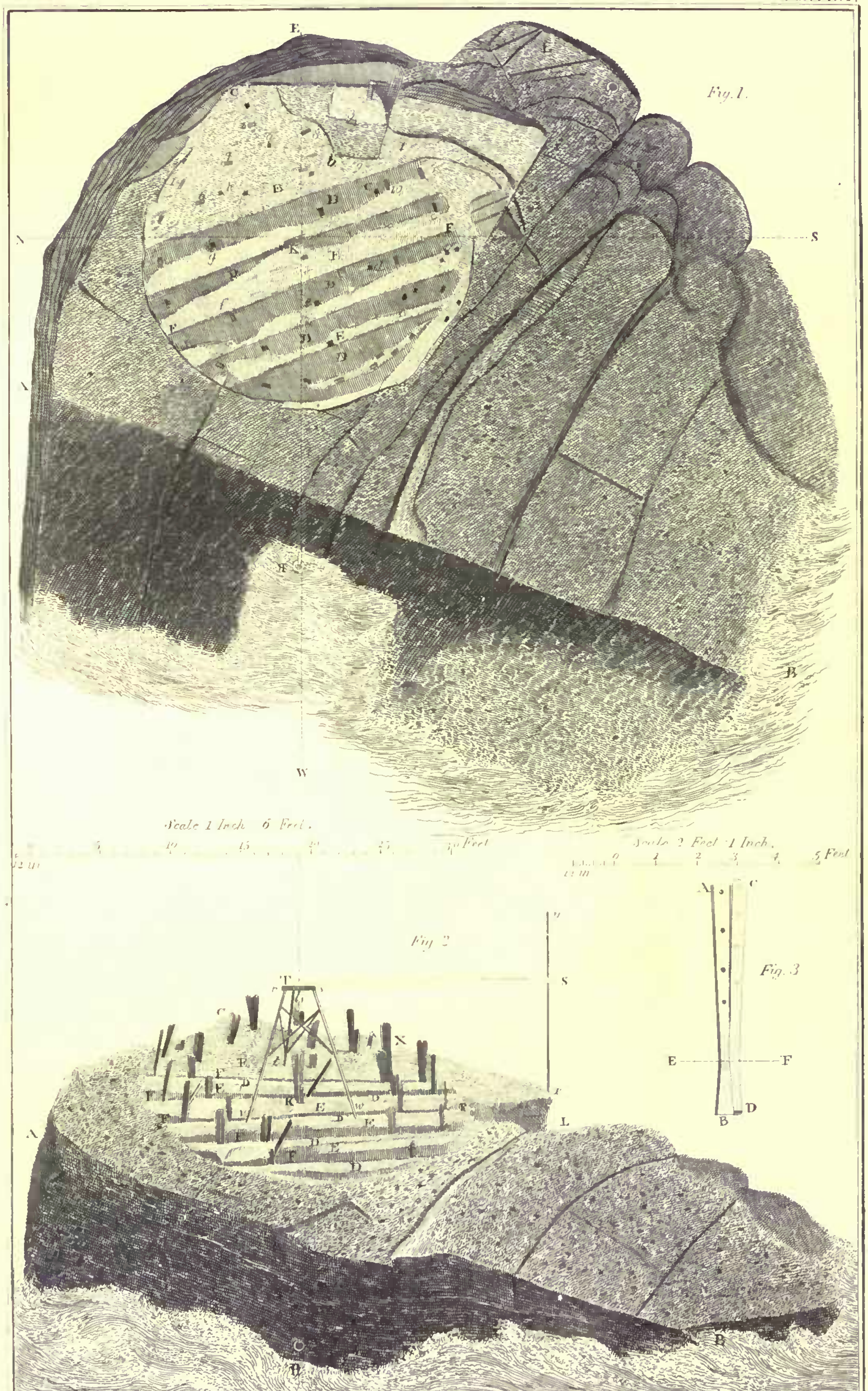
On the 18th of the same month, the first course of the lantern was begun; on the 24th, the last stone, being that which makes the door-head of the lantern, was set; and on Sunday evening, the 26th, the whole of the masonry was completed.

Stress of weather prevented the landing of the frame-work till Saturday, the 15th of September; on which day, "between three and four in the morning, the Weston was got into the gut, and delivered of her cargo, consisting of the pillars, sashes, and frame-work of the lantern. I gave my principal attention to the establishing the frame of the lantern upon a bed of lead, and the screwing of it carefully together; seeing that every joint was filled, and screw covered with white-lead and oil, ground up thick for paint; and every crevice so full that the bringing the screws home made the white-lead matter to ooze from every juncture; thereby to exclude all wet and moisture, and so as to prevent the iron-work from rusting.

"Sunday, September the 16th, was remarkably fine; so that by the evening the whole frame of the lantern was screwed together, and its groundsill was rested upon a bed of lead; which was done in the following manner: The whole frame being screwed together, was raised from its bearing upon the stone about three eighths of an inch, by a competent number of iron wedges; and adjusted by them to an exact perpendicular. Both the stone and the iron were taken care to be oiled before they were applied to each other; and one of the eight sides, having its wedges withdrawn, was run with hot lead; and making a place for it to overflow, as much could be used as would competently heat both the iron and stone, to bring them to a close bearing with the lead; then on the lead's cooling, as the frame became supported on one side by the lead, the wedges of a second side were withdrawn, and treated in the same manner, and so successively till the whole rested upon a solid basement of lead. It was not supposed that the succeeding mass could be sufficiently heated to re-melt the ends of the parts already leaded, as in the case of the chains: but being heated so as to bring them to a close contact, this I judged sufficient, as the lead so applied had no other intent but to bear weight, and give the frame of the lantern one solid uniform bearing.

"Monday, the 17th. This morning was also exceedingly fine; and the Weston being in sight, which was appointed to bring out the cupola, we began to set up our shears and tackle for hoisting it. This perhaps may be accounted one of the most difficult and hazardous operations of the whole undertaking; not so much on account of its weight, being only about eleven hundred, as on account of the great height to which it was to be hoisted, clear of the building; and so as, if possible, to avoid such blows as might bruise it. It was also required to be hoisted to a considerable height above the balcony floor; which, though the largest base we had for the shears to stand upon, was yet but fourteen feet within the rails; and therefore narrow, in proportion to their height. The manner in which this was managed, will, in a great measure, appear by the representation thereof, in *Plate* VI. (see the uppermost stage); but is more minutely explained in the technical detail of that Plate. As the legs of the shears that had been used upon the rock would have been in the way of the cupola they were now removed, as being done with there, and were used as a part of this machinery. About noon the whole of our tackle was in readiness; and in the afternoon the Weston was brought into the gut; and in less than half an hour her troublesome cargo was placed upon the top of the lantern, without the least damage.

"Tuesday, September the 18th, in the morning, the wind was at south-east, with intervals of thick fog; however,



Drawn by M. A. Nicholson.

Eng[d] by R. Thew

between those I had the satisfaction, with my telescope, to perceive the Eddystone boat, on board of which I expected the ball to be. The wind and tide were both unfavourable to the vessel's getting soon near us; therefore being desirous to get the ball screwed on, before the shears and tackle were taken down, one of the yawls was dispatched to bring it away. This being done, and the ball fixed, the shears and tackle were taken down. By this time the joiners had set up and completed the three cabin bedsteads, (for their plan and position between the windows, see *Plate* IV. *Figure* 8.)

"On Friday, the 21st, all the copper sash-frames were got completely fixed in, and ready for receiving the glass.

"On Sunday Morning, the 23d, the yawl landed two glaziers and a coppersmith, with their utensils and materials; the former began to glaze the lantern, and the latter to fit and put up the funnels. This day, with my assistant, the mason, I began to fix twenty-four iron cramps; that is three to each rib of the roof, and which were obliged to be fixed after the roof was together; and being fixed inside, and surrounding the ribs, served to key home the plates of the cupola to the ribs. For this purpose small wood wedges were used, as being more supple, elastic, and compliant, than wedges of metal, and therefore more suitable to this particular purpose. This day also the Eddystone boat brought out and landed a plumber, with his utensils and materials. The most considerable work for the plumber was the covering the whole balcony floor with thick plates of lead; and which extended from the top of the plinth, or first course of the basement of the lantern, quite down to the drip of the corona. They were fitted on separately, in sixteen pieces, and soldered together, in place, with strong ribbed joints; and, to prevent the sea from laying hold of them at the drip, and beating them up, they were turned under about one inch and a half; and being near half an inch thick, I judged them sufficiently stubborn to prevent being unripped.

"Thursday the 27th, the lead-work upon the balcony and corona being now entirely finished, and the cupola completely keyed home to the ribs; the straps and bolts were applied at each angle of the lantern, for screwing it down to the floor of the balcony.

"Friday, September the 30th, the joiners finished their work, which consisted of the following articles. Three cabin beds, to hold one man each, with three drawers and two lockers in each, to hold his separate property, which were fixed in the upper room, or chamber. (See plan thereof, *Plate* IV., *Figure* 8.) In the kitchen, besides the fire-place and sink, were two settles with lockers, a dresser with drawers, two cupboards, and one platter case. (*Figure* 7, of the same *Plate*, shows how these were disposed.) In the lantern a seat was fixed, to encompass it all round, the doorway excepted, serving equally to sit upon, or stand to snuff the candles; and to enable a person to look through the lowest tier of glass panes at distant objects, without having occasion to go on the outside of the lantern into the balcony. Besides the above, the joiners had fixed the ten window-frames, with their sashes; all which were bedded in putty, and falling into rebates cut for them in the original formation of the stone, they could be at any time removed, and replaced at pleasure, as they were fastened in only with wooden pins, driven into holes bored in the stone."

On Michaelmas-day, the glazing of the lantern was completed; on the 1st of October, the copper funnel was finished and tried by lighting a fire in the stove.

"The tackle was also fixed for raising and lowering the chandeliers; and those being hung, there was now nothing to hinder our making trial by lighting the candles, while it was daylight, to see that everything, regarding the light, operated in a proper manner. Accordingly, this afternoon, we put up twenty-four candles into their proper places, and continued them burning for three hours; during which time we had a very effectual trial; for it had blown a hard gale of wind at south-east all day, which still continued; and, keeping a fire at the same time in the kitchen, they both operated together without the least interference; not any degree of smoke appearing in the lantern, or any of the rooms: and, by opening the vent-holes at the bottom of the lantern, it could be kept as cool as we pleased; whereas, in the late lighthouse, this used to be complained of, as being so hot, especially in summer, as to give much trouble by the running of the candles.

"Wednesday, October the 3d, we began to fix the conductor for lightning. As the copper funnel reached through the ball, and from thence came down to the kitchen floor, above forty feet, (see *Plate* II.) I considered this as containing so much metal, that, if struck with lightning, it would thus far be sufficient conveyance; then joining the kitchen grate to the leaden sink, by a metal conveyance, the sink pipe of lead would convey it to the outside. From the sink pipe downwards, which being on the north-east side, was consequently the least subject to the stroke of the sea, we continued the electrical communication by means of a strap of lead, about one inch and a half broad and three-eighths thick, fixed on the outside by being nailed to oaken plugs, driven into two jumper-holes in the solid of each course; the prominent angles of the strap being chamfered off, it was bedded and brought to a smooth surface with putty. At the foot of the leaden strap, an eye-bolt of iron was driven into the rock; and to this was fixed an iron chain, long enough to reach at all times into the water; its lower end being left loose to play therein, and give way to the stroke of the waves: by this means an electrical communication was made from the top of the ball to the sea."

Everything being now completed, notice was sent to the Trinity House, and, on Tuesday evening, the 16th of October, 1759, the lights were first exhibited, amidst the fury of a violent storm.

This excellent building exhibited no other light than what was produced by twenty-four candles, which was not always sufficient, till 1809, when Mr. Robinson, surveyor of lighthouses to the corporation of the Trinity House, superseded these candles by the same number of Argand lamps, each accurately fixed in the focus of a large parabolic reflector of richly plated copper, arranged on circular frames; and consequently giving light in every direction. The improved brightness of the light, by this exchange, exceeded the most sanguine expectation of all in the neighbourhood of Plymouth.

TECHNICAL REFERENCES TO THE PLATES.

"*Plate* I.—*A plan and perspective elevation of the Eddystone Rock, as seen from the west; showing also the theodolite.*

"The representation is as I found the rock; *Figure* 1 being the plan, and *Figure* 2 the upright view. The same letters refer to the same parts in both; the cross lines upon the plan answer to the cardinal points, east, west, north, and south, according to the true meridian.

"L is the landing-place, and C the summit of the rock; the general declivity being towards the south-west; the grain of the laminated moor-stone that composes it being nearly parallel thereto. It has, however, considerable irregularities; for upon the line A B the rock makes a sudden drop of four and a half or five feet; and, by overhanging to the westward, when there is a ground-swell at south-west, the sudden check causes the sea to fly in an astonishing manner, even in moderate weather.

"The surface of the rock is shown, as supposed to have been for ages past; except where it is visibly altered by man's hand, chiefly within the circular area of the late building. The flat treads of the steps cut by Rudyerd are marked D; the upright faces of the steps F; and E denotes the spawled parts, parallel to the grain of the rock.

"*a b c d e f g h* show the remains of the cavities of eight of the twelve great irons fixed by Winstanley; of which the stump of one only, viz., that at *e*, remained for my inspection; it was run in with lead, and had continued fast, till in planting a dovetail there it was cut out, and found club-ended. Which of the other holes, that are left unmarked, made up the remaining four, I could not make out; as doubtless several of them appertained to the additional work that he fixed in the fourth year.

"*Figure* 3. A pair of Rudyerd's iron branches, to a scale three times larger than that of the plan; wherein A B is the main branch, or dovetail part; C D the key, driven hard in, but without touching the bottom; their depth in the rock is denoted by supposing the line E F its surface. The holes in the branches served to fasten the timbers, by large bearded spike-bolts. Of those branches I traced thirty-six original pairs, of different sizes; and two more modern: their places are shown in the upright, *Figure* 2, by inspection; and likewise in the plan, *Figure* 1, at 1, 2, 3, 4, 5, and 6, 7, 8, 9, 10, &c. forming a double circle; also two pair of them at K, to fix the mast, on two sides, to the centre. The irons that remained in the rock, are distinguished in the plan by being hatched with slant lines, the empty holes or cavities by being black. Those that remained whole, whether fast or loose, are distinguished in *Figure* 2, by their shapes.

"X. The place of the cave on the east side.

"R. A strong ring-bolt, put into the rock on the recommencement of the building in 1757, for fastening the western guy-chain of the shears.

"*Figure* 2, *r s t v w*. The three-legged stool, steadied with cross-braces. Upon the middle of the upper round plank *r s* was screwed down the theodolite T, to whose index was screwed the long horizontal rule T S, divided into feet, inches, and parts, upon one edge, tending to the centre. Upon any marked point of the rock to be ascertained, suppose *x*, the rod *x y* was set upright by a spirit-level, and was preserved in an upright position by two small slips of deal, applied as shores or struts, in two different directions. The divided edge of the rule being brought against the upright rod, was shoved up by a short staff, held in the hand tight against the rod, till a spirit-level laid upon the top of the rule showed it to be level. In this position the index would show the degree and minute of the circle; the upright rod would mark the distance from the centre upon the rule; and the rule would mark upon the rod, how much the intersection was above its bottom at *x*.

"*Plate* II. No 1.—*South elevation of the stone lighthouse completed upon the Eddystone in* 1759.

"A. The landing-place.

"B. The cave in the east side of the rock.

"C. The steps cut to mount the rock to the entry-door.

"D. An iron rod, serving as a rail to hold by, in passing to the foot of the ladder, occasionally put out from the entry-door at E.

"No. 2.—*Section of the Eddystone lighthouse upon the east and west line, as relative to* No. 1, *supposing it the low-water of a spring-tide.*

"In the section of the rock, A B shows the upright face or drop, marked with the same letters as No. 1, and the line B C shows the general direction of the grain and slope of the rock to the south-westward.

"The dotted line *a b* shows the level of the base of the first stone. The black line *c d* is the base of the stone in the first course that is intersected by the east and west line; and *e f* 1 is the level of the top of the first course, and bed of the second; 2, 3, 4, 5, and 6, mark relatively the tops of the six courses that bring the artificial part of the foundation upon a level with the reduced top of the natural rock; *e* 6 *f*, being the first entire course, marked VII. as being the seventh above the ground-joint.

"*f*. The foot of the temporary ladder; and there is shown the manner in which the ground-joint of the stone-work was sunk into the rock, all round, at least three inches.

"*h*. The first marble plug, or central joggle, that went through the sixth course, and reached half-way through the seventh; and so in succession to the top of Course XIV.

"*i k*. The place of the marble cubic joggles inlaid between each two courses, which were in an octagon disposition round the centre.

"*l*. Smaller cubes between the fifth and sixth course.

"Course XIV. terminates the entire solid; as upon it is pitched the entry and well-hole for the stairs. The temporary ladder, *f g*, to the entry-door D, is only put out when wanted; and then is lashed by eye-bolts to the stone; at other times, having a joint in the middle, it folds, and is laid along in the entry.

"Above the top of the entire solid, the centre stone being omitted to give space for the well, the cubic joggles were of double the number, and half the size. Course XXIV. terminated that part of the building called *the solid:* and here the habitable of the building began, whereof E is the lower store-room.

"F. The store-room door.

"G. The upper store-room.

"H. The kitchen.

"I. The fire-place, from which the smoke ascends through the floors and lantern, through a copper funnel, and through the ball.

"K. The bed-room.

"L. The stone-basement of the lantern.

"M. The lantern door into the balcony.

"N. The cupola.

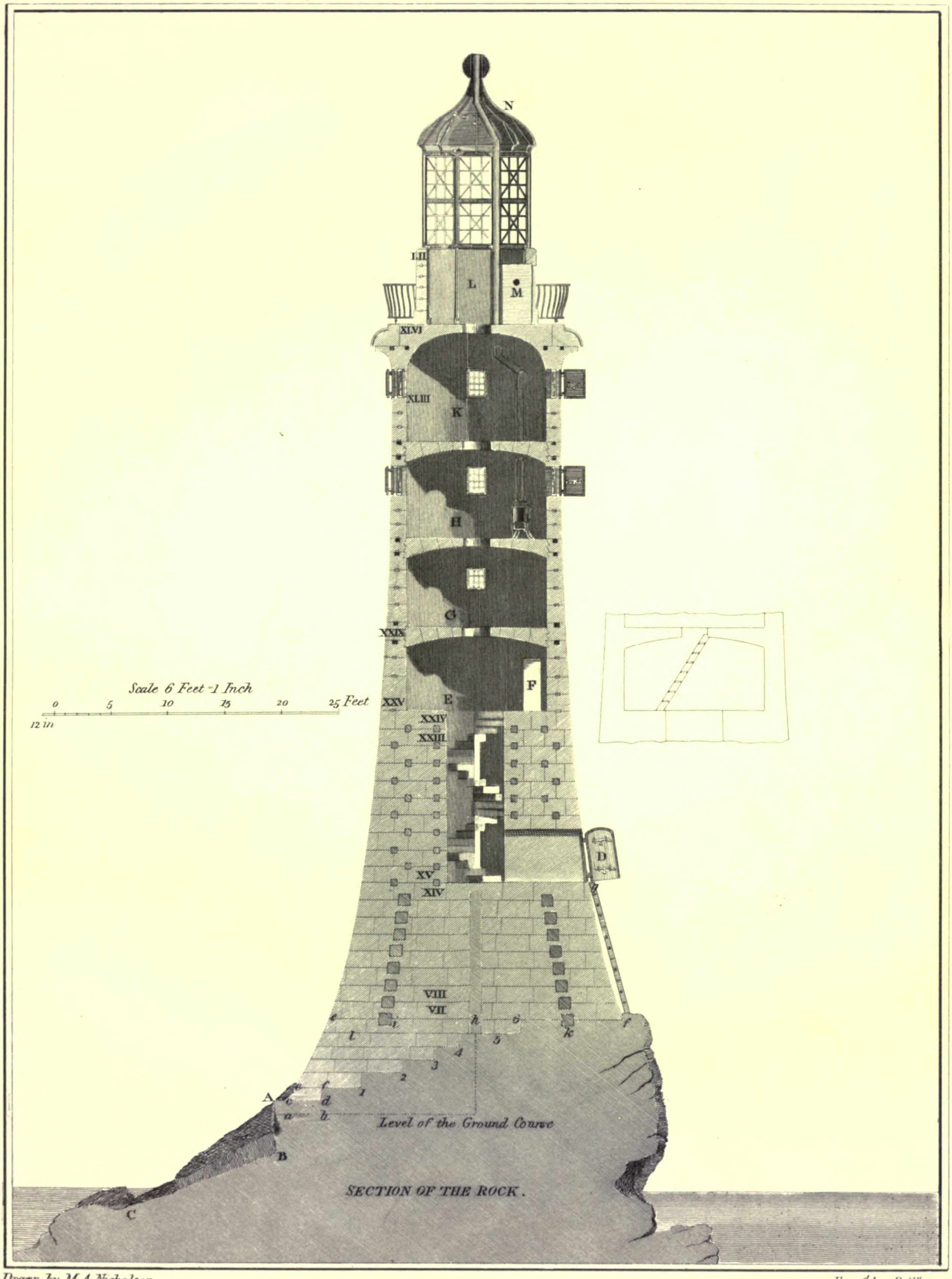
"The ascent from room to room is by the perforations through the middle or key-stone of every floor; and the detached figures show the means, by inclined step-ladders, removable at pleasure.

"*Plate* III.—*Plans of the rock after being cut, and prepared to receive the stone-building. Showing the six foundation courses.*

"*Figure* 1. Plan of the rock, as prepared for the stone-work, somewhat extended, to show how it applies to *Plate* I. The line A B shows also here the place where the surface drops, as specified, *Plate* II. No. 2.

"In this figure, Course I. appears in its place, as fixed with its trenails and wedges. The part darker shaded, and marked D D, was not reduced to a dovetail on account of fissures, but was sunk two inches lower than the rest of Course II. The stones laid therein would therefore be encompassed by a border, and held fast in every direction. The letters E. W. N. S. in all the figures, denote the cardinal points; the same letters, in every figure, denoting the same parts.

"The part of the rock marked C, rises above the rest by an ascent, or step, of fifteen to eighteen inches, according to the line D F G E; which, lying somewhat without the general contour of the building, and affording a firm abutment, the advantage was taken; and the work of the first and second course carried against it, as shown at G.



Drawn by M A Nicholson.

Eng^d by. R Thew.

EDDYSTONE LIGHT HOUSE.

PLATE II. Nº 1

rawn by M A Nicholson.

Engraved by R Thew

5 10 15 20 25 *Feet*

Fig. 3.

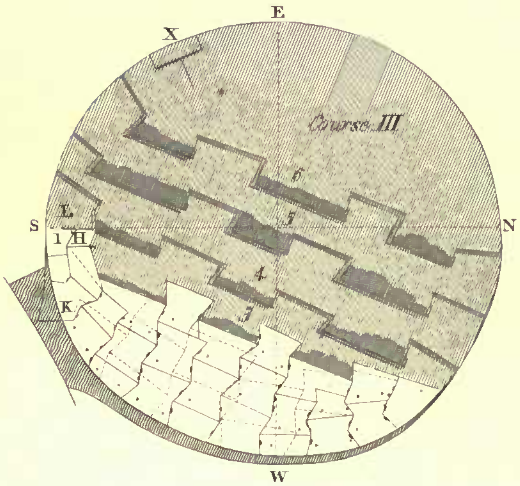


Fig. 6.

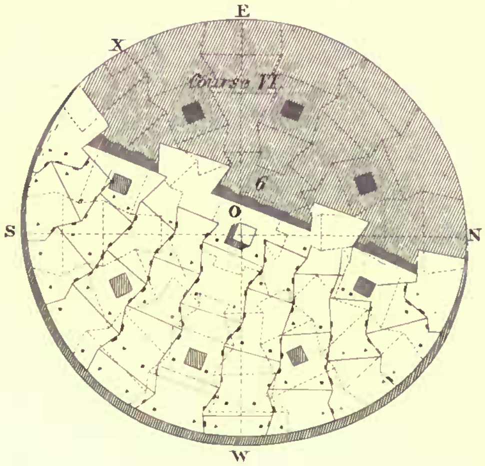


Fig. 2.

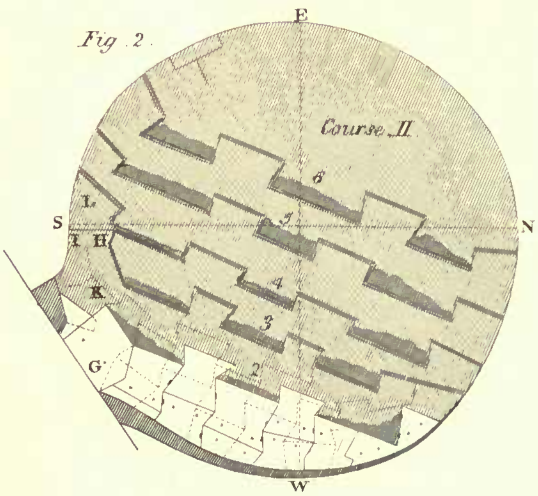


Fig. 5.

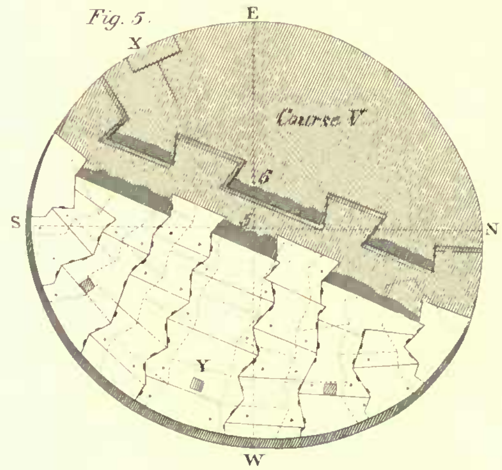


Fig. 1

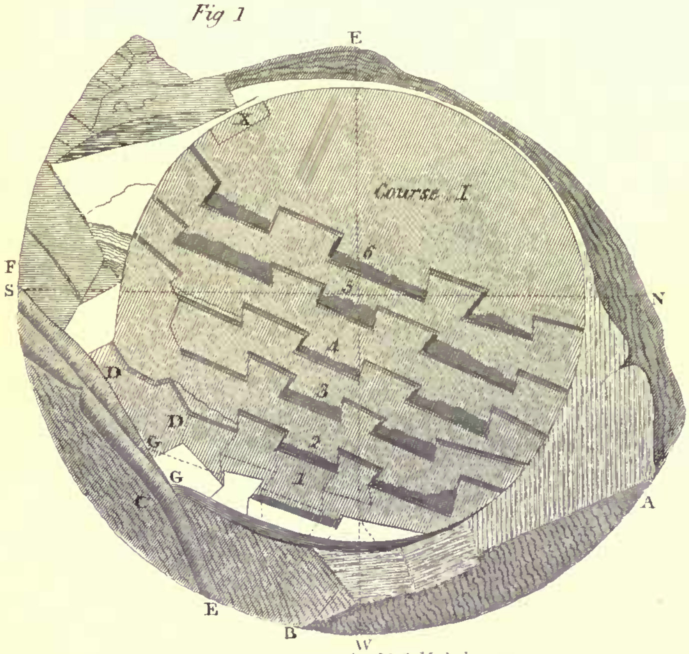
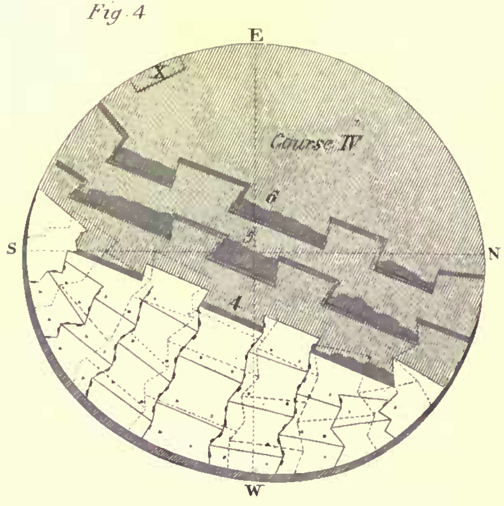


Fig. 4



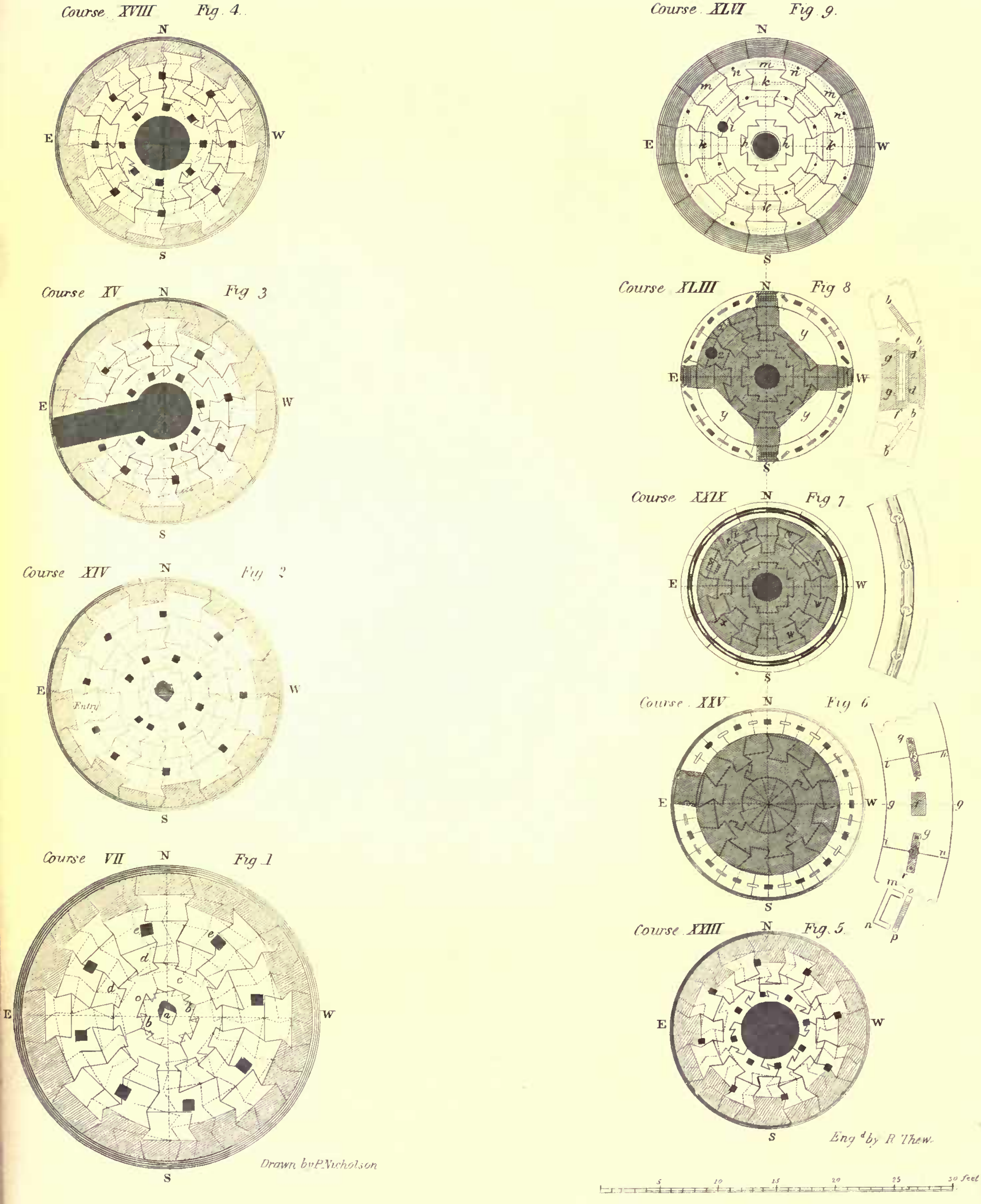
Feet 30 25 20 15 10 5 0

Drawn by M. A. Nicholson

Eng.d by R. Thew.

LIGHTHOUSE.

PLATE IV.



"1, 2, 3, 4, 5, and 6. The level platforms, or steps, for the different courses, whose upper sides are even with these numbers in *Plate* II. No. 2 being upon the level of Rudyerd's lowest step.

"x. A piece of stone engrafted into the rock, serving as a bridge to cross a chasm, opened by cutting down the top of the rock to that level, into the cave. Of this stone is formed a part of the border that encircles the work.

Figure 2 shows how the buttress, o, was terminated in the second course. It also shows the places of the trenails and wedges; which in all these figures are shown in the same manner. The dotted lines everywhere refer to the course that is to come on; and shows how it will break joint upon the course supposed laid.

"*Figure* 3 shows how the space H I K, in *Figure* 2, is filled up in *Figure* 3, being confined in by the rise of the step L at H I, and the cramps *a b;* the ground proving here irregularly shattered by cutting the steps for the former lighthouse.

"*Figure* 4 shows the structure of Course IV., where, in this, as all the others, the stones lighter-coloured denote the Portland, the darker the moor-stone.

"*Figure* 5. The position of three joggle-holes, Y, between this course and the next above.

"*Figure* 6 shows Course VI. complete, which brings the whole work to a level with the reduced rock: it shows the joggle-holes for the eight cubes; and the central plug-joggle, fixed in place at o, ready for the reception of the centre stone of Course VII.

"*Plate* IV.—*Plans of all the different courses from the top of the rock to the top of the balcony-floor inclusive.*

"*Figure* 1. The proper plan of Course VII. relative to the section, *Plate* II. No. 2. As being the first entire course, the trenails and wedges are shown; but afterwards omitted in the draughts, to prevent crowding the figures. The black lines and dotted lines show the joints of the alternate courses. The centre-stones, and the four stones surrounding, were alternately of the same size to the top of Course XIV.

"*a.* The centre plug, first set.

"*b b.* The square part of the centre stone; from each of whose four sides a dovetail projects, and thereon are fixed the four stones *c c*, by joint-wedges and trenails, as per figure; which five stones united make one stone, sufficiently large to receive eight smaller dovetail stones *d d;* and whose projecting parts form dovetails to receive another circle, or order of stones, fixed like the former. The cubic joggles are shown at *e e*.

"*Figure* 2. The plan of Course XIV. ending the fundamental solid, and on which the entry and well-hole are begun. It also shows the diminution from Course VII. Upon this figure is shown the distribution of the smaller cubic joggles, which take place upon the entire solid. The entry here appears to have a small inclination with the E. and W. line, which was not noticed in the section, *Plate* II. No. 2, to avoid ambiguities.

"*Figure* 3. The plan of Course XV. being the first of the entry-door and well-courses.

"*Figure* 4. The plan of Course XVIII. showing the work of the entry closed in, and the solid re-united. Also the manner of hook-jointing the four stones round the centre to each other; which, in the courses below the entry-door, were united by dovetails to the centre-stone. Joint wedges were applied in the hook, as per figure. Thus the arrangement, in circles from the centre, was again complete. In the entry-courses, as every piece had at least one cubic joggle and two trenails, the work was secure against all ordinary attacks of the sea: the weakness being on the east side; but when capped and bonded together by this 18th Course, the whole was again considered as one entire stone, out of which the cavity had been cut.

"*Figure* 5 shows Course XXIII. ready for putting on the cap-course of the solid.

"*Figure* 6. The cap-course, making the store-room floor, in its finished state; the first course of the habitable part of the building, viz. Course XXV. being upon it; and showing the store-room door, with its joggles, joint-stones, and cramps.

"The detached figure, relative to it, shows a part of the top of the wall of Course XXV. to a triple scale; wherein *h h i i* denote one of the pieces of stone, whereof sixteen complete the circle: *f* shows one of the joggles used in this part of the building; being slices of marble the size of a common brick, let half its thickness into the middle of the stone; so that the next course above, breaking joint upon the middle of this, according to the dotted line *g g*, half the joggle's length will take one of the upper stones, whose joint comes upon it, and the other half joggle the other: by which means every stone is fixed to its place, as it were, by two steady pins, one at each extreme. The black lines, *h i*, showing the joint at each end of this stone: the small lozenge figures, *k* and *l*, show the shape of grooves, cut from the top to the bottom of each end of each stone, and which, when two are joined together, form that figure: *k* denotes the lozenge empty, or unfilled, and *l* the lozenge filled with a joint stone.

"*m n.* The shape of one of the cramps, in upright; and *o p* as seen upon the flat. The holes in the stones at *q r* are bored, to receive the round shanks of the cramp, and the rectangular cavities *q r* are sunk, to bury the flat of the cramp *o p*.

"*Figure* 7. The plan of the kitchen floor, and the upper bed of Course XXIX. that encircles it: showing one of the endless chains; of which, as appears in the section, *Plate* II. No. 2, there are two to each floor. The detached figure shows an enlargement of the chain and groove that contains it.

"In the principal figure, the dotted lines at *s* show the place of the fire-grate.

"*t t.* The sink.

"*v v.* The dresser.

"*w w.* The settle.

"*x.* A place for a claw table, leaving a vacancy to the window between each.

"*Figure* 8. The plan of the bedchamber, taken upon the top of Course XLIII. which gives the horizontal sections of the windows.

"*y y y.* The places of the three cabin beds for the light-keepers.

"*z.* The hole in the floor for the copper funnel from the kitchen.

"*a.* The place of the clock.

"In the detached figure, *b b* shows how the cramps are disposed in the reduced jambs of the windows.

"*c.* The plan of the rebate, to receive the shutters, or ports of the windows, whereof the uprights are seen in *Plate* II.

"*d.* The sill of the clear opening; against the solid of which the window frame *e f* and sashes are lodged; the whole of which go in together, and are held in by wooden pins, two above and two below, as shown at *g g*: the holes being bored in the solid stone. If those pins are cut off, the whole can be drawn out and renewed, without injury to the stone-work. The joint of the wood frame with the stone-work is secured against wet by white-lead and oil.

"*Figure* 9. The plan of the cap of the main column, being in *Plate* II. No. 2, the 46th Course, and composes the balcony floor.

"*h h.* The man-hole in the centre, correspondent to the other floors.

"*i.* The funnel hole accordant with *z* in the last figure.

"The dotted lines *k k* trace out the octagon base of the lantern.

"The place of the under rail of the balcony is shown by the dotted lines *m m m*; and *n n n* denote sections of the studs upon which those rails are supported, correspondent to the uprights of *Plate* II.

"*Plate* V.—*Original ideas, hints, and sketches, from whence the general form of the present building was taken.*

"*Figure* 1. The bole of a spreading oak; its side-branches being lopped off, rising out of the ground with a sweep; its taper diminishing till the sides become perpendicular; and on the insertion of the great boughs, again swells and overhangs.

"*Figure* 2. The manner in which the smaller boughs and branches are obliquely inserted into the greater, with the reconciling curves that form the union.

"*Figure* 3. A specimen of paving to be found in the walking paths of London streets; being a mode of dovetailing in stone.

"*Figure* 4. A sample of stone dovetailing in the upright, taken from Belidor's *Archit. Hydraul.*

"*Figure* 5. A copy of the first complete design made out for the solid courses of the Eddystone. The only material alteration afterwards was to diminish the size and weight of the outward circle of stones.

"*Plate* VI.—*A view of the rock on the east side; and of the work advanced to Course* XV. *the first of the entry-courses; showing the manner of landing and hoisting the stones, &c. in every after-stage of the building.*

"*Figure* 1. The boat Weston in the gut, delivering her cargo.

"P. Q. The two fender piles, to prevent her rubbing against the rock.

"X. The cave, here seen in front.

"D. The gulley, through which a momentary cascade makes its way; and which was proposed to be stopped.

"E F G. The shears; from the head of which are suspended the main tackle-blocks A B, whose tackle-fall, after going to the snatch-block E, passes to the windlass, or jack-roll, whose frame being of iron, is fastened to the rock as per figure.

"The enlarged detached figure *a* shows the frame and roll frontwise, as seen from the snatch-block.

"*b.* The side-view thereof, the roll being seen endwise.

"*c.* The manner of coupling the back-stay to the upright stancheons; and *d* shows, by a figure still more enlarged, the upper end of the stancheons for receiving the gudgeons of the roll.

While the stone is hoisting, the man represented at I is heaving-in the tackle-fall of the runner and tackle H K: for, till the stones are cleared of the boat, the shears lay out considerably, and the out-hawler guy-rope, L M, is slack. This crosses the gut, and is fixed by a ring-bolt to one of the rocks of the south reef. By such time, therefore, as the stone is hoisted by the main tackle to the height of the entry-door, the shears are got into the perpendicular; and then by easing the out-hawler guy-tackle, L N, the stone comes into the entry door.

"The runner and tackle H K is hooked to the guy-chain, O, which crosses the work, and passes down to the ring on the west side of the rock; marked R in *Plate* I.

"In the detached *Figure* 2, the anchor-like piece of iron, by which the main tackle-blocks are hung, is shown to an enlarged scale at *e f g h*. This anchor being suspended upon a round bolt at *e*, that passes through the tops of the two shear legs, swings freely between them, and always putting itself in a perpendicular position, and producing fair bearings upon them, without any unnatural strain or twist, enables them to support the greatest weight possible.

"In like manner the two arms of the anchor *g h*, having the two guy-tackles hooked to them, the action of those tackles is upon the suspending bolt, and the feet of the shears turning freely upon eye-bolts fixed in the rock, they are at liberty to conform themselves to the position wanted; so that the stress upon the legs is always endwise.

"After the building was raised to the height shown *Figure* 1, the work was hoisted through the well-hole, till it arrived at the top of the solid, by means of the triangle and twelve-fold blocks wherewith the work was set; and are shown as standing upon the wall at the first vaulted floor by the letters *i k l m*, being the fourth stage: but after that was completed (the man-hole being too small, and the height too great, without losing time) a jack-roll was established, as shown at the third stage in the lower store-room at Q: and a pair of movable shears, the figure whereof is shown at the fifth stage, as upon the wall, at the kitchen-floor; which, instead of guy-ropes, had a back leg, longer than the rest, whose bottom or foot cut with a notch, stepped upon the internal angle of the opposite wall; and was long enough to suffer them to lean over sufficiently for the stone at P to clear the wall. The shears themselves were prevented from falling over by a luff-tackle, shown upon the back leg, whose lower block hooked upon a lewis, in that stone the back leg stepped upon; by which it was brought tight and steady. When the stone was to be landed, this tackle being a little slacked, till the notch could be disengaged, and then set upon, the back leg would, by going over the wall, suffer the shears to come to the perpendicular, or beyond it.

"The stones, now become in general less weighty, a common tackle was employed at the shear-head, which would go down to the entry door, and there met the stones hoisted by the great shears: the tackle-fall of the movable shears, being taken to the jack-roll Q, the stones were got to the top of the building, in the same time they were raised from the boat to the entry-door.

"The detached figure R is the plan of the movable shears; where the check, or safety rope, *n*, is shown at the foot of the back leg.

"In this manner all the heavy materials were got up; the movable shears rising with the work, till the cupola was to be set upon the lantern.

"The sixth stage shows the apparatus used for this purpose. The great shears being now done with, were taken down and put through the windows of the uppermost room, and there, being well steadied, served as booms. The detached figure S being the plan of this stage, shows their particular disposition; wherein *o p* show the places or feet of the legs of the shears used for this particular purpose; also marked with the same letters in the relative upright. In this, the rope *q r* shows a side-stay to the leg *o r*; and *s t* is the stay of the leg *p t*, each fastened to *q s*, the extremes of the booms.

"From each end of the cross-tree at the head of the shear-poles proceeded the ropes *w x*, *y x*, which, joining in one guy-rope at *x*, proceeds over a pulley in the end of the temporary timber at *z*: from thence, with the intermediation of a tackle, 1, 2, it proceeds to, and fixes at the extreme end of the boom 3; and as the weight to be hoisted will principally lay upon this guy, the stay, or shroud rope, 3, 4, is

LIGHTHOUSE.

PLATE V.

Fig. 2.

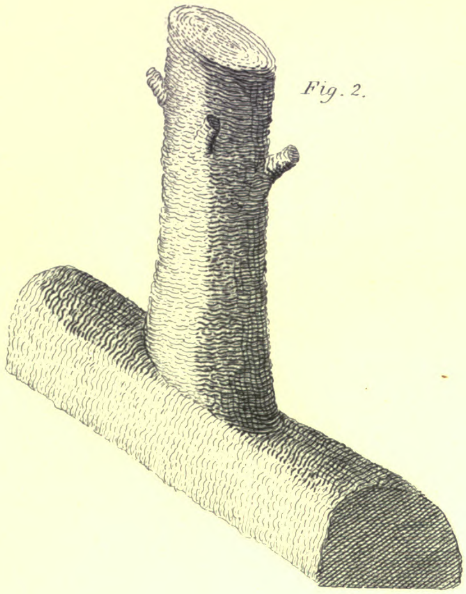
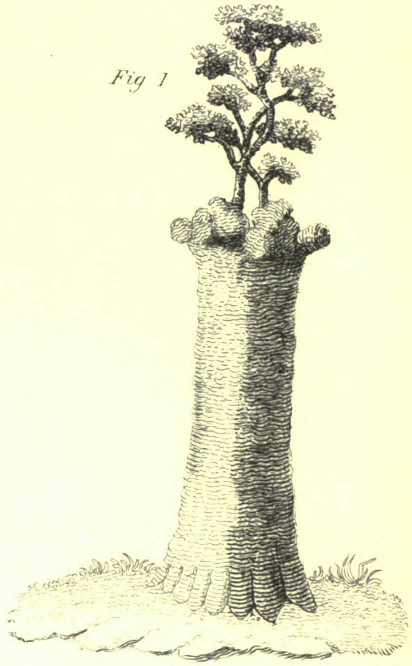


Fig 1.



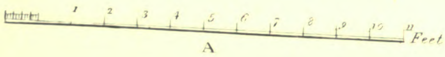


Fig. 5.

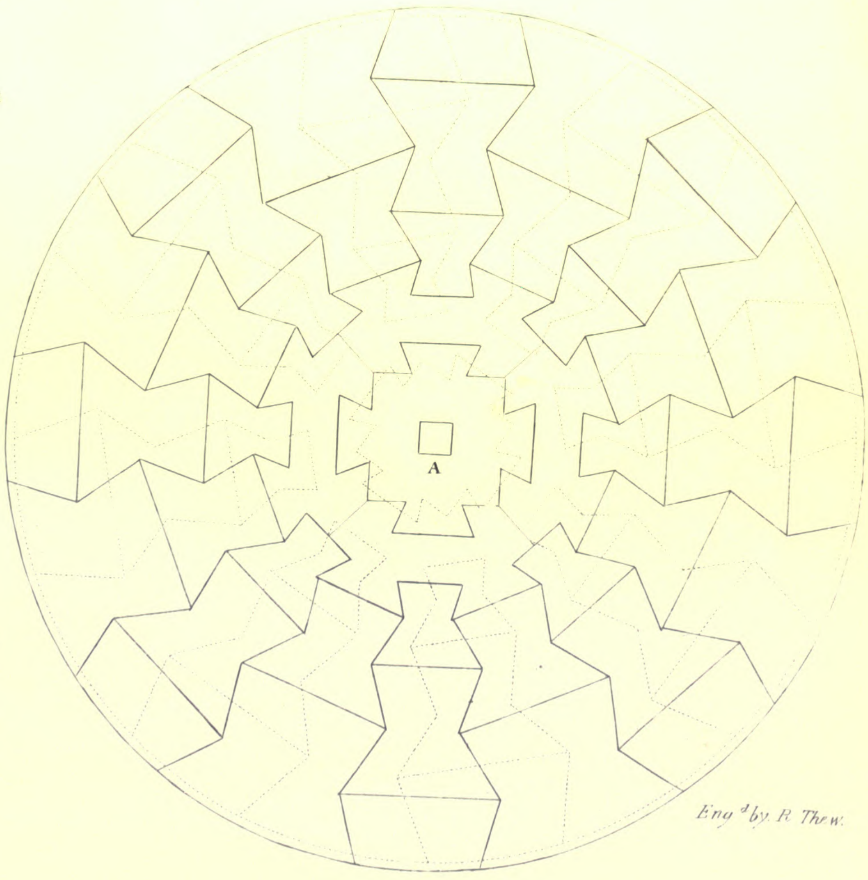


Fig: 4.

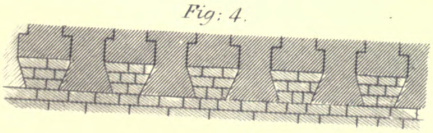
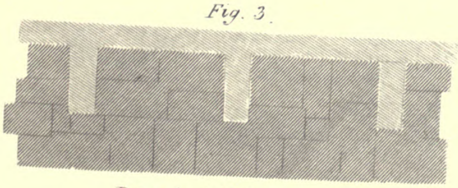


Fig. 3.



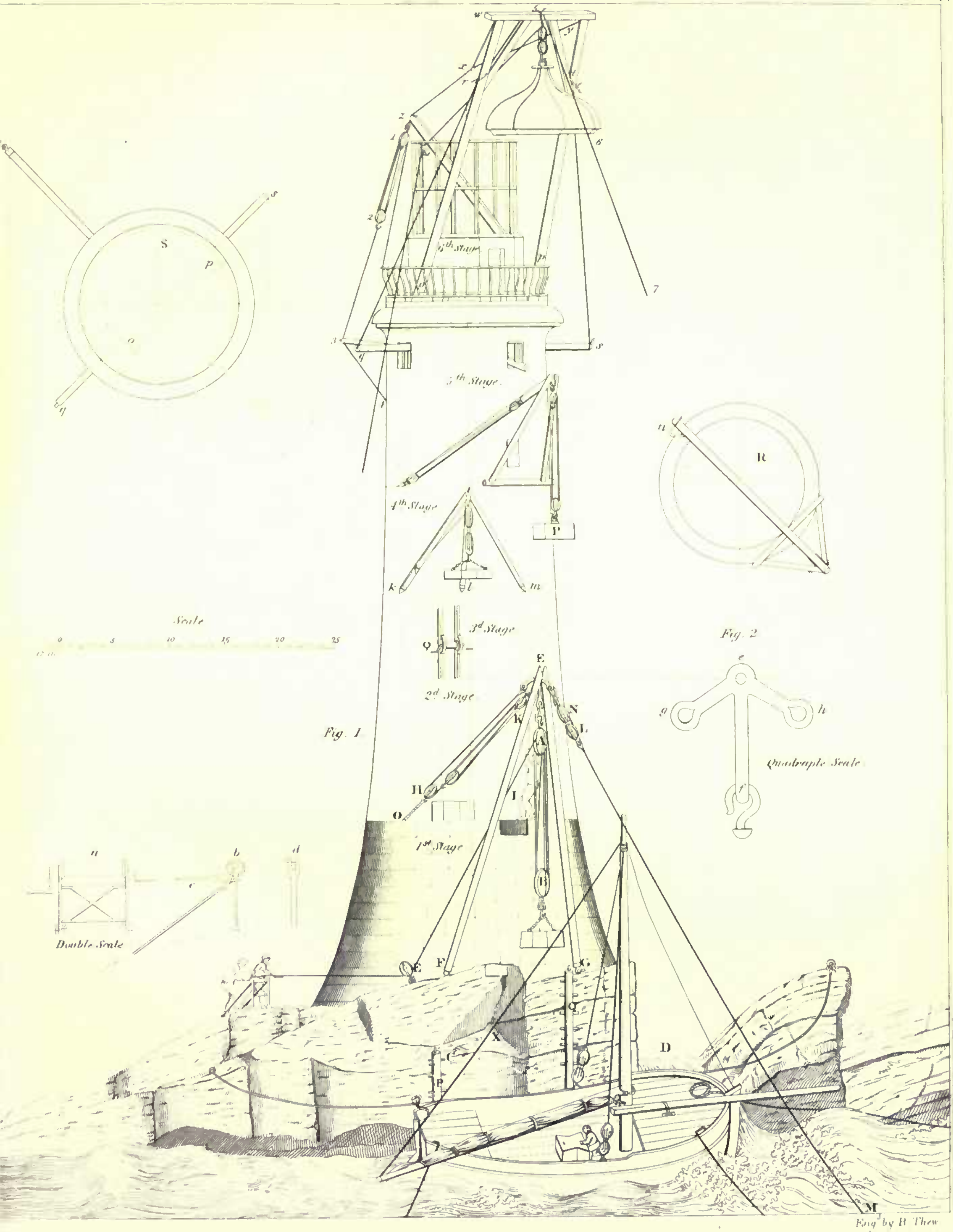
Drawn by P. Nicholson

Eng.d by R. Thew.

LIGHT HOUSE

A View of the Rock on the East side and of the work advanced to course XV, being the first of the Entry courses, shewing the manner of Landing and Hoisting the stones &c, in every stage of the Building.

PLATE VI.

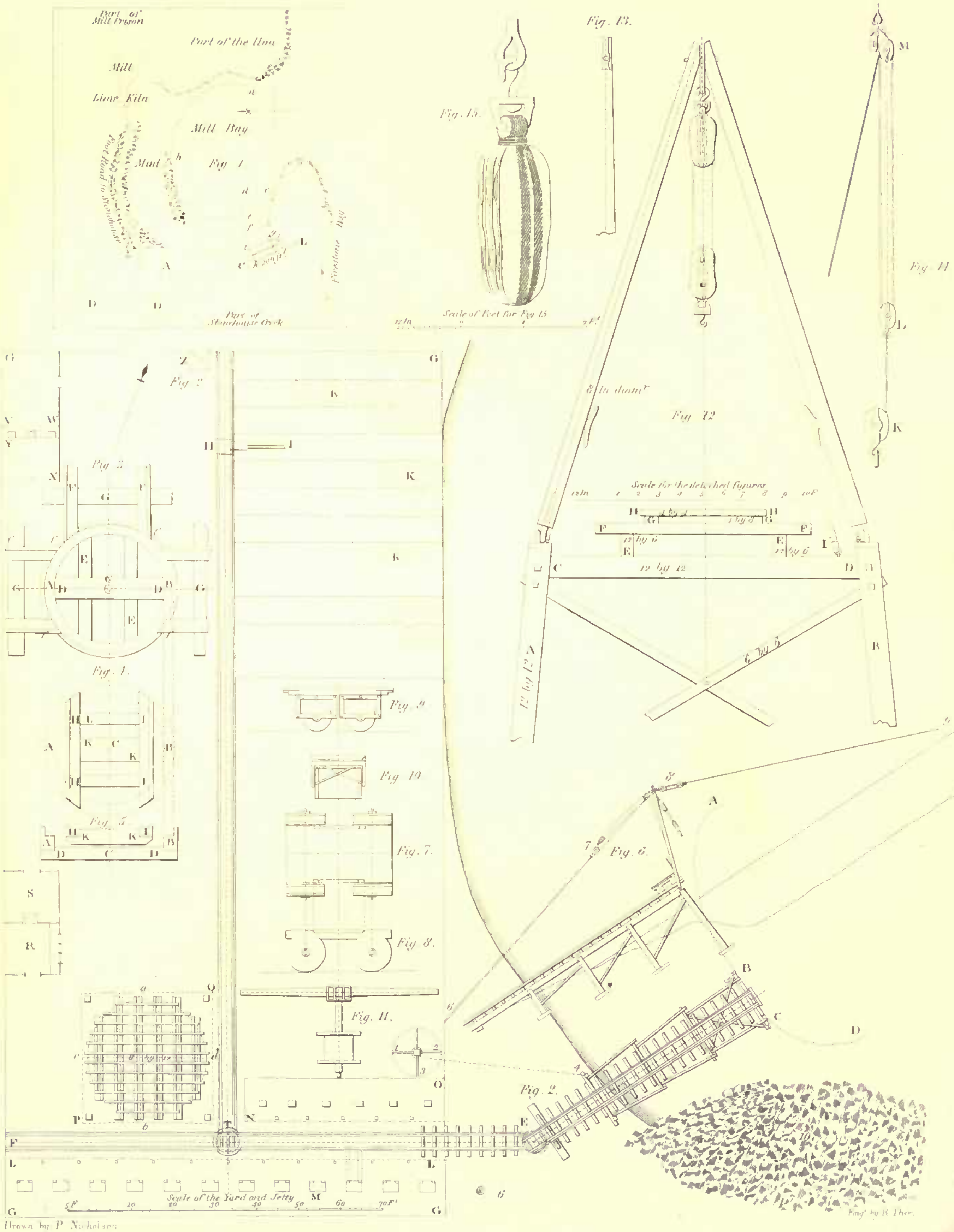


Engd by R. Thew

LIGHT HOUSE.

PLATE. VII.

Plan and description of the Work Yard and Mill Bay with its furniture and utensils



Drawn by P. Nicholson

Eng.d by R. Phee.

passed from thence through the window of the room below, and is there fixed.

"It is now plain, that by the tackle 1, 2, the shears can be let go over as far as necessary, and brought back into the perpendicular; but to counteract this main guy, and keep all steady, the rope 5, 6, 7, with a small tackle upon it, performs the office of an out-hawler guy, fixing to the same ring in the rocks, as that of the main shears had before done. This apparatus enabled the cupola to be hoisted and set on whole without a bruise.

"*Plate* VII.—*Plan and description of the work-yard at Mill-Bay, with its furniture and utensils.*

"*Figure* 1. The general plan of Mill-Bay, wherein the dotted line *a b c* shows the line of low-water spring tides.

"*d e.* The channel dug from low water to convey vessels to the head of the jetty *f g*.

"*h i k l.* The area of the work-yard.

"Since the removal of this work, has been built L the long room.

"A C. The marine barracks.

"D D. New streets of Stonehouse.

"*Figure* 2. Plan of the work-yard and jetty. A B C D, the line terminating the head of the channel. Now any vessel lying against the two large piles B C, on which a pair of shears being erected, can be unloaded of her cargo of stone, and delivered upon a wheel-carriage; that passing along the jetty to the turn-rail E, the carriage is there turned round till it becomes fair with the rail-road E F; and passing along it, enters the work-yard, whose boundary is marked by G O G O.

"At T is another turn-rail, which enables the carriage to go on with its burden; either in the straight line, or to turn there and go along the rail-road in the middle of the yard, and arriving at any destined point, suppose H, it is there met by a roll-carriage; for which, planks being temporarily laid, as at I, the burden (being transferred on small rollers) will be easily moved thereon to the extremity of the yard sideways; and thus stones can be deposited, as at K K (shown edgewise upward) upon any point of the area of the yard, and returned by the same means.

"The area bounded by the line O G, and the dotted line L L, is the Portland workshed.

"M denotes one of the bankers; to which, from the wheel-carriage (supposed on the rail-road opposite) strong joists being laid, as shown by the dotted lines, the pieces of stone are brought on small rolls; the bankers having notches sunk therein, to receive the ends of the joists.

"In like manner, the area N O was the shed for the moorstone workers.

"The square area P Q denotes the extent of a roof, supported by four posts, covering the platform; whereof *a b* represents the platings of rough stone walls; *c d* one of its principal floor timbers, 6 by 12; these being covered with three-inch planks, and brought to a true level, made a stout floor, upon which the courses were brought together.

"R. The cabin for the foreman of the yard.

"S. A small store-room for tools and iron-work.

"G W. The store-shed for Watchet lime and puzzolana.

"V X. The shed for bucking or beating the larger parts of the puzzolana upon W Y, the bank with three cast-iron beds upon it.

"*Figure* 3. Supposed a detached figure, being the ground-plan of the turn-rail at T (*Figure* 2) to an enlarged scale, wherein A B is a dormant circle of wood well supported; of which C marks the centre-pin fixed in the transverse beam D D: E E being connected studs.

"F F. Portions of the rails, whereon the wheels move, which are kept in place by the fillets *f f*, nailed on each side.

"G G. The sleepers for supporting the rails at about a yard's distance middle and middle; as is also shown near E, in *Figure* 2.

"*Figure* 4. The plan of the movable turn-rail, and *Figure* 5 the relative upright; shewing also the section of the dormant circle. The three last figures having a mutual reference, the same parts are marked with the same letters: and furthermore, in *Figure* 4 and 5.

"H I. The rail part of the turn-rail, correspondent to those parts marked F F, *Figure* 3, in width and height. The rail parts, H I, are strongly framed upon the cross beam K K, and connected by the pieces L L. The whole being poised, with its burden, upon the pin C, but without absolutely touching the dormant circle A B while turning; for bearing only upon the flat shoulder of the pin, it turns easily; but, when it is bringing on, or wheeling off, the equilibrium upon the pin being destroyed, the ends, H, I, are then supported upon the dormant circle, and the wheels will move steady.

"*Figure* 7 shows the plan, and *Figure* 8 the upright view of the wheel-carriage, to the same scale as that of *Figures* 3, 4, and 5. Also *Figure* 9, and *Figure* 10, give the upright views of the roll-carriage in two directions, to the same scale; which show distinctly the manner of supporting the axis of the rolls on iron frames; and how the iron frames are kept upright by four pair of cross bars.

"*Figure* 11. The upright of the capstan-roll, axis, and middle part of the bar to the same scale. At 1, 2, is shown the capstan in full, to the scale of the yard; and 3, 4, and 5, mark the direction of the rope, which, from a snatch-block at 5, ascends to the upper block of the main tackle, suspended from the top of the shears, as per *Figure* 6, wherein the in-hauler guy-tackle is marked 7, being a runner and tackle; and the out-hauler, marked 8, are simple blocks. The guy-rope, 7, 6, was attached to a ring-bolt, passing through a large rough stone, rammed into the ground; its place being shown at 6, (*Figure* 2,) the out-hauler guy 8, 9, being secured in the same manner.

"The marble rocks, marked 10, go round the point of the bay.

"*Figure* 12. The elevation of the upper part of the jetty-head in front, with the shears upon it, to an enlarged scale; more particularly to show the smaller parts.

"A, B. The front pair of piles, to which the cross-beam C D is bolted, and, in like manner, to each pair of piles.

"E, E. The ends of the longitudinal half balks.

"F F. The cross joists.

"G, G. The ends of the flat rails that the wheels of the carriage run upon.

"H H. A single cross timber, serving as a stop to the carriage at the end.

"I. The snatch-block.

"*N. B.* The scantlings are marked, because this jetty or scaffold, erected as slight as possible for a temporary purpose, sustained the whole tonnage of the Eddystone matter, in and out, without derangement.

"The detached *Figure* 13, gives a part of the top of one of the shear legs, showing how they were plated on each side to support the bolt of the anchor from bending, and thereby from splitting the poles.

"*Figure* 14. The enlarged figure of the runner and tackle (marked 7, in *Figure* 6.)

"K. The runner-block of one large single pulley.

"L M. The tackle-blocks, of three pulleys each, making a purchase of twelve, equivalent to the great blocks.

"*Figure* 15. An upright diagonal view of the main-tackle blocks; having six pulleys each upon two pins; the larger tier being ten, and the lesser eight inches diameter. This figure distinctly shows the method of salvagee strapping; being double, that the pins being readily knocked out, they could be frequently greased without trouble.

"*N. B.* The shears, blocks, and tackles, used at Mill Bay, were nearly the same as at the rock; and one pair of main tackle blocks at each place, with the same pulleys, went through the whole service; but the pins were renewed each season, and sometimes oftener, being of wood, on account of the salt-water; but were frequently greased. The main tackle-fall at each place was no larger a rope than of three inches circumference; being a white rope, remarkably soft laid, hauser-fashion; and which is of material consequence.

"*Plate* VIII.—*Descriptions of supplemental matters, having reference to the Eddystone building.*

"*Figure* 1. An upright front view of the great tackle, or purchase-blocks of twenty sheaves, or pulleys.

"*Figure* 2. A side view of the same blocks, referring to *Figure* 1. The advantage of this construction is, that the tackle-fall, or running-rope, may be reeved through the twenty sheaves, without a cross or interference; so that the standing part, or beginning, may be in the middle of the upper block: and the ending, hauling part, or fall, upon the middle pulley of the same block. The weight therefore being suspended by twenty ropes instead of six, as in common triple-blocks, the tackle-fall, as relative to a given weight, may be lesser or of fewer yarns in the same proportion; which renders the whole much more flexible and pliant, and which, together with the advantage derived from the mode of reeving, occasions their rising and falling nearly upon a parallel. Beginning in the middle, the greater sheaves are reeved as far as can be on them; from thence going to the first of the smaller sheaves, and reeving the whole of them throughout, you then go to the first of the greater sheaves, before left unreeved, ending upon the middle sheave of the upper block; and thus arises a diminution of the friction from the more equal distribution thereof.

"*Figure* 3. An upright section of the store-room, to an enlarged scale; in it is shown the centre whereon the upper store-room floor was turned; and in like manner the rest.

"*Figure* 4. The plan relative thereto, the letters being common to both.

"*a b, c d.* Two of the sixteen ribs, formed to the circle of the vaults of the floors. These ribs are connected at their ends by two wooden rings, *e f, g h i k;* the former supported by four posts, three of which are shown in their places, and the latter by eight; of which only one is shown on the right hand, and one on the left, to avoid confusion. The rings are each made to take asunder, that after striking the centre they might be got out of the room.

"At *l l, m m,* two of the ribs are supposed taken out, to show their bearings upon the rings; they were open centres, that it might be seen underneath when the joints were fair.

"*Figure* 7, of *Plate* IV., shows how the sixteen radii of stones would apply to the sixteen ribs. In this plan, *Figure* 4, A shows the well-hole, and B B the cross timbers for supporting the four middle posts, whose places are marked out by dotted little squares.

"*Figure* 5. An elevation, and *Figure* 6, the relative plan of a dial stone, taken professedly from the general figure of the Eddystone lighthouse; being the design of the late James, Duke of Queensberry, and by him erected at Amesbury, Wilts, with a dial upon it, by Mr. Ramsden. The drawing, of which this is a copy, was given me by the Duke; and is placed here as an instance, that the Eddystone column may be applied to some uses of architecture.

"*Figure* 7. One of the silver medals given to the seamen as a token of the service.

"*Figure* 8. The tool wherewith the stones were got up from the bottom of the gut.

"A. One of the stones with two trenail holes.

"Suppose this stone lying flat in the bottom of the gut, the side A uppermost. The tool has a pole or staff, *b b*, about twelve feet long, sufficient to reach the bottom. This single prong, *c*, is forged to a very single taper, such as to be thrust eight or nine inches into a trenail hole, (all of them being bored to a gauge) it can be driven by the pole, till fast; observing that the arm *e* corresponds to the centre of gravity of the stone. The water is generally so clear as to see to the bottom; and, in case of any ruffle by the wind, can be in a great measure freed from agitation, by looking through a speaking trumpet, whose mouth is put down eight or ten inches into the water. The rope *d e f* being then set upon by the main tackle, instead of its drawing out, the length of the arm *g* causes the prong to jamb the faster in the hole; and the staff being quitted by the hand, with a cord to hinder its flying off too far, the whole assumes the position of the figure; and, when brought above water, is lowered into a yawl.

"*Figure* 9. A section of one of the mortar buckets, and in it the beater.

"*Figure* 10. One of the internal faces of the lantern's glass frames, and therein the cross bars of iron, as they were actually fixed. Besides the flat at each end of each bar, distinguished by a darker shade, and through which the screws passed; each end was also cranked about an inch, so as to set the transverse part of the bars clear of the copper sash-frame; and they were cleared of each other at their intersection, by one of them being made straight, the other curved in that part. All the panes being taller than the candles, the chandelier rings are so hung, that when the candles are at rest, dispensing their light, that of one chandelier passes through the range of panes A, and that of the other through the range B; and when the candles are snuffed, one of the rings of lights being seen through the range C, the other mounts to D, and *vice versa.*

"*Figure* 11. The chain of triangles from the Eddystone to the flag-staff of the garrison of Plymouth, for ascertaining their distance trigonometrically.

"*Figure* 12. An enlargement of the work within the headlands of the Sound.

"The whole country about Plymouth Sound being very uneven, I could not readily obtain a base better, than by very carefully measuring the two lines B G, B W, taking the intercepted angle W B G; whence the right line W G was obtained, making a base of 1871 feet, and which I cannot suppose to err more than half a foot. Again, the nearest place from whence the two beacons, W, G, could be commodiously seen for the purpose, was the point S; and all the three angles of the triangle W S G, being likewise carefully taken, I conclude the angle W S G $= 10° 23'$, taken true to a minute; that is, to $\frac{1}{623}$d part of the whole angle. The line S W could therefore be determined within $\frac{1}{623}$d part; which being considered as a new base of larger extent, may be esteemed true within $\frac{1}{600}$th part of the whole. From this, and the angles taken as marked upon the scheme, the lines W P, W M, and W E, were successively determined; and finally F E, the distance of the flag-staff from the Eddystone, came out very near, but somewhat less, than fourteen miles. But the interior harbour of Plymouth, called Sutton Pool, being about three furlongs farther from the Eddystone, than the flag-staff, the whole distance may be esteemed fourteen miles and a quarter from Plymouth harbour."

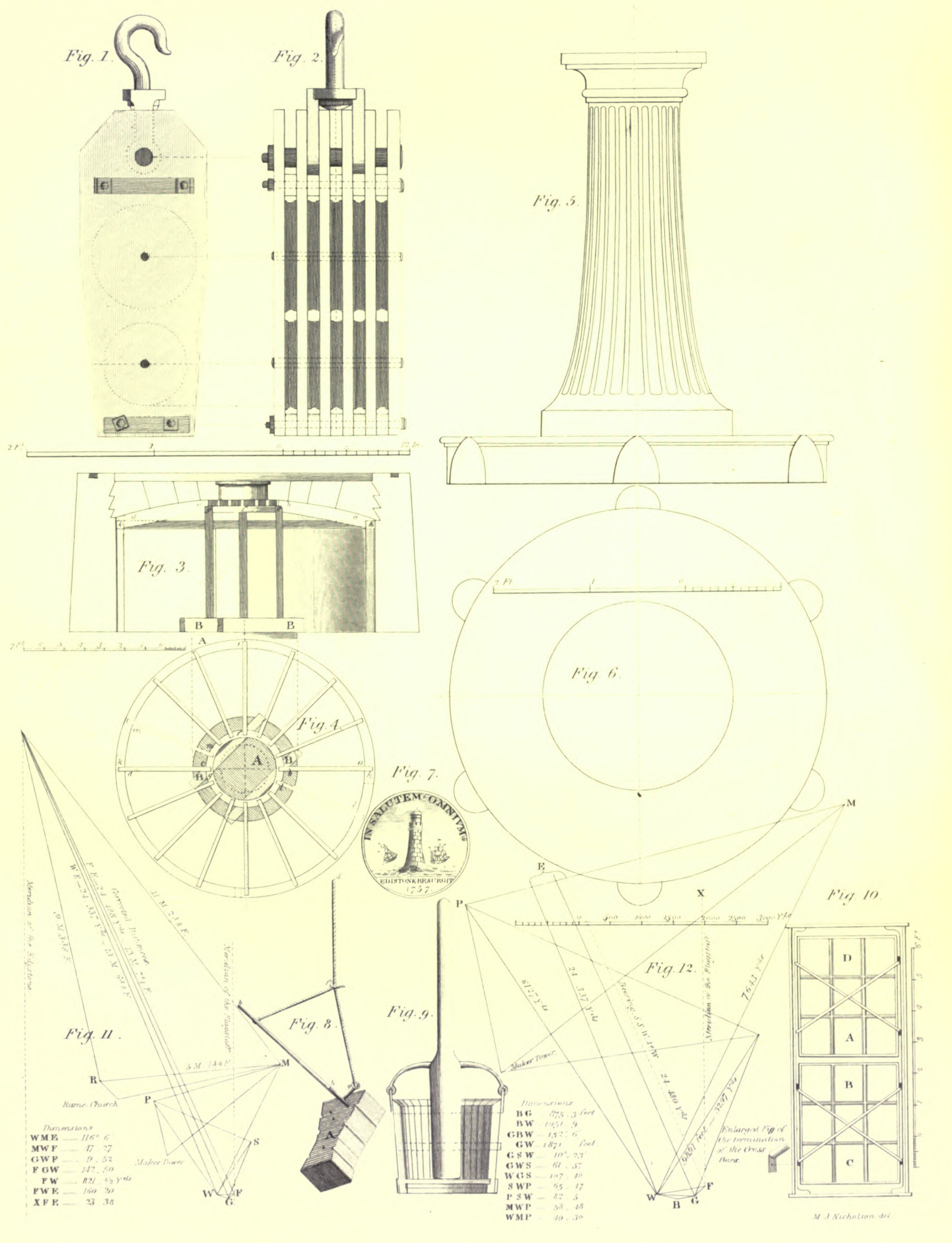


Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
IN SALUTEM OMNIUM
EDISTONE RESURGIT
1757
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
Fig. 12.
Rame Church
Maker Tower
Meridian of the Edystone
Meridian of the Flagstaff
Enlarged Fig. of the termination of the Cross Bars.
Dimensions
WME — 116° 6′
MWF — 47 27
GWF — 9 . 52
F GW — 142 . 50
FW — 821 ½ Y^ds
FWE — 160 20
XFE — 23 38
Dimensions
BG 875 . 3 feet
BW 1051 . 9
GBW 152 . 6
GW 1871 feet
GSW — 10° . 23′
GWS — 61 . 57
WGS — 107 . 40
SWP — 65 . 47
PSW — 82 . 5
MWP — 58 . 48
WMP — 40 . 30
M. A. Nicholson del.

Thus was completed the Eddystone Lighthouse, which must ever be considered a masterpiece of its kind. The merit of utility is not its only characteristic; but in beauty, as well as in strength and originality, it deserves the highest amdiration. And when we remember the extraordinary difficulties by which a work like this must have been surrounded, we must own, that had its contractor left no other memento of his genius, the Eddystone alone would be sufficient to immortalize the name of Smeaton.

EDGE, the intersection of the two planes or surfaces of a solid, which is consequently either straight or curved according to the direction of the surfaces. *See* ARRIS.

EDGE is also that side of a rectangular prismatic body, which contains the length and thickness, but in this sense of the term, the body to which it applies is generally understood to be very thin; thus we say, "the edge of a door," the "edge of a board," meaning the narrow side.

EDGE OF A TOOL, the meeting of the surfaces when ground to a very acute angle.

EDGE-TOOLS, all those which chip or shave in the operation of working.

EDGING, in carpentry, the reducing of the edge of ribs or rafters, whether externally or internally, so as to range in a plane, or in any curved surface required; backing is a particular case of edging, and only applies to the outer edges of ribs or rafters, but edging, or ranging, is a general term, and applies indifferently, either to the backing or internal surface. *See the terms* BACKING and RANGING.

EDIFICE, (from the Latin, *ædificium*,) a building constructed either for use or ornament. The word is not usually applied to a mean or inferior building, but to temples, churches, or elegant mansions, and to other great structures. *See* BUILDING, HOUSE, TEMPLE, &c.

EDILE, (Latin, *ædilis*, from *ædes*, a building,) an officer in ancient Rome, whose business was to superintend buildings of all kinds, more especially those of a public character, as temples, aqueducts, bridges, &c.

EFFIGY, a representation or likeness of anything, the term being particularly applied to sculptured representations of human figures. Such effigies were very common on tombs erected from the fourteenth to the sixteenth centuries, and were of various materials, stone, marble, alabaster, and even of the precious metals.

EGGS, ornaments in the form of oblong spheroids having their greater axis inclined, projecting at the top and receding at the bottom, but each axis in a plane perpendicular to the surface of the ovolo. In straight mouldings, all the axes will be in the same plane; but in annular mouldings or those generated round an axis, all the axes of the spheroids will be in the surface of a cone, whose vertex will be downwards, and will terminate in the apex. The eggs are most generally truncated, or have their upper part cut off by a plane parallel to the horizon. *See* ECHINUS.

EGYPTIAN ARCHITECTURE. The character of the Egyptians, as developed in early history, would naturally lead us to suppose, that an inquiry into their style and manner of building would form a subject for interesting study, not only to the antiquary, but also to all such as take any interest in general history; and such doubtless is the case. The history of the place attaches an unusual interest to everything connected with it. Of the early history of Egypt, like that of the other primæval nations we know but little for certain, all narrative dating back beyond a certain period, having an air of mystery about it, which it is not easy to penetrate, and this fact is more especially true, as regards the origin of nations. If we believe the records of the Egyptian priests, as handed down to us by Herodotus, Manetho, Eratosthenes, and others, we shall have to carry back the date of its origin far beyond the period generally assigned as the commencement of history. Manetho gives us a series of dynasties upon dynasties, which, if successive, reach beyond the bounds of time; to obviate which difficulty, it has been suggested, that they were not all successive, but several contemporaneous, reigning over different parts of the country; but, indeed, the whole matter would seem to be fabulous, for in the same place is related the gigantic stature of several kings, their wonderful exploits, and other circumstances characteristic of mystical and confused tradition. The first king alluded to by historians is Menes or Men, who is supposed to have lived above 2,000 years B.C., about the time of the foundation of Assyria by Nimrod, and of the reign of the Chinese emperor Yao, with whom the historical period of China begins. It is doubtful which of these nations came first into existence; we are inclined to give the preference to the Assyrians, but whichever takes the lead, there was probably but little difference between them in point of time. It is certain that Egypt stood out pre-eminent in civilization, and that, too, at a very early period; its success in the cultivation of the arts, and in the pursuit of science, was greater than that of any contemporaneous people, as is evident from their remains to be seen at the present day. At the close of Manetho's sixteenth dynasty, the irruption of the Hyksos, or shepherds, is supposed to have taken place; his seventeenth dynasty consisting of shepherd-kings, from which period it is alleged that the erection of the existing edifices must commence, all the previously existing buildings having been destroyed by the shepherds. As a proof of this, is adduced the circumstance, that at Carnac, and other of the oldest monuments of Thebes, sculptures and painted stones, of good workmanship, are to be found, used as mere materials in the body of the walls.

Besides the ancient authors already mentioned, we have Strabo and Diodorus Siculus, who have given some account of Egypt and its buildings, and to these we shall have to refer occasionally as we proceed.

In turning to modern writers on this subject, we shall find but few who enter fully into the subject previous to the commencement of the present century, little or nothing having been known of Egyptian buildings unless it were of the Pyramids, until the French expedition, at the close of the last century; no satisfactory delineations of the temples, or their details, had been taken, but only such sketches as were calculated to convey some general idea of their characteristic massiveness. To Denon, and the contributors to the great French work on this subject, we are principally indebted for our present information. Pococke and Norden have treated somewhat largely on their researches in this country, but their remarks are too general and too loose to be of much service. Denon had advantages unattainable by any of his predecessors; independent of his own high qualifications, his efforts were seconded by the able assistance of men of talent, sent out for the purpose, themselves well fitted for the task. Besides these, we may mention Belzoni and Champollion; and, amongst our own countrymen, Savary and Wilkinson.

According to Manetho's account, the temples to which the remains described by Denon belong, were erected by the first dynasties of the Pharaohs, or about 2,200 before Christ: these first structures, however, were destroyed by the invading shepherds, as before noticed. These usurpers were, in turn, driven out by the Pharaohs, who were restored to their throne about 2,000 years B.C., and thereupon set about rebuilding the temples, the remains of which are seen at this day.

The character of Egyptian architecture is that of massy grandeur and severe simplicity, as exhibited in the simple, well-defined outline, and in the colossal dimensions of their temples, and the immense blocks of material employed in their construction. The great object of the builders seems to have been, that the strength and durability portrayed in the prodigious magnitude of their structures should serve to typify their own greatness. They did not consider, when they were erecting their temples, that they were building them for an age, but for eternity; nor, comparatively speaking, were they deceived in the estimate of their works; for now, after the lapse of three or four thousands of years, we have some portions which are likely to last as many more centuries, unless wantonly destroyed by the hand of man. Had, indeed, the buildings only to contend with the ravages of time, we should have many a structure perfect, where it is now a heap of ruins; had it not been for the reckless destruction of these wonderful monuments by Cambyses, it is questionable whether they would not all have been entire at the present day, and certainly in a better state of preservation than many modern buildings which have not numbered as many ten years as the former have centuries. Even now, the carving, and, in some instances, paintings, to be seen in the ruins, are as fresh and bright as if only just executed.

The immense size of the stones employed, and the mechanical art necessary for transporting them from the quarry, and afterwards raising them to the required elevation in the temples, when building, cause these sacred structures to appear like works of superhuman labour. In every degree, they exhibited a solemn majesty of style, and imposing grandeur; while austere simplicity, combined with order, uniformity, and regularity, pervade the whole design.

This, with the solidity and massiveness of the parts, and the prodigious dimensions of the stones, imparted an air of the most impressive and awful sublimity on the mind of the beholder.

Belzoni, who visited Egypt, observes, in his enthusiastic manner, when entering this magnificent temple—"I was lost in a mass of colossal objects, every one of which was more than sufficient of itself to attract my attention; I seemed alone in the midst of all that is most sacred in the world; a forest of enormous columns, adorned all round with beautiful figures, and various ornaments, from top to bottom; the graceful shape of the lotus, which forms the bell-shaped capitals, and which is so well-proportioned to the columns; the friezes, also adorned in every part with symbolical figures in low relief, representing battles, processions, triumphs, priests, and sacrifices; all relating to the ancient history of the country. The walls of the sanctuary, usually formed of red porphyry granite; the high portal, seen at a distance from the openings of this vast labyrinth of sacred edifices on each side of me, had such an effect upon my soul as to separate me in imagination from the rest of mortals, exalt me on high above all, and cause me to forget entirely the trifles and follies of life!" "It further appears," he says, on entering the city of Thebes, "like entering a city of giants, who, after a long conflict, were all destroyed, leaving ruins of their various temples as the only proof of their former existence." Champollion exclaims of Carnac, "These porticos must be the work of men one hundred feet in height;" and Denon adds, "Such structures appear like dreams, or the works of giants!"

Of the impression made upon the mind of Denon by these stupendous structures we have sufficient evidence in his work on the subject; the few following passages have been selected from a multitude of a similar kind.

Of the portico of Hermopolis, he says, "This was the first monument which gave me an idea of the ancient Egyptian architecnure, the first stones that I had seen which had preserved their original distinction without being altered or deformed, and had remained there for four thousand years; here I fancied I saw engraven on every stone the words Posterity—Eternity. It gave an idea of the immense range and high perfection to which the arts had arrived in this country. If a peasant should be drawn out from his mud-cottage, and placed before such an edifice as this, would he not believe that there must exist a wide difference between himself and the beings who were able to construct it, and, without any idea of architecture, would he not say, 'This is the work of a god; a man could not dare to do it, or inhabit it.'"

This is his first impression, nor is his admiration less apparent at the close of his researches; novelty may excite wonder and interest, but merit alone can maintain them. At a later period, the description of Tentyra calls forth the following remarks:—

"Nothing is more simple and better put together than the few lines which compose this architecture. The Egyptians borrowing nothing from the styles of other nations, have here added no foreign ornament, no superfluity of materials: order and simplicity are the principles which they have followed and they have carried them to sublimity. At this point they have stopped, and have attached so much importance to preserving the unity of design, that though they have loaded the walls of these edifices with bas-reliefs, inscriptions, historical and scientific representations, none of these rich additions intersects a single line of the general plan, all of which are religiously preserved unbroken; the sumptuous decorations which appear to the eye when close to the building, all vanish at a short distance, and leave full to view the grand elements of architectural composition which are dictated by sound reason. It never rains in this climate, all that is wanted therefore is a covering of plat-bands to give shade, but beyond this neither roof nor pendiment are added; the plain-slope is the principle of solidity; they have therefore adopted this form for every main supporter, doubtless with the idea that stability is the first impression that architecture should give, and is an essential constituent of this art. With these people the idea of the immortality of the Deity is presented by the eternity of his temple; these ornaments, which are always rational, always consistent, always significant, demonstrate a steadiness of principle, a taste founded upon truth and a deep train of reasoning; and if we even had not a full conviction of the eminent height to which they had attained in the abstract sciences, their architecture alone, in the state in which we now find it, would give the observer of the present day a high opinion of the antiquity of this nation, of its cultivation, and the impressive gravity of its character."

Of Carnac he at last exclaims—"One is fatigued to describe, and to read, and to think, of such a conception; after having seen it, one can hardly credit the reality of the existence of so many structures collected in one spot, of their size, of the determined resolution (*constance obstinée*) which exacted their erection, and of the incalculable expense of such magnificence."

Of the æsthetic character of Egyptian architecture, our author observes:—"These monuments, (Tentyra,) which imprinted on the mind the respect due to a sanctuary of the divinity, were the open volumes in which science was unfolded, morality dictated, and the useful arts promulgated; everything spoke, every object was animated with the same mind. The opening of the doors, the angles the most private recess, still presented a lesson, a precept of admirable harmony; and the lightest ornament on the gravest feature of the architecture, revealed under living images the abstract truths of astronomy."

"Painting added a further charm to sculpture and architecture, and produced at the same time an agreeable richness, which did not injure either the general simplicity or the gravity of the whole. To all appearance, painting in Egypt was then only an auxiliary ornament, and not a particular art; the sculpture was emblematical, and, if I may so call it, architectural.

"Architecture was therefore the great art, or that which was dictated by utility, and we may from this circumstance alone infer the priority, or at least the superior excellence, of the Egyptian over the Indian art, since the former, borrowing nothing from the latter, has become the basis of all that is the subject of admiration in modern art, and what we have considered as exclusively belonging to architecture, the three Greek orders, the Doric, Ionic, and Corinthian. We should therefore be cautious of entertaining the false idea which is so prevalent, that the Egyptian architecture is the infancy of this art, since it is, in fact, the complete type."

Such is the universal and oft-repeated admiration of modern travellers: had such expressions been used by an ancient author, and the buildings now demolished, we should have been apt to treat the matter as purely fabulous, but now they are undoubted realities, and stand as evidence of the truth of history. Such structures could doubtless have been erected solely under a despotic government, and probably, for the most part, by captives or slaves, and not by free Egyptians, as we read of the Israelites in the time of Moses being tasked in this manner; the manual labour employed on such structures must have been enormous. It is a matter of the greatest wonder how such immense masses of material were transported from the quarries, and fixed so accurately in their respective places; even in the present day, with all the advantages of machinery and steam-power which we possess, the erection of such structures as those of Egypt would be considered no light undertaking. Notwithstanding the vast magnitude of these erections, they were remarkable not only for their size, but no less for their enrichment; ornamentation of various kinds was lavishly distributed over the whole surface. It is true, the buildings appear to greatest advantage when exhibited as a whole, yet each minute portion will bear, nay, require, minute examination; a close inspection reveals the most elaborate enrichment, while a distant view exhibits the noble outline and the grander features of architectural composition.

No two styles would at first sight appear more dissimilar, more antagonistic, than the Egyptian and Gothic, the one ponderous and massive, the other light and elegant; the one flat, of low proportions, and presenting a great extent of unbroken horizontal lines, the other slender, lofty, and aspiring. What contrarieties do they present! and yet we shall find that they have many characteristics in common, not indeed in their architectural features, but in the æsthetic principles followed out in their construction and decoration. The temples of the Egyptians were but the embodiment of their religion; their massive proportions typified the greatness, as the continuity of the outline and repetition of parts illustrated the eternity and immutability of their deity. Their objects of worship inspired feelings of profound awe, so likewise did their temples. Nor were their decorations merely the result of caprice, but of studied design; every detail was subservient to some great end, and suggested by some urgent reason; they all have a symbolical meaning, illustrative of the Divine attributes, and consist, in short, of a series of religious dogmas and precepts, embodied as it were in forms. They were, as is said of the pictorial and carved enrichment of Gothic edifices, the books of the unlearned, each object speaking more intelligibly and more impressively to the eye and mind of the beholder, than would whole volumes of written precepts.

"The materialism of Egyptian worship," says a writer on this subject, "rendered all these details essential; it fixed the imagination on physical nature, and obliged the ecclesiastics to seek those forms best calculated to express the dogmas of their religion. And in contemplating their architecture, it is impossible not to be struck with the manifest influence religion has had in its creation." In allusion to another similarity as regards the circumstances connected with the erection of Egyptian and Gothic edifices, he says, "The priests, who were the great depositories of all knowledge, were the exclusive designers of their religious edifices; they alone directed the taste of the architect and the sculptor; and they employed architectural grandeur, with all its accessories, to influence the minds of those people whose actions they wished to govern; nor can I imagine anything better suited to inspire religious awe, and a profound reverence for the divinity, as well as his earthly agents amongst an idolatrous people, than this style of architecture." In passing, we may remark upon another affinity between the two styles, which approaches more nearly to an architectural characteristic, and that is, the practice of copying nature, all the decorative details of Egyptian, as of Gothic architecture, being the most beautiful imitations of the natural productions of their country—the lotus, palm, reed, papyrus, &c.

Having thus given a description of the general character of this style of architecture, it will be as well to proceed at once to the consideration of the buildings more in detail, as regards plan, distribution, and arrangement of parts, method of construction, and such like; in doing which we shall take as an illustration the temple at Edfou, or Apollinopolis Magna, one of the largest in Egypt.

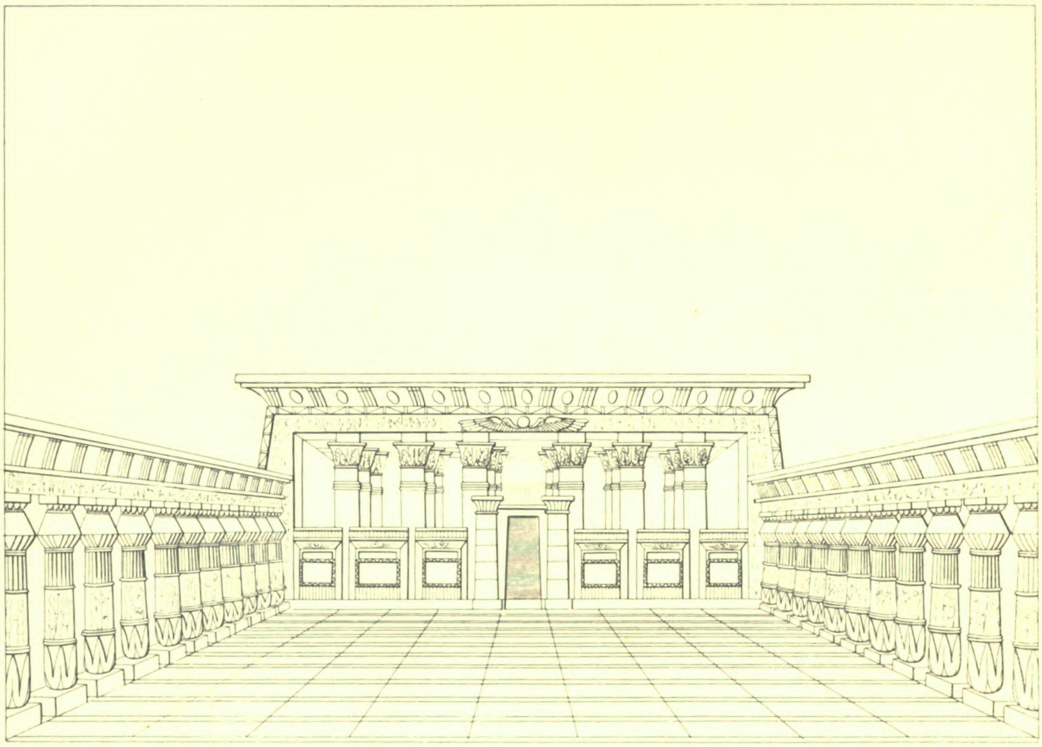
The size of this temple is much more comprehensive, and its arrangement much more complicated than that of Grecian structures, for whereas the latter consisted of a single cell surrounded by a wall with external columns, the former was composed of several courts, one within and beyond the other, and having columns for the most part within the walls. The entrance to the whole building was through a door placed between, and somewhat in advance of two enormous pyramidal towers, termed propylæa, which rose considerably above the general mass of the building, and were covered on the sides with sculptured figures of colossal size. The plan of each pyramid in this case measures 104 feet in length and 37 feet in width at the base, the dimensions diminishing gradually to the summit, where they are 84 feet by 20 feet, the heihgt being about 150 feet. Each mole is finished by a projecting cornice, and is surrounded on all sides by a bold torus moulding. They may be considered as solid structures, for although they contain chambers with their approaches, still these bear so small a proportion to the entire mass, that they amount to no more than small voids or cavities. The colossal entrance between the pyramids is crowned with a cornice, and finished at the angles with a torus-moulding similar to the propylæa, and was probably furnished with folding doors, as the notches for hinges are still visible. This door-way gave admission into a peristyle court having twelve columns on either side, and four on either side of the entrance at a little distance from the propylæa. The pillars at the sides are placed at some distance from a wall, which commences at the moles and surrounds the entire temple, and the space between this wall and the columns is roofed over, so as to form a covered-way or piazza, which leads on either side to the doors of the staircases in the propylæa, and is continued in a similar manner in front of them, on the entrance-side of the area. The colonnade throughout is picnostyle, which seems to have been the usual disposition, the intercolumn being seldom greater than a diameter and a half, except in the centre of a portico, where a doorway intervened, which practice is identical with that of the Greeks, as evinced in the Doric order. The height of the colonnade from the base of the columns to the top of the projecting cornice, with which they were surmounted, is about 38 feet. This court is not level, but has a considerable ascent towards the farthest side, which is effected by a series of low and very wide steps, extending the whole width of the quadrangle, and commencing at its entrance. The width of each step is that of a column and intercolumn, and the total rise is 56 feet. This alteration of level seems to have been introduced for the purpose of giving elevation to the grand portico which forms the farther side of the court, and consists of eighteen columns, in three rows of six each, placed one behind the other, and flanked on either side by a wall so as to resemble a Greek hexastyle in antis, with the exception that here there are three parallel rows one behind the other, while in Grecian temples there are never more than two. The portico, however, bears a greater resemblance to the propylæa of the Greeks, than to their temples, both being open in front, and enclosed on their other sides, having several rows of columns one behind the other. The columns in this portico, or pronaos, are loftier than those in the court below. and are surmounted like them with a projecting cornice. The spaces between the front row of columns are filled up to about half their height with a screen or dado, which gives the upper part of the intercolumn the appearance of a window. The middle intercolumn is treated in a somewhat different manner, the wall or screen being carried up somewhat higher, and advanced a little in front of the general line; the sides likewise being flanked with short columns, and the entrance to the pronaos being cut through the screen. In the wall at the further end of this first hall, is an entrance into a second of smaller dimensions, a space being taken off each side for passages. This hall is hypostyle, covered with a flat roof composed of thick slabs of stone, resting on large stone beams, which are supported again by twelve columns disposed in three rows of four each, closely set, so as to leave only narrow passages between them. From this hall we come into a chamber, having its greatest length in the width of the building, as also has the portico, and having entrances to the passages at the side of this chamber, and the hypostyle hall, from which access is obtained by means of steps to the top of the *sekos*. Beyond this is another similar chamber of smaller dimensions, having a cell on either side, supposed to have been for the priests. Entrance is obtained from this chamber into the sanctuary, which is a small covered chamber having its greatest length parallel with that of the main building; its size is about 33 feet by 17, and in it was placed the image of the deity. Round the two sides and further end of the sanctuary, is a passage, to which access is obtained from the second chamber, and round this again a larger area of similar shape, into which the smaller one led, and which gave access to the top of the sanctuary. In most instances, in front of the whole building, and a short distance in advance of the propylæa, were erected two obelisks of great height, and covered with hieroglyphics, and in front of them a long avenue, or *dromos*, as it is called, formed by two rows of sphinxes, placed at short intervals from each other, the space between the two rows forming a way or road to the temple. Strabo, the historian, who saw this temple we have been describing, alludes to this avenue—"Before the pillars or propylæa," says he, "is a paved road or avenue about 100 feet in breadth, or sometimes less, and in length from the entrance from 300 to 400 feet, or even more. This is called the dromos; through the whole length of which, and on each side of it, sphinxes are regularly placed at the distance of 30 feet from each other, which forms a double row on each side. Between the sphinxes you advance towards the temple, until you come to a large propylæum or triumphal entrance, through which you pass; and as you advance, you come to another propylæum, which you pass through; then to a third; and still keep passing on until you come to the entrance into the temple."

The above description, although of a particular example, will answer with but little alteration for any other temple, all such buildings being built on a similar plan, with but slight variations in particular instances. They all consist of a *sekos*, or sanctuary, of small dimensions, situate near one extremity of the building, surrounded on all sides with chambers, passages, and courts, and approached through a series of covered halls and colonnaded atria, the whole of the buildings being inclosed within an outer wall, and having a grand entrance flanked by two pyramidal moles. No matter to what date a building may belong, or what position it may occupy, the general form is the same, the only difference being in the size, and in the number of adjoining courts and buildings. In some cases, we have two or more propylæa, and courts preceding the temple, and sometimes avenues of columns crossing the courts in a line from the entrance. The temple at Luxor has as many as three courts, the first with a double peristyle, the second with a double range of columns extending throughout its length, and the third flanked by colonnades, each consisting of a double row of columns. To give some idea of the magnitude of this work, we may add, that in the second court, the columns were 56 feet high, and 11½ feet in diameter.

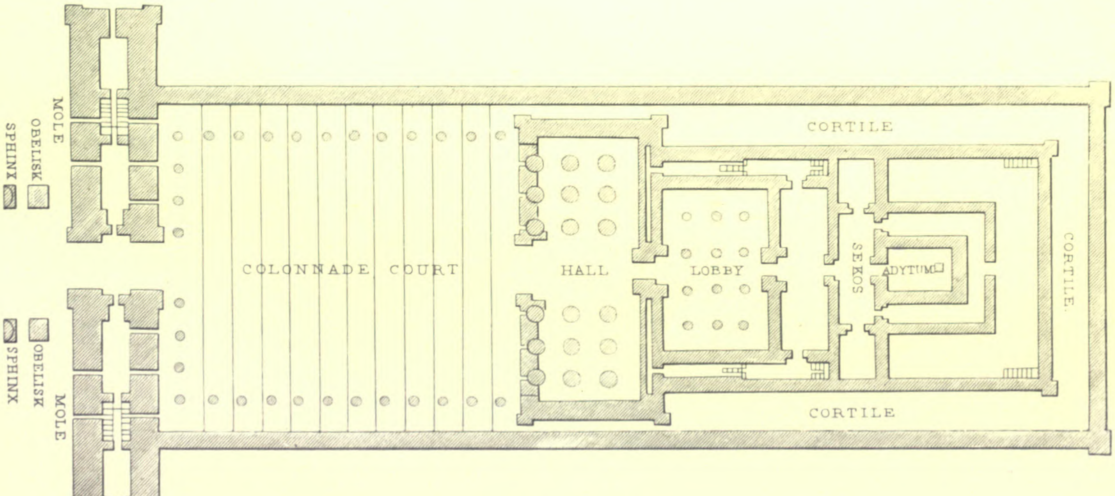
We now pass on to consider the elevation of such buildings more in detail. The contour of the elevation was pyramidal throughout; not only did the obelisks and propylæa present this appearance, but even the walls, spreading out at the base, and converging towards the apex, and as these formed the external face of the building, they gave the whole a pyramidal appearance, which doubtless adds considerably to the expression of strength, which is a marked characteristic of the style. The columns are the only parts of the building in which this form is not observable, their profile being for the most part vertical. This is just the reverse of Grecian architecture; for there the walls are vertical, and the columns sloping or conical, the general effect, however, is the same—pyramidal; for whereas in the Grecian buildings, the sloping columns are placed on the exterior, in those of Egypt the walls are external, surrounding the upright columns, so that the profile of the building, taken as a whole, is the same, although the arrangement is reversed.

An Egyptian order—if we may so apply the term—consists, like the Greek, of column and entablature, which parts we proceed to consider separately. Existing remains offer us examples of columns in great variety, differing in shape, proportions, and decoration, a few specimens only of which we can pretend to notice. The diversity observable in them is so great, that it would be futile to attempt a detailed classification; for examples which present similarities of form or decoration, differ in proportions, while those agreeing in the latter vary in many other particulars. As in other styles, the column consists of three members, base, shaft, and capital: the first, however, can scarcely be termed a distinct member, being in some cases scarcely recognizable, and in none forming a very prominent feature. It is usually a plain circular slab of stone or plinth, sometimes projecting from and at others flush with the face of the shaft, or of the same projection as the widest or bulging portion of the shaft, and

PLAN AND INTERIOR COURT OF EGYPTIAN TEMPLE AT EDFOU.

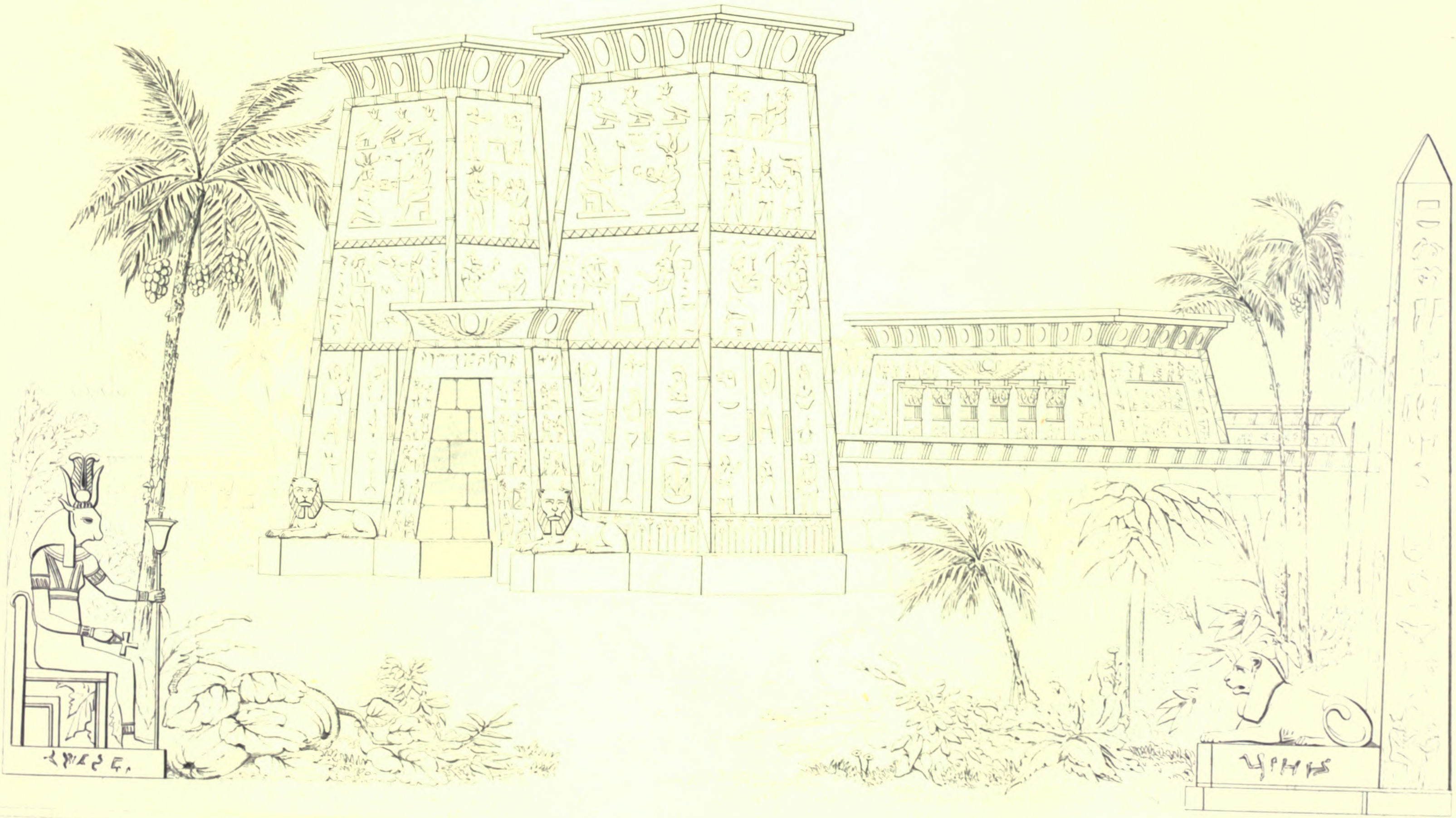


COURT OF THE TEMPLE.



GENERAL PLAN.

R. Brown Arch^t.



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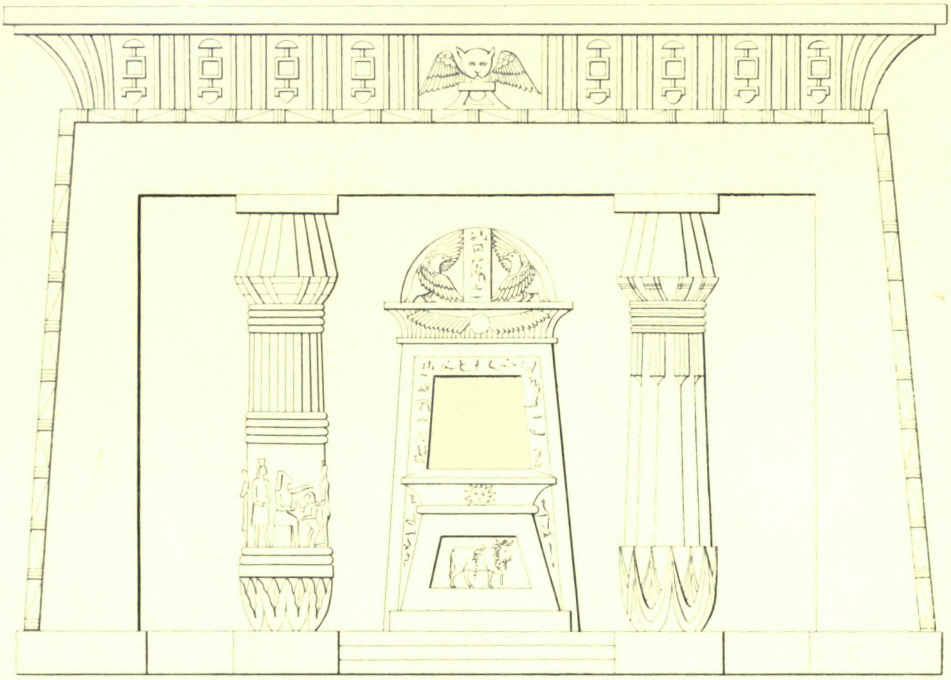
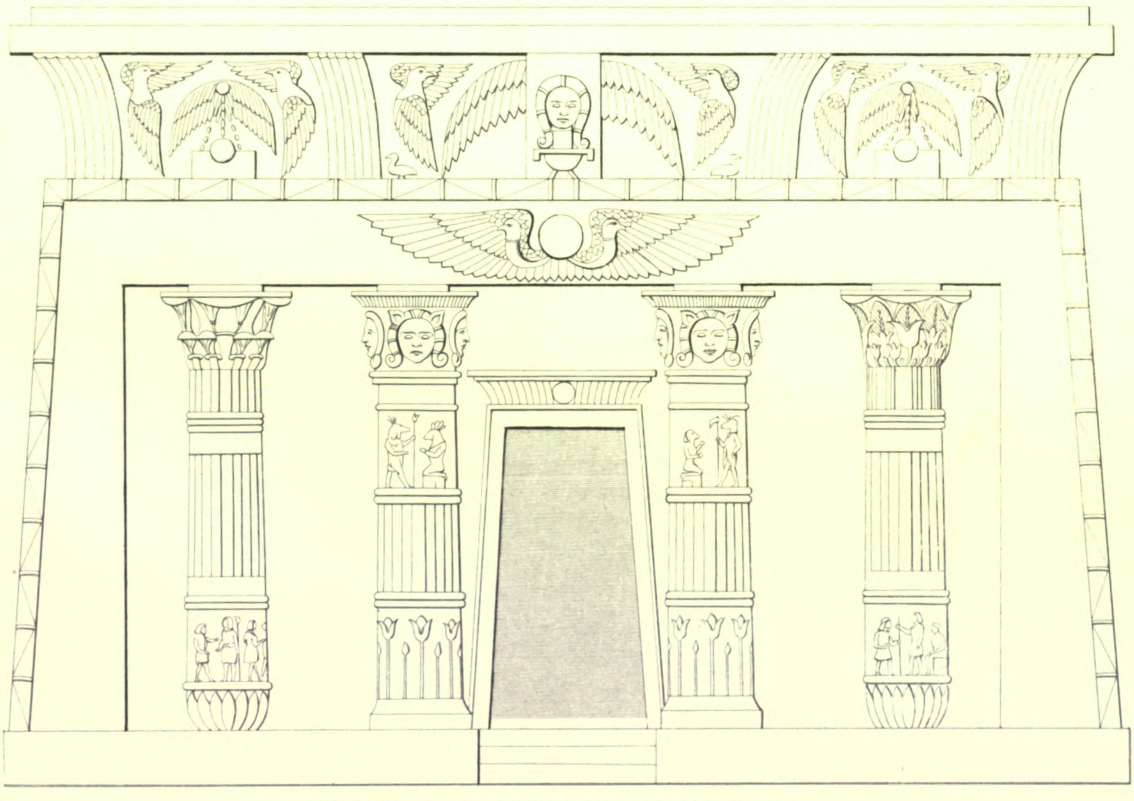
EGYPTIAN FACADES OF PORTICOS.



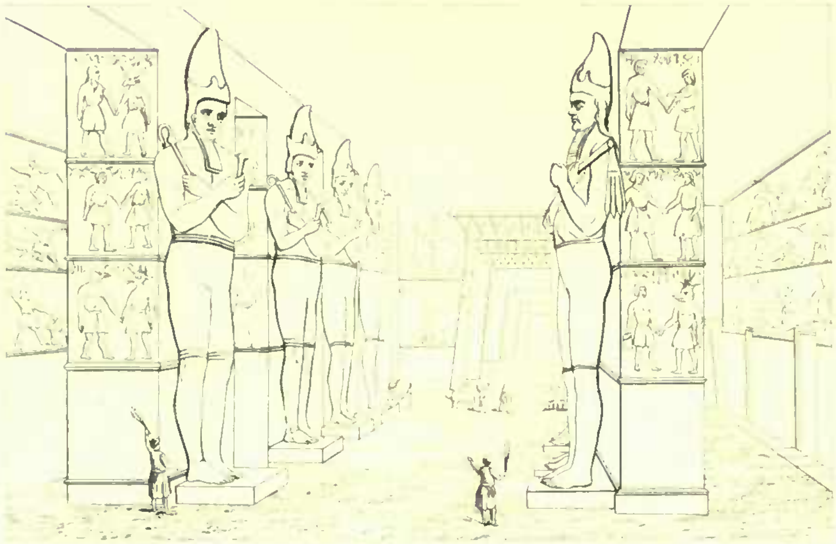
AN EGYPTIAN TEMPLE AND ALTAR OF OSIRIS



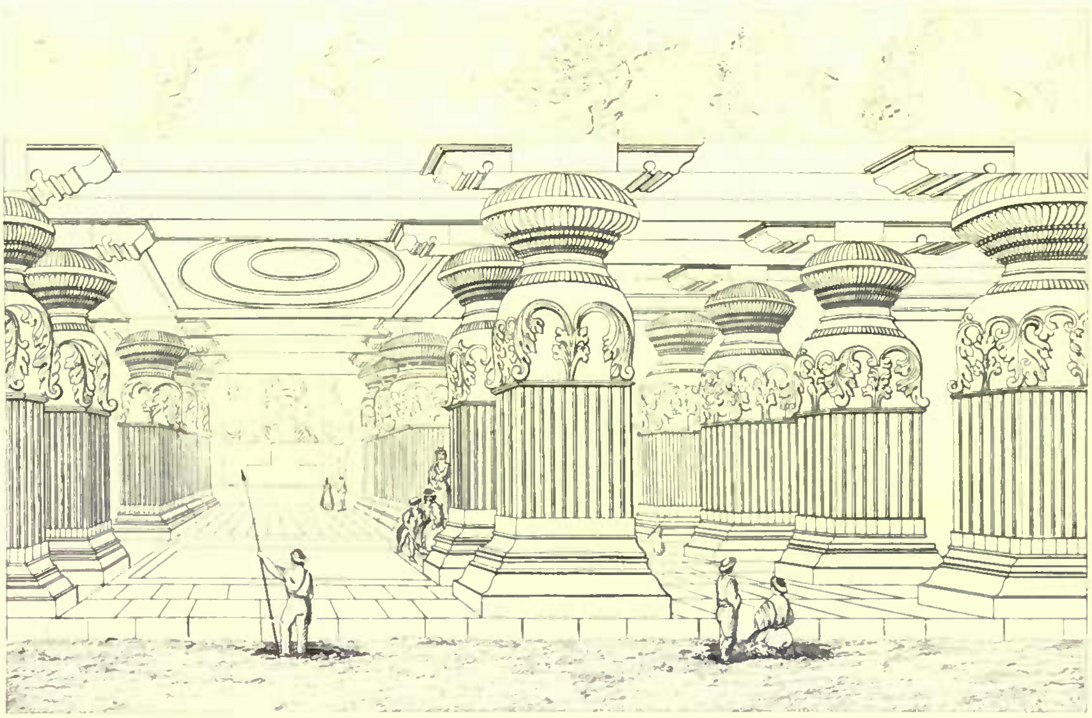
FACADE OF AN EGYPTIAN TEMPLE OF ISIS

R. Brown Archt. | R. Thew sc.

EGYPTIAN INTERIOR OF A TEMPLE AT IBSAMBAL.



HINDOO INTERIOR OF A TEMPLE AT ELLORA.



projecting forwards somewhat at their junction, where the shaft curves inwards.

The shafts present many variations, both in contour and decoration; their most usual form is that of a cylinder, or more nearly approaching the cylindrical than any other figure, there being frequently a slight difference between the upper and lower diameters. Sometimes the shaft contracted suddenly immediately above the base, the contour of this portion being curvilinear, and forming a tangent with the upper surface of the base, resembling in shape the calyx of a flower, the similarity to which is made the more remarkable by the leaves carved upon its surface. This last form can scarcely be recommended for its beauty; for in spite of the assertions of its admirers, it certainly does present an appearance of weakness. It is said that in such cases the judgment comes to the assistance of the senses, and corrects the eye, and that what is well known to be strong, cannot fairly be said to appear weak, and this is doubtless true to a certain extent; nevertheless, speaking abstractedly and artistically, this form is decidedly objectionable. In some instances, the columns slope downwards in a slight degree, similar to those of Greece. The cylindrical shafts are usually reeded, giving the surface the appearance of a number of staves or reeds placed round a common centre, or of a bundle of reeds, whence this kind of column has obtained the name of the *bundle pillar*. This resemblance is borne out by the fact, that such shafts are usually cinctured at intervals by bands consisting of three or more rings, which gives one the idea of a bundle of reeds bound round with reeds or rushes to preserve them in their position. These bands are sometimes of greater width, and have a plain surface, or one of the intervals between two bands is left blank, which again is often filled up with hieroglyphics or other ornaments. Specimens of reeded shafts of the different descriptions mentioned, are to be found at Beni-hassan, Hermontis, and Latopolis, and indeed in almost every locality; they are more prevalent than any other form. At other times, the reeds entirely disappear, the plain shaft being divided vertically into a number of compartments as before, by means of annulets or bands of reeds, and these compartments filled in with hieroglyphics; many elaborate examples of this kind are to be seen at Dendera.

Although cylindrical shafts are by far the most general, yet we occasionally meet with examples of a polygonal form, and sometimes with plain rectangular piers; a remarkable instance of the former exists at a temple at Eilethyas, on the right bank of the Nile, a few miles south of Esneh, where, in the interior of a large vestibule, the whole of the roof, as Mr. Barry informs us, is supported on polygonal columns of sixteen sides. Examples of the rectangular piers are described by the same writer as existing at Beni-hassan.

Instances of the employment of Caryatid figures in the place of columns are not unfrequent, they are placed in front of square piers, and do not bear the whole weight of the superincumbent mass, whic his mainly supported by the piers. Examples of this kind are to be found at Ramesseion, Thebes, and Ibsambal, on the banks of the Nile, between Egypt and Ethiopia. The pronaos of the last-named temple, according to Belzoni, is 57 feet long and 52 wide, supported by two rows of square pillars, each having a figure of Sesostris attached to it about 30 feet high, finely executed, and in good preservation. The pillars are five and a half feet square, and the sides are covered with hieroglyphics.

Of capitals, Egyptian architecture affords a vast variety, widely differing in form and character. One prevailing form is the bulging or bulbous capital, which projects from the shaft in a flat curve, but, instead of continuing to expand as it proceeds upwards, it recedes back, gradually diminishing in thickness, until at its junction with the abacus its diameter equals that of the shaft; the contour is similar to that which would be produced by a slightly yielding body pressed down by a superincumbent weight. Sometimes this capital exhibits a plain surface, only relieved by hieroglyphics arranged in horizontal rings, as at Kournon; at others, it is divided into eight or more compartments, or shafts, running vertically from top to bottom, and covered with hieroglyphics, or reeded, in which latter case another subdivision of shafts frequently takes place about half way up the capital, or the shafts are interrupted by one or more horizontal bands, either plain or covered with hieroglyphics, as at Latopolis. The simplest capital of this kind is where the reeds of the shaft are carried up without any interruption, with the exception of a band at the top of the shaft, underneath the bulge of the capital.

Another form of capital, which was frequently adopted, is the bell-shaped, resembling, in contour, an inverted bell, and covered with leaves, flowers, &c., or they may be said to resemble the bell and petals of a flower, the upper rim turning over, and bending downwards. This rim was sometimes perfectly circular, but at others divided into a number of convex curves, forming so many distinct petals. The lotus, papyrus, and palm seem to have been the favourite plants for introduction into this kind of capital, and so beautifully were they carved, as frequently to exhibit the most delicate and minute parts, such as the petals, pistyles, reeds, &c. Examples are to be found in almost every building; among others we may mention those of Hermontis, Latopolis, and Apollinopolis Magna, where there are some exquisite specimens; indeed, all the capitals of this form are exceedingly delicate and beautiful, of elegant form, and chaste enrichment. An example of somewhat similar character is given selected from the temple of Esneh, but in this case the contour is different, being convex instead of concave; the treatment, however, is similar, and the design good. Another capital is frequently introduced in the greater temples, which may be termed a double capital, the lowermost of which consists of four Isis' faces, disposed so as to form a square larger than the shaft, the folds of the head-dress on each side hanging down, and projecting beyond it at the corners. Above each face is a projecting abacus, with a concave face, and standing upon these, a square temple, which forms the second capital. Instances are likewise to be found of triple capitals, which consist of the last-mentioned double form placed above one of the bell-shaped kind. Another instance of a double capital is given, taken from the temple of Typhon, which consists of a rectangular block placed upon a bell-shaped capital, against each of the four sides of which sits an image of the god. Heads of animals are sometimes carved in the place of capitals, amongst which are those of the bull, which form is worthy of notice as approximating to the capitals found at Persepolis. Rarely we find columns without capitals, or with a simple rectangular block, which is little better than an abacus. The Egyptian abacus varies from the Grecian in being nothing more than a plain square plinth, of considerably smaller dimensions than the capital, and therefore receding from, not projecting over, as in classical architecture; indeed it scarcely forms a member of the capital at all, for, on account of its great depth behind the capital, it is scarcely visible, unless it be of extraordinary height; its purpose seems to be, to form a marked division between the column and entablature, and obviate that heaviness of appearance which would otherwise be occasioned. The bulging capitals form an exception to this rule, for in them the abacus projects, and overhangs the capital, the object of which is apparent from the peculiar shape of the capital; in this case it is usually ornamented with hieroglyphics or otherwise.

We have here referred to some few of the specimens of capitals which remain, and but a few, for there is a great variety, several of which may frequently be found in the same building: and even in the same hall, or other part of a building, may be seen capitals of different design though of the same general appearance, which circumstance is similar to that observable in Gothic buildings. The proportions vary in like manner; they seem to have had no settled rule as to design or proportion, which were purely matters of individual taste. The arrangement was generally picnostyle, especially in the covered halls, where they had to support large masses of stone, which were used for roofing.

The design for the entablature, on the contrary, seems to have been unalterable, for with the exception of some little diversity in the ornamentation, they are universally of the same form and character, and this is the case, however much buildings may differ as regards their columns. It comprises two parts only, the epistylium and the cornice, the former of which was flush with the walls underneath at each end of the colonnade, answering to the Greek antæ, with which likewise they are enclosed within a bold torus-moulding, and present a similar appearance to the architrave of a door being returned at the sides. The torus-moulding is a marked feature in Egyptian buildings, running up every angle of the building, and then returning on both sides underneath the cornice. The architrave is frequently plain, sometimes covered with hieroglyphics, but most frequently has a winged globe over the entrance in the centre, which is supposed to have been symbolical of the deity.

The cornice is a very prominent feature in this style, and is introduced as a crowning or finish in every situation, with or without the architrave: it is seen at the entrance of the temple, over the doorway and propylæa; within, over the colonnade and portico; and on the exterior, crowning the whole length of wall. It consists of but little more than a deep cove, but produces a great and beneficial effect by the bold shadow which it casts. The surface is divided into panels by an ornament similar to the Doric triglyph, or a band of three or more reeds placed side by side, with generally a narrow interval between each two; when, however, the band is composed of a greater number of reeds, they are placed close together. The metopes or panels are filled up with some kind of ornamentation. This formed the termination of the building, for the roof being flat, there was no such thing as the pediment, the finishing line was horizontal.

Let us return for a few moments to the column, the simplest form of which appears in an example at Beni-hassam, as figured by Mr. Barry, and in reference to which he says:

"The prototype would appear to have consisted of four large reeds of the Nile, placed upon an angular block, and tied together by cords near the top, forming thereby the capital. Small sticks are introduced between the reeds at the place of ligature, to render the figure of a more circular form, and afford the means of more firmly tying the whole together. The top is crowned by a square abacus, and the reeds being thereby confined, the effect of any incumbent weight upon them would be to produce the form."

A column similar to the above, but in a more forward state of development, is to be seen at the British Museum; it consists of double the number of reeds, placed together in the same manner, with similar base and abacus. But besides the difference as to number, there is in this example another variation in the method of joining shaft and base, the reeds in this case being turned under so as to meet the base in a curve, a form frequently adapted in more elaborate specimens.

The next change seems to have been the introduction of horizontal bands, which became requisite, as the reeds increased in number, to hold them firmly together; in some cases we find several bands, of one, two, or more reeds. The next step was to leave one or more of the spaces between the bands plain, and the next to cover it with hieroglyphics, till at last we find all the divisions of this description, at the Tentyris. The progress of the capital would seem to have been of a like nature; at first we find them composed of the same materials as the shaft, with only a band to mark the separation, and a flat square abacus at the top. The capital is, however, of a somewhat different contour, bulging out towards the lower end or ligature. In the second example we have adduced, the same form is preserved, but the capital and abacus, as well as the shaft, are covered with hieroglyphics. The next alteration would be similar to what took place in the case of the shaft: the capitals were divided horizontally into bands, as at Latopolis, and these again ornamented with hieroglyphics as at Kournou.

The bell-and-vase-shaped capitals are of an entirely different description, and cannot be said to have been a development of the above; they must have arisen from an entirely new adaptation of natural forms; while the above consists of mere reeds, the new form was an imitation of foliage and flowers belonging to that climate—the palm, the lotus, and the papyrus. The outline as well as the decoration of this kind of capital, deserves the highest praise for its taste, combining as it does the admirable properties of severity and grace, and will bear comparison with the best examples of classic design, not excepting the Corinthian, to which it bears a very remarkable resemblance, so much so as to give us reason to believe that the Romans were indebted to Egypt for the origin of their most admired order. Some specimens bear a slight resemblance to the Ionic; we may allude to that at Latopolis, but this is not so obvious, although we certainly have the upper part of the Ionic capital with its volutes repeated as a minor decoration.

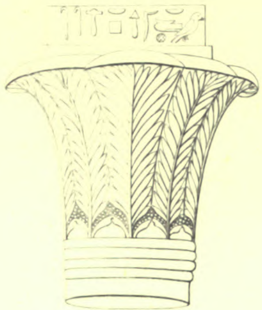
The square capitals, again, with a representation of the head of Isis or other deity on its four sides, form a third class, which seems to have had its origin in symbolism, or at any rate in the mysteries of religion; a supposition which is in some measure confirmed by the usual accompaniment of a temple.

There are some columns to be seen in Egypt of a very different description to any we have noticed, and to which Mr. Barry has called attention in a note appended to Mr. Gwilt's edition of Chambers; they bear a marked resemblance to the Grecian Doric, and are considered of earlier date than any existing specimen of that order. One illustration represents a portico of two fluted columns in antis, the flutes of which are shallow, and twenty in number, and the capital consists of an abacus only; the height of the column is about $5\frac{1}{2}$ diameters. Another striking example is found at Kalaptchie, on the borders of the Nile, in which, says Mr. Barry, "The abacus is square, and 11 inches thick; the shaft, which has a trifling diminution, is 7 feet 8 inches high, and 3 feet 2 inches diameter. The circumference is in 24 divisions, whereof 4, which are at right angles to each other, are flat faces covered with hieroglyphics, and the other intervening ones are sunk into flat elliptical flutes $\frac{1}{4}$-inch deep."

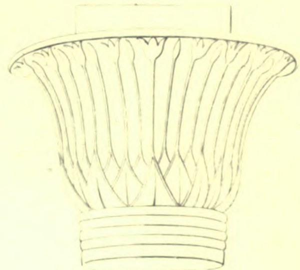
Another example is to be seen at Amada in Nubia, but here we have two different kinds adjoining each other, which throw some light upon the origin and purport of such columns. In this case the columns are but square piers with a slight projection at top and bottom, for abacus and base, not very different from those already described, as placed behind the Caryatid figures at Ipsambal; the pier at

EXAMPLES OF EGYPTIAN CAPITALS OF COLUMNS

FROM TEMPLE OF ACCLAOU



FROM TEMPLE OF APOLLONOPLIS



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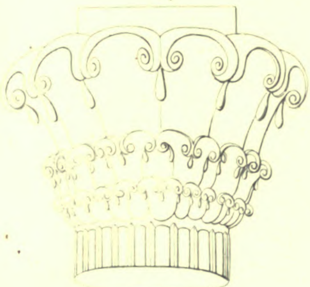
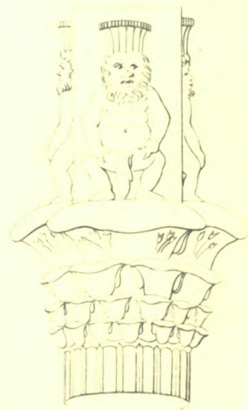


FROM TEMPLE OF LATOPOLIS



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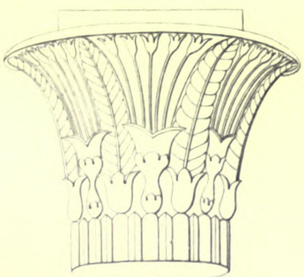

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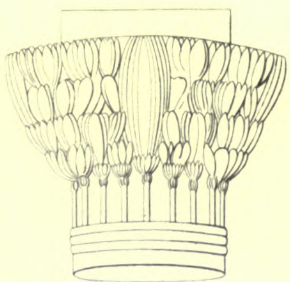
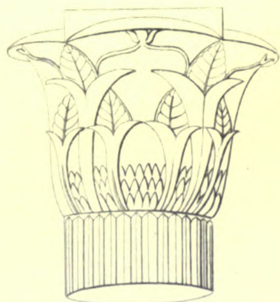


FROM TEMPLE OF ESNE



FROM TEMPLE OF HERMONTIS

R. Brown del.

the angle, however, presents a somewhat different appearance, for while the abacus and base remain as before, the shaft is both circular and fluted, the rounding of the angles seeming to have been effected as a matter of convenience, and the fluting as of ornament. We have already alluded to the not unfrequent occurrence of polygonal shafts, and we cannot help thinking that these, as well as the fluted examples just now described, find a common origin in the square pier of which they are all improvements. We are inclined to coincide with Mr. Barry in the following remarks:—"The general resemblance of the fluted columns to those of the Grecian Doric order, is manifest, and, in addition to many other remarkable indications in the Egyptian temple, clearly points to Egypt as the source of both Greek and Roman architecture." *See* Doric Order, Column.

Having now laid before the reader a general description of the elementary parts and details of Egyptian architecture, as well as of the usual form and distribution of their temples, it is our intention to give some more particular account of the more noted erections, and, in following out this scheme, we cannot do better than give the accounts of the various authorities in their own words.

The principal remains are to be found in Upper Egypt, in the cities lying on both sides of the Nile, but the spot in which they are most numerous and imposing, is in the neighbourhood of Thebes. The following is a list of the larger temples:—

Temple of Jupiter, at Karnac; of Jupiter Ammon; of Apollo, at Apollinopolis Magna; of Osiris, at Tentyra; of Venus; of Thebais, at Knubis. Temples at Luxor, Dendera, Edfou, Esneh, or Latopolis, Hermopolis, Ombos, Syene, Queron, Ipsambul; Caryatic temple, at Rhamesseion, and various temples in the islands of Philæ and Elephantina. In addition to which, we have the tombs and pyramids, the labyrinth, and various monuments, obelisks, and other isolated works.

We have already stated, that the grandest monuments are to be found at Thebes, and, of such, those of Karnac and Luxor take the pre-eminence; they form two separate erections, but are connected together by a long avenue of sphinxes, as hereafter mentioned. We select these two as subjects for the first description, the authorities being Denon and Wilkinson.

For a general description of the temple at Karnac, we shall refer to the French traveller, M. Denon, who, writing at the latter end of the last century (1798-9), says:—

"It is the sumptuousness alone of the Egyptians which is to be seen at Karnac, where not only quarries, but mountains, are piled together, and hewn out into massive proportions, the traits of which are as feebly executed, as the parts are clumsily connected; and these masses are loaded with uncouth bas-reliefs and tasteless hieroglyphics, by which the art of sculpture is disgraced. The only objects there which are sublime, both with regard to their dimensions and the skill which their workmanship displays, are the obelisks, and a few of the ornaments of the outer gates, the style of which is admirably chaste. If in the other parts of this edifice the Egyptians appear to us to be giants, in these latter productions they are geniuses. I am accordingly persuaded that these sublime embellishments were posteriorly added to the colossal monuments of Karnac. It must, however, be granted, that the plan of the temple is noble and grand. . . To the known descriptions of this great edifice of Karnac should be added, that it was but a temple, and could be nothing else. All that exists at present, in a somewhat entire state, relates to a very small sanctuary, and had been disposed in this way to inspire a due degree of veneration, and to become a kind of tabernacle. On beholding the vast extent of these ruins, the imagination is wearied with the idea of describing them. Of the 100 columns of the portico alone of this temple, the smallest are 7½ feet in diameter, and the largest 12. The space occupied by its circumvallation contains lakes and mountains. In short, to be enabled to form a competent idea of so much magnificence, it is necessary that the reader should fancy what is before him to be a dream, as he who views the objects themselves rubs his eyes to know whether he is awake. With respect to the present state of this edifice, it is, however, necessary, at the same time, to observe, that a great part of the effect is lost by its very degraded state. The sphinxes have been wantonly mutilated, with a few exceptions, which barbarism, wearied with destroying, has spared, and, on examining which, it is easy to distinguish, that some of them had a woman's head, others that of a lion, a ram, a bull, &c."

For the following more particular description of this temple, we are indebted to Sir I. G. Wilkinson.

"The principal entrance of the grand temple lies on the north-west side, or that facing the river. From a raised platform commences the avenue of Criosphinxes, leading to the front propyla, before which stood two granite statues of a Pharaoh. One of these towers retains a great part of its original height, but has lost its summit and cornice. In the upper part, their solid walls have been perforated through their whole breadth, for the purpose of fastening the timbers that secured the flag-staffs usually placed in front of these propyla; but no sculptures have ever been added to either face, nor was the surface yet levelled to receive them. Passing through the pylon of these towers, you arrived at a large open court, 275 feet by 329, with a covered corridor on either side, and a double line of columns down the centre. Other propyla terminate this area with a small vestibule before the pylon, and form the front of the grand hall, 170 feet by 329, supported by a central avenue of 12 massive columns, 66 feet high (without the pedestal and abacus), and 12 in diameter; besides 122 of smaller, or rather less gigantic dimensions, 41 feet 9 inches in height, and 27 feet 6 inches in circumference, distributed in seven lines on either side of the former. Other propyla close the inner extremity of this hall, beyond which are two obelisks, one still standing on its original site, the other having been thrown down and broken by human violence. A small propylon succeeds to this court, of which it forms the inner side; the next contains two obelisks of larger dimensions, being 92 feet high and 8 square, surrounded by a peristyle, if I may be allowed the expression, of Osiride figures. Passing between two dilapidated propyla, you enter another smaller area, ornamented in a similar manner, and succeeded by a vestibule, in front of the granite gateway of the pyramidal towers, which form the façade of the court of the sanctuary. This last is also of red granite, divided into two apartments, and surrounded by numerous chambers of small dimensions, varying from 29 feet by 16, to 16 feet by 8. A few polygonal columns, of the early date of Osirtesen I., the contemporary of Joseph, appear behind these in the midst of fallen architraves of the same era, and two pedestals of red granite crossing the line of direction in the centre of the open space to the south-east, are the only objects worthy of notice, until you reach the column or edifice of the third Thothmes. The exterior wall of this building is entirely destroyed, except on the north-east side; to it succeeds a circuit of thirty-two pillars, and within this square are twenty columns, disposed in two lines, parallel to the outer walls, and to the back and front row of pillars. Independent of the irregular position of the latter with regard to the columns of the centre, an unusual caprice has changed the established order of the architectural details, and capitals and cornices are reversed, without adding to the beauty or increasing the strength of the building. A series of smaller halls and chambers terminates the extremity of the temple, one of which is remarkable as containing the names of the early predecessors of Thothmes III., their founder. In the western lateral adytum are the vestiges of a colossal hawk seated on a raised pedestal; the sculptures within and without containing the name of Alexander, by whose order this was repaired and sculptured.

"The total dimensions of this part of the temple behind the inner propyla of the grand hall, are 600 feet, by about half that in breadth, making the total length, from the front propyla to the extremity of the wall of circuit, inclusive, 1,180 feet. The additions made at different periods, by which the distant portions of this extensive mass of buildings were united, will be more readily understood from an examination of the survey itself than from any description, however detailed, I could offer to the reader; and from this it will appear that Diodorous is fully justified in the following statement: that 'the circuit of the most ancient of the four temples at Thebes measured thirteen stadia,' or about one mile and two-thirds English; the thickness of the walls, 'of 25 feet,' owing to the great variety in their dimensions, is too vague to be noticed; but the altitude of the building, to which he allows only 45 cubits, falls far short of the real height of the grand hall, which, from the pavement to the summit of the roof, inclusive, is not less than 80 feet."

The next description of Luxor is from the same writer:—

"Luqsor, which occupies part of the site of ancient Diospolis, still holds the rank of a market-town, the residence of a Kàshef, and head-quarters of a troop of Turkish cavalry. Its name signifies the Palaces, and some might perhaps feel inclined to trace in that of El Qasryn, or El Uqsorayn, (the dual of the word Qasr,) by which it is sometimes designated, the existence of the two distinct parts of this building, erected by Amunoph III. and Remeses II. The former monarch, who, at the time of its foundation, appears to have reigned conjointly with his brother, built the original sanctuary and circumjacent chambers, with the addition of the large colonnade and pylon before it, to which Remeses II. afterwards added the great court, the pyramidal towers, or propyla, and the obelisks and statues.

"These, though last in the order of antiquity, necessarily form the present commencement of the temple, which, like many others belonging to different epochs, is not 'two separate edifices,' but one and the same building. A dromōs, connecting it with Karnak, extended in front of the two beautiful obelisks of red granite, whose four sides are covered with a profusion of hieroglyphics, no less admirable for the style of their execution, than for the depth to which they are engraved, which in many instances exceeds two inches.

"Two sitting statues of the same Remeses are placed behind these, one on either side of the pylon; but, like the obelisks, are much buried in the earth and sand accumulated around them. Near the north-west extremity of the propyla, another similar colossus rears its head amidst the houses of the village, which also conceal a great portion of the interesting battle-scenes on the front of these towers. At the doorway itself is the name of Sabaco, and on the abacus of the columns beyond, that of Ptolemy Philopater, both added at a later epoch.

"The area, whose dimensions are about 190 feet by 170, is surrounded by a peristyle, consisting of two rows of columns, now almost concealed by the hovels and mosk of the village. The line of direction no longer continues the same behind this court, the Remessean front having been turned to the eastward, in order to facilitate its connection with the great temple of Karnak, rather than to avoid the vicinity of the river, as might at first be supposed.

"Passing through the pylon of Amunoph you arrive at the great colonnade, where the names of this Pharaoh and his brother are sculptured. The latter, however, has been effaced, probably by order of the surviving monarch, as is generally the case wherever it is met with, and those of the immediate successor of Amunoph III. and of Osirei are introduced in its stead.

"The length of the colonnade to the next court is about 170 feet, but its original breadth is still uncertain, nor can it be ascertained without considerable excavation. To this succeeds an area of 155 feet by 167 surrounded by a peristyle of 12 columns in length and the same in breadth, terminating in a covered portico of 32 columns 57 feet by 111.

"Behind this is a space occupying the whole breadth of the building, divided into chambers of different dimensions, the centre one leading to a hall supported by 4 columns, immediately before the entrance to the isolated sanctuary.

"On the east of this hall is a chamber containing some curious sculpture, representing the accouchement of queen Maut-m-shoi, the mother of Amunoph and his brother; the two children nursed by the deity of the Nile, and presented to Amun, the presiding divinity of Thebes; and several other subjects relating to their education and subsequent history.

"The sanctuary, which had been destroyed by the Persians, was rebuilt by Alexander (the son of Alexander, Ptolemy being governor of Egypt,) and bears his name in the following dedicatory formula:

"'This additional work made he, the king of men, lord of the regions, Alexander, for his father Amunre, president of Tape (Thebes;) he erected to him the sanctuary, a grand mansion, with repairs of sand-stone, hewn, good, and hard stone, instead of his —— majesty, the king of men, Amunoph.' Behind the sanctuary are two other sets of apartments, the larger ones supported by columns, and ornamented with rich sculpture, much of which appears to have been gilded.

"Behind the temple is a stone quay, of the late era of the Ptolemies or Cæsars, since blocks bearing the sculpture of the former have been used in its construction. Opposite the corner of the temple, it takes a more easterly direction, and points out the original course of the river, which continued across the plain now lying between it and the ruins of Karnak, and which may be traced by the descent of the surface of that ground it gradually deserted. The southern extremity of this quay is of brick, and indicates in like manner the former direction of the stream, which now, having formed a recess behind it, threatens to sweep away the whole of its solid masonry, and to undermine the foundations of the temple itself.

The road to Karnak lies through fields of *halfeh* indicating the site of ancient ruins, and here and there, on approaching that magnificent building, the direction of the avenue, and the fragments of its sphinxes, are traced in the bed of a small canal, or watercourse, which the Nile, during the inundation, appropriates to its rising stream. To this succeeds another dromos of Criosphinxes, and a majestic pylon of Ptolemy Euergetes, with his queen and *sister* Berenice, who in one instance present an offering to their predecessors and parents, Philadelphus and Arsinöe. In one of the compartments within the doorway, the king is represented in a Greek costume, of which there are some other instances in Ptolemaic ruins. Another avenue of sphinxes extends to the propyla of the isolated temple behind this gateway, which was founded by Remeses IV., and continued by Remeses VIII., and a late Pharaoh, who added the hypæthral area and the propyla. His name, and the exact era at which he flourished, are not precisely ascertained; but if, as is very probable, we are authorized to read Bocchoris, this part will date in the time of the twenty-fourth dynasty, or about 810 B.C. Other names appear in different parts of the building, among which are those of Amyrteus and Alexander on the inner and outer gateways of the area."

Having made this digression in favour of Karnac and Luxor, we will now continue our descriptions, taking our examples in geographical order, commencing at the northern extremity of Upper Egypt, and travelling southwards. The first remains of which we have any notice are those of Hermopolis Magna, but they are little better than mounds of ruins, the portico described by Denon having been demolished. This portico was of great merit, and consisted of twelve columns in two rows of six each, surmounted with cornice and entablature. The next place we arrive at is Dendera, the ancient Tentyris, which contains ruins of several temples. The following account is given by Wilkinson.

"The name of Tentyris, or Tentyra, (in Coptic Tentoré, or Nikentore.) seems to have originated in that of the goddess Athor or Aphrodite, who was particularly worshipped there; and that the principal temple was dedicated to that goddess, we learn from the hieroglyphics, as well as from a Greek inscription of the time of Tiberius, in whose reign its magnificent portico was added to the original building. Egyptian sculpture had long been on the decline before the erection of this temple; and the Egyptian antiquary looks with little satisfaction on the graceless style of the figures, and the crowded profusion of ill-adjusted hieroglyphics, that cover the walls of Ptolemaic and Roman monuments; but architecture still retained the grandeur of an earlier period; and though the capitals of the columns were frequently overcharged with ornament, the general effect of the porticos erected under the Ptolemies and Cæsars, is grand and imposing, and frequently not destitute of elegance and taste. The same remarks apply to the temple of Dendera; and from its superior state of preservation, it deserves a distinguished rank among the most interesting monuments of Egypt. For though its columns, considered singly, may be said to have a heavy, and perhaps a grotesque, appearance, the portico is doubtless a noble specimen of architecture; nor is the succeeding hall devoid of beauty and symmetry of proportion. On the ceiling of the *pronaos*, or portico, is the Zodiac, which has led to much learned controversy, and which has at length, through the assistance of the Greek inscription, and the hieroglyphical names of the Cæsars that cover its exterior and interior walls, been confined to the more modest and probable antiquity of eighteen hundred years.

"The details of the cornice offer a very satisfactory specimen of the use of triglyphic ornament, which is common in many of the oldest Pharaohnic temples, though arranged in a somewhat different manner, and without so remarkable a metope as in the present instance.

"On the frieze, or rather architrave, is a procession to Athor, and among the figures that compose it are two playing the harp, and another with the tambourine. The inscription is on the projecting summit of the cornice, and commences with the name of the emperor Tiberius. Those of Aulus Avillius Flaccus, the military governor or prefect, and Aulus Fulmius Crispus, commander of the forces, though purposely erased, are still traced when the sun strikes obliquely on the surface of the stone; but the date of the emperor's reign is unfortunately lost.

"The small planisphere which was in one of the lateral chambers on the right-hand side of the temple, and behind the pronaos, has been removed to France, and from its position it probably dated a few years before the Zodiac. Numerous are the names of Cæsars in this temple. In the portico may be distinguished those of Tiberius, Caligula, Claudius, and Nero, and on the former front of the temple, now the back of the pronaos, are those of Augustus and Caligula. This was in fact the original extent of the building, and it was previous to the addition of the portico that it was seen by Strabo.

"The oldest names are of Ptolemy Cæsarion, or Neocæsar, and Cleopatra, who are represented on the back wall of the exterior; and it is probable that the whole *naos* was the work of the Ptolemies, though the sculptures remained unfinished till the reign of Tiberius, who, having erected the portico, added many of the hieroglyphics on the exterior walls.

"The portico is supported by twenty-four columns, and is open at the front, above the screens that unite its six columns; and in each of the side-walls is a small doorway.

"To this succeeds a hall of six columns, with three rooms on either side; then a central chamber, communicating on one side with two small rooms, and on the other with a staircase. This is followed by another similar chamber (with two rooms on the west, and one on the east side) immediately before the isolated sanctuary, which has a passage leading round it, and communicating with three rooms on either side. The total length of this temple is 93 paces (or about 220 feet,) by 41, or, across the portico, 50.

"In front of the temple was the dromos, extending for the distance of 110 paces to an isolated pylon, bearing the names of Domitian and Trajan. The attributes of Athor throughout this building very much resemble those of Isis; and she is in like manner represented nursing the young child Harpocrates, who is said, in the hieroglyphics, to be the 'son of Athor.'

"'Behind the temple of Venus,' says Strabo, 'is the chapel of Isis:' and this observation agrees remarkably well with the size and position of the small temple of that goddess; as it consists merely of one central and two lateral adyta, and a transverse chamber or corridor in front, and stands immediately behind the south-west angle of that of Athor. To it belonged the pylon that lies 170 paces to the eastward, and which, as we learn from a Greek inscription on either face of its cornice, was dedicated to Isis, in the thirty-first year of Cæsar (Augustus); Publius Octavius being military governor or prefect, and Marcus Claudius Posthumus, commander of the forces. In the hieroglyphics, besides the name of Augustus, are those of Claudius and Nero.

"Ninety paces to the north of the great temple of Athor is another building, consisting of two outer passage-chambers, with two small rooms on either side of the outermost one, and a central and two lateral adyta, the whole surrounded, except the front, by a peristyle of twenty-two columns. The capitals, ornamented or disfigured by the representation of a Typhonian monster, have led to the supposition that this temple was dedicated to the evil genius; but as the whole of its sculptures refer to the birth of Harpocrates, it is evident that it appertains to the great temple of Athor, who is here styled his mother; and it may be said rather to be dedicated to Harpocrates than to Typhon, who is only introduced in a subordinate character, as relating to the young deity. The names are of Trajan, Adrian, and Antoninus Pius.

"Around these buildings extends a spacious enclosure of crude brick, about 240 paces square, having two entrances, one at the pylon of Isis, the other at that before the great temple.

"About 230 paces in front of the pylon of Athor is an isolated hypæthral building consisting of fourteen columns, united by intercolumnar screens, with a doorway at either end; and a short distance to the south is the appearance of an ancient reservoir. A little to the north-east of it are other remains of masonry; but the rest of the extensive mounds of Tentyris present merely the ruins of crude brick houses, many of which are of Arab date.

"Five hundred paces east of the pylon of Isis is another crude brick enclosure, with an entrance of stone similar to the other pylons, bearing the name of Antoninus Pius. Over the face of the gateway is a singular representation of the sun, with its sacred emblem the hawk, supported by Isis and Nephthys. This enclosure is about 155 paces by 265, and at the south-east corner is a well of stagnant water.

"The town stood between this and the enclosure of the temples, and extended on either side, as well as within the circuit of the latter; but on the north-west side appear to be the vestiges of tombs.

"Between the town and the edge of the sandy plain to the south, is a low channel, which may once have been a canal; and it is not improbable that it was to this that the Tentyrites owed their insular situation mentioned by Pliny."

We next arrive at Kous, the site of the ancient Apollinopolis Parva, but the only distinguishable remains of the temple there consist of a large gate; proceeding therefore southward, we arrive at Thebes, the temples of which we have already described. On the opposite side of the river, however, we have several buildings worthy of note, of which the first is that of Qórneh or Kurnu, of which Wilkinson speaks thus:—

"To commence with the ruins nearest the river:—the first object worthy of notice is the small temple and palace at old Qórneh, dedicated to Amun, the Theban Jupiter, by Osirei, and completed by his son Remeses II., the supposed Sesostris of the Greeks. Its plan, though it evinces the usual symmetrophobia of Egyptian monuments, presents a marked deviation from the ordinary distribution of the parts which compose it. The entrance leads through a pyloné, or pylon, bearing, in addition to the name of the founder, that of Remeses III., beyond which is a dromos of 128 feet, whose mutilated sphinxes are scarcely traceable amidst the mounds and ruins of Arab hovels. A second pylon terminates this, and commences a second dromos of nearly similar length, extending to the colonnade or corridor in front of the temple, whose columns of one of the oldest Egyptian orders are crowned by an abacus, which appears to unite the stalks of waterplants that compose the shaft and capital.

"Of the intercolumniations of these ten columns, three only agree in breadth, and a similar discrepancy is observed in the doorways which form the three entrances to the building. The temple itself presents a central hall about fifty-seven feet in length, supported by six columns, having on either side three small chambers, one of which leads to a lateral hall, and the opposite one to a passage and open court on the east side. Upon the upper end of the hall open five other chambers, the centre one of which leads to a large room supported by four square pillars, beyond which was the sanctuary itself; but the dilapidated state of the north end of this temple affords but little to enable us to form an accurate restoration of the innermost chambers. The lateral hall on the west, which belonged to the palace of the king, is supported by two columns, and leads to three other rooms, behind which are the vestiges of other apartments; and on the east side, besides a large hypæthral court, were several similar chambers extending also to the northern extremity of its precincts."

The next building that attracts our notice is the Memnonium, and tomb of Osmandyas, of which ancient authors have given us such wonderful accounts; we give that of Diodorus Siculus:—

"Ten stadia from the tombs of the kings of Thebes," says this historian, "one admires that of Osimondué. The entrance to it is formed by a vestibule built with various-coloured stones. It is 200 feet long and 68 in elevation. On coming thence one enters under a square peristyle, each side of which is 400 feet long. Animals formed of blocks of granite 24 feet high, serve as columns to it, and support the ceiling, which is composed of squares of marble of 27 feet every way. Stars of gold, upon an azure ground, shine there the whole length of it. Beyond this peristyle opens another entry, followed by a vestibule built like the former, but more loaded with all sorts of sculpture. Before it are three statues formed of single stones, and hewn by Memnon Syenite. The principal one, which represents the king, is seated. It is the largest in Egypt; one of his feet, accurately measured, exceeds seven cubits. The two others, borne on his knees, one on the right, the other on the left, are those of his mother and his daughter. The whole work is less remarkable for its enormous size, than for the beauty of the execution and the choice of the granite, which in so extensive a surface has neither spot nor blemish. The colossus has this inscription:—'*I am Osimondué, the King of Kings; if any one wishes to know how great I am, and where I repose, let him destroy some of these works.*' Besides this, we see another statue of his mother, cut out of a single block of granite, and 30 feet high. Three queens are sculptured on the head, to show that she was daughter, wife, and mother, of a king.

"At the end of this portico, one enters into a peristyle more beautiful than the former. On a stone is engraved the history of the war of Osimondué against the revolted inhabitants of Bactria. The façade of the front wall shows this prince attacking ramparts, at the foot of which runs a river. He combats advanced troops, having by his side a terrible lion, which defends him with ardour. The wall on the right presents captives in chains, their hands and private parts cut off, in order to stigmatize their cowardice. On the wall to the left, different symbolical figures, very well sculptured, recall the triumphs and the sacrifices of Osimondué on his return from this war. In the middle of the peristyle, at the place where it is exposed, an altar was prepared, composed of a single stone of marvellous size, and of exquisite workmanship. In short, against the bottom wall, two colossuses, each of them of one block of marble, and 40 feet high, are seated on their pedestals. One comes out of this admirable peristyle by three gates; one of them between two statues, the two others are on the sides; they lead to an edifice 200 feet long, the roof of which is supported by 8 columns. It resembles a magnificent theatre; several figures in wood represent a senate employed in distributing justice. On one of the walls one observes 30 senators, and in the midst of them the president of justice, having at his feet a collection of books, and the figure of Truth with her eyes shut, suspended at his neck. One passed thence into a square surrounded by palaces of different forms, where were seen carved on the table all sorts of dishes which could flatter the taste. In one of them, Osimondué, clad in a magnificent dress, was offering to the gods the gold and silver he drew yearly from the mines of Egypt. Below was written the value of this revenue, which amounted to 32 millions of silver minas. Another palace contained the sacred library, at the entrance of which, one read these words: *Remedies for the Soul.* A third contained all the divinities of Egypt, with the king, who offered to each of them the suitable presents; calling Osiris, and the princes his predecessors, to witness that he had exercised piety towards the gods and justice towards men. By the side of the library, in one of the most beautiful buildings of the place, were to be seen twenty tables surrounded by their beds, on which reposed the statues of Jupiter, Juno, and Osimondué. His body is thought to be deposited in this place. Several adjoining buildings preserved the representations of all the sacred animals of Egypt. From these apartments one mounted to the king's tomb, on the top of which was placed a crown of gold, a cubit wide, and 365 round. Each cubit answered to one day of the year, and the rising and setting of the stars for that day was engraven on each of them, with such astrological observations as the superstition of the Egyptians attached to them. It is said that Cambyses carried off this circle when he ravaged Egypt. Such, according to historians, was the tomb of Osimondué, which surpassed all others, both by its extent, and by the labour of the able artists employed on it."

Upon this passage Savary remarks, "I dare not take upon me to warrant all these facts, advanced by Diodorus Siculus on the authority of preceding writers; for in his time the principal part of these buildings no longer existed. I admit even that all these wonderful descriptions would pass for pure chimeras in any other country; but in this fruitful land, which seems to have been first honoured with the creative genius of the arts, they acquire a degree of probability. Let us examine what remains to us of these monuments, and our eyes will compel us to believe in prodigy. Their ruins are in heaps, near to *Medinet Abou*, in the space of half a league's circumference. The temple, the peristyles, the vestibules, present to the eye nothing but piles of ruins, amongst which rise up some pyramidal gates, whose solidity has preserved them from destruction; but the numerous colossuses described by Diodorus, are still subsisting, though mutilated. That which is nearest to these ruins, composed of yellow marble, is buried two-thirds of its height in the earth. There is another in the same line, of black and white marble, the back of which is covered with hieroglyphics for 30 feet in length. In the space betwen them, trunks of columns and broken statues cover the ground, and mark the continuation of the vestibules. Farther on we distinguish two other colossal statues, totally disfigured. A hundred toises from them, the traveller is struck with astonishment at the sight of two colossuses, which, like rocks, are seated by the side of each other. Their pedestals are nearly equal, and formed of blocks of granite 30 feet long, and 18 feet wide. The smallest of these colossuses is also of a single block of marble; the other, which is the largest in Egypt, is formed of five courses of granite, and broken in the middle; it appears to have been the statue of Osimondué, for one sees two figures cut in *relievo*, the length of his legs, and which are about one-third of his height. These are the mother and the daughter of this prince. The other colossus, which is of one stone, and which corresponds with the dimensions of Diodorus Siculus, represented also the mother of the king. To give you an idea of the gigantic stature of the great colossus, it is enough to tell you, that his foot alone is near 11 feet long, which answers exactly to the seven cubits of Diodorus. This statue, the half of which remains upon its base, and is what Strabo calls the statue of Memnon, uttered a sound at the rising of the sun. It possessed formerly great renown. Several writers have spoken of it with enthusiasm, regarding it as one of the seven wonders of the world. A multitude of Greek and Latin inscriptions, that are still legible, on the base and the legs of the colossus, testify that princes, generals, governors, and men of every condition, have heard this miraculous sound."

The following account of a portion of the above, which is given somewhat more in detail, is from Wilkinson.

"Following the edge of the cultivated land, and about 180 yards to the west of this building, are two mutilated statues of Remeses II., of black granite, with a few substructions to the north of them; and 770 yards farther to the west, lies, in the cultivated soil, a sandstone block of Remeses III., presenting in high relief the figure of that king, between Osiris and Pthah; 1,400 feet beyond this, in the same direction, is a crude brick enclosure, with large towers, which once contained within it a sandstone temple, dating probably from the reign of the third Thothmes, whose name is stamped on the bricks, and who appears to have been the contemporary of Moses.

"Other fragments and remains of crude brick walls proclaim the existence of other ruins in its vicinity; and about 1,000 feet farther to the south-west, is the palace and temple of Remeses II., erroneously called the Memnonium: a building which, for symmetry of architecture and elegance of sculpture, can vie with any other monument of Egyptian art. No traces are visible of the dromos, that probably existed before the pyramidal towers which form the façade of the first hypæthral area, a court whose breadth of 180 feet, exceeding the length by nearly 13 yards, is reduced to a more just proportion, by the introduction of a double avenue of columns on either side, extending from the towers to the north wall. In this area, on the right of a flight of steps leading to the next court, was the stupendous Syenite statue of the king seated on a throne, in the usual attitude of these Egyptian figures, the hands resting on his knees, indicative of that tranquillity which he had returned to enjoy in Egypt, after the fatigues of victory. But the fury of an invader has levelled this monument of Egyptian grandeur, whose colossal fragments lie scattered around the pedestal, and its shivered throne evinces the force used for its demolition.

"If it is a matter of surprise how the Egyptians could transport and erect a mass of such dimensions, the means employed for its ruin are scarcely less wonderful; nor should we hesitate to account for the shattered appearance of the lower part by attributing it to the explosive force of powder, had that composition been know at the period of its destruction. The throne and legs are completely destroyed, and reduced to comparatively small fragments, while the upper part, broken at the waist, is merely thrown back upon the ground, and lies in that position which was the consequence of its fall; nor are there any marks of the wedge, or other instrument, which should have been employed for reducing those fragments to the state in which they now appear. The fissures seen across the head, and in the pedestal, are the work of a later period, when some of these blocks were cut for millstones by the Arabs, but its previous overthrow will probably be coeval with the Persian invasion. To say that this is the largest statue in Egypt, will convey no idea of the gigantic size or enormous weight of a mass, which, from an approximate calculation, exceeded, when entire, nearly three times the solid content of the great obelisk of Karnak, and weighed about 887 tons, 5 hundredweight and a half.

"No building in Thebes corresponds with the description given of the tomb of Osymandyas by Hecatæus. Diodorus, who quotes his work, gives the dimensions of the first or outer court, two plethra, or 181 feet 8 inches English, agreeing very nearly with the breadth, but not the length of that now before us; but the succeeding court, of four plethra, neither agrees with this, nor can agree with that of any other Egyptian edifice; since the plan of an Egyptian building invariably requires a diminution, by no increase of dimensions, from the entrance to the inner chambers; and while the body of the temple, behind the portico, retained one uniform breadth, the areas in front, and frequently the portico itself, exceeded the inner portion of it by their projecting sides. The peristyle and 'columns in the form of living beings,' roofed colonnade, sitting statues, and triple entrance to a chamber supported by columns, agree well with the approach to the great hall of this temple. The largest statue in Egypt can scarcely be looked for but in the building before us, yet the sculptures to which he alludes, remind us rather of those of Medeenet Hábo; nor is it impossible that either Hecatæus or Diodorus have united or confounded the details of these two edifices.

"The second area is about 140 feet by 170, having on the south and north sides a row of Osiride pillars, connected with each other by two lateral corridors of circular columns. Three flights of steps lead to the northern corridor behind the Osiride pillars, the centre one having on each side a black granite statue of Remeses II., the base of whose throne is cut to fit the talus of the ascent. Behind these columns, and on either side of the central door, is a limestone pedestal, which, to judge from the space left in the sculptures, must have once supported the sitting figure of a lion, or perhaps a statue of the king. Three entrances thence open into the grand hall, each strengthened and beautified by a sculptured doorway of black granite, and between the two first columns of the central avenue, two pedestals supported (one on either side) two other statues of the king. Twelve massive columns form a double line along the centre of this hall, and eighteen of smaller dimensions, to the right and left, complete the total of the forty-eight which supported its solid roof, studded with stars on an azure ground. To the hall, which measures 100 feet by 133, succeeded three central and six lateral chambers, indicating, by a small flight of steps, the gradual ascent of the rock on which this edifice is constructed. Of nine, two only of the central apartments now remain, each supported by four columns, and each measured about 30 feet by 55; but the vestiges of their walls, and appearance of the rock, which has been levelled to form an area around the exterior of the building, point out their original extent. The sculptures, much more interesting than the architectural details, have suffered still more from the hand of the destroyer; and of the many curious battle-scenes which adorned its walls, four only now remain."

Still southward is the village of Medeenet Haboo, which contains the ruins of two temples, of which we have not space to give a particular account. The smaller one consists of an open area 125 feet by 80, the north side being formed of a row of eight columns, through which access is obtained to a transverse area, having two pyramidal towers at its extremity, and between them an entrance into an hypæthral court with similar towers. These lead into a court 60 feet long, with a colonnade on either side, and at its extremity an entrance into the sanctuary, which is surrounded by colonnades and chambers. The larger edifice is approached through a dromos 265 feet in length, at the end of which are two propylæa leading into a large hypæthral court. At the further side of this court an entrance through pylons is given into a very fine peristyle court 123 feet by 133 feet, at the extremity of which is the portico. The large court contains specimens of Caryatid columns.

We now arrive at a different class of buildings—the tombs or catacombs, which consist of subterranean apartments and passages excavated out of the rock, and extending over a vast tract of land in the neighbourhood of Thebes, near Kurnu. The two following descriptions are from the writer previously quoted; the first relates to one of the tombs of the kings, which was first opened by Belzoni:—

"The tomb, which of all others stands pre-eminently conspicuous, as well for the beauty of its sculpture as the state of its preservation, is undoubtedly that discovered and opened by Belzoni. But the plan is far from being well regulated, and the deviation from one line of direction greatly injures its general effect; nor does the rapid descent by a staircase of twenty-four feet in perpendicular depth, on a horizontal length of twenty-nine, convey so appropriate an idea of the entrance to the abode of death, as the gradual talus of other of these sepulchres. To this staircase succeeds a passage of eighteen feet and a half by nine, including the imposts; and, passing another door, a second staircase descends in horizontal length twenty-five feet; beyond which two doorways, and a passage of twenty-nine feet, bring you to an oblong chamber twelve feet by fourteen, where a pit, filled up by Belzoni, once appeared to form the utmost limit of the tomb. Part of its inner wall was composed of blocks of hewn stone, closely cemented together, and covered with a smooth coat of stucco, like the other walls of this excavated catacomb, on which was painted a continuation of those subjects that still adorn its remaining sides.

"Independent of the main object of this well, so admirably calculated to mislead, or at last check, the search of the curious and the spoiler, another advantage was thereby gained in the preservation of the interior part of the tomb, which was effectually guaranteed from the destructive inroad of the rain-water, whose torrent its depth completely intercepted; a fact which a storm, some years ago, by the havoc caused in the inner cambers, sadly demonstrated.

"The hollow sound of the wall above-mentioned, and a small aperture, betrayed the secret of its hidden chambers, and a palm-tree, supplying the place of the more classic ram, forced, on the well-known principle of that engine, the intermediate barrier, whose breach displayed the splendour of the succeeding hall, at once astonishing and delighting its discoverer, whose labours were so gratefully repaid.

"Its four pillars, supporting a roof twenty-six feet square, are decorated, like the whole of the walls, with highly-finished and well-preserved sculptures, which, from their vivid colours, appear but the work of yesterday; and near the centre of the inner wall, a few steps lead to a second hall of similar dimensions, supported by two pillars, but left in an unfinished state, the sculptors not having yet commenced the outline of the figures the draughtsmen had but just completed. It is here that the first deviations from the general line of direction occur, which are still more remarkable in the staircase that descends at its southern corner.

"To this last succeed two passages, and a chamber seventeen feet by fourteen, communicating by a door, *nearly* in the centre of its inner wall, with the grand hall, which is twenty-seven feet square, and supported by six pillars. On either side is a small chamber opposite the angle of the first pillars, and the upper end terminates in a vaulted saloon, nineteen feet by thirty, in whose centre stood an alabaster sarcophagus, the kenotaph of the deceased monarch, upon the immediate summit of an inclined plane, which, with a staircase on either side, descends into the heart of the argillaceous rock for a distance of a hundred and fifty feet. This, like the entrance of the tomb and the first hall, was closed and concealed by a wall of masonry, which, coming even with the base of the sarcophagus, completely masked the staircase it covered and levelled with the floor.

"A small chamber and two niches are perforated in the north-west wall; at the upper end a step leads to an unfinished chamber, 17 feet by 43, supported by a row of four pillars; and on the south-west are other niches and a room about 25 feet square, ornamented with two pillars and a broad bench (hewn, like the rest of the tomb, in the rock) around three of its sides, four feet high, with four shallow recesses on each face, and surmounted by an elegant Egyptian cornice. It is difficult to account for the purport of it, unless its level summit served as a repository for the mummies of the inferior persons of the king's household; but it is more probable that these were also deposited in pits.

"The total horizontal length of this catacomb is 320 feet, without the inclined descent below the sarcophagus, and its perpendicular depth 90, or, including that part, about 180 feet, to the spot where it is closed by the fallen rock."

The second description is of tombs of more recent date, executed during the twenty-sixth dynasty, in the seventh century before our era; they are of great extent, and unusual uniformity.

"The smallest, which are those behind the palace of Remeses, commence with an outer court decorated by a peristyle of pillars, and to this succeeds an arched entrance to the tomb itself, which consists of a long hall, supported by a double row of four pillars, and another of smaller dimensions beyond it, with four pillars in the centre. The largest of them, and indeed of *all* the sepulchres of Thebes, are those in the Assaseef, one of which far exceeds in extent any one of the tombs of the kings. Its outer court, or area, is 103 feet by 76, with a flight of steps descending to its centre from the entrance, which lies between two massive crude brick walls, once supporting an arched gateway. The inner door, cut like the rest of the tomb in the limestone rock, leads to a second court, 53 feet by 67, with a peristyle of pillars on either side, behind which are two closed corridors; that on the west containing a pit and one small square room, the opposite one having a similar chamber, which leads to a narrow passage, once closed in two places by masonry, and evidently used for a sepulchral purpose.

"Continuing through the second area you arrive at a porch, whose arched summit, hollowed out of the rock, has the light form of a small segment of a circle, and from the surface of the inner wall are relieved the cornice and mouldings of an elegant doorway.

"This opens on the first hall, 53 feet by 37, once supported by a double line of four pillars, dividing the nave (if I may so call it) from the aisles, with half-pillars, as usual, attached to the end-walls. Another ornamented doorway leads to the second hall, 32 feet square, with two pillars in each row, disposed as in the former. Passing through another door, you arrive at a small chamber, 21 feet by 12, at whose end-wall is a niche, formed of a series of jambs, receding successively to its centre. Here terminates the first line of direction. A square room lies on the left (entering), and on the right another succession of passages, or narrow apartments, leads to two flights of steps, immediately *before* which is another *door* on the right. *Beyond* these is another passage, and a room containing a pit 45 feet deep, which opens at about one-third of its depth on a lateral chamber.

"A third line of direction, at right angles with the former, turns to the right, and terminates in a room, at whose upper end is a squared pedestal.

"Returning through this range of passages, and re-ascending the two staircases, the *door* above alluded to presents itself on the left hand. You shortly arrive at a pit (opening on another set of rooms, beneath the level of the upper ground-plan), and after passing it, a large square, surrounded by long passages, arrests the attention of the curious visitor. At each angle is the figure of one of the eight following goddesses:—Neith, Sate, Isis, Nephthys, Netpe, Justice, Selk, and Athor, who, standing with outspread arms, preside over and protect the sacred inclosure, to which they front, and are attached.

"A gentleman, an author, whose reading is far more respectable than his judgment, has not failed to discover something extraordinary in the position of these figures, referring, as he supposes, to the crucifix, adopted by the Christians.

"Eleven niches, in six of which are small figures of different deities, occur at intervals on the side-walls, and the summit is crowned by a frieze of hieroglyphics. Three chambers lie behind this square, and the passage which goes round it *descends* on that side, and rejoins, by an *ascending* talus on the next, the level of the front. A short distance further terminates this part of the tomb, but the above-mentioned pit communicates with a subterranean passage opening on a vaulted chamber, from whose upper extremity another pit leads, *downwards*, to a second, and ultimately through the ceiling of the last, *upwards*, to a third apartment, coming immediately below the centre of the square above noticed. This has one central niche, and seven on either side, the whole loaded with hieroglyphical sculptures, which cover the walls in every part of this extensive tomb.

"But to give an idea of its length, and, consequently, of the profusion of its ornamental details, I shall briefly state the total extent of each series of the passages both in the upper and under part of the excavation. From the entrance of the outer area to the first deviation from the original right line, is 320 feet. The total of the next range of passages to the chamber of the great pit, is 177 feet. The third passage, at right angles to this last, is 60 feet; that passing over the second pit, is 125; and adding to these three of the sides of the isolated square, the total is 862 feet, independent of the lateral chambers.

"The area of the actual excavation is 22,217 square feet, and with the chambers of the pits 23,809, though, from the nature of its plan, the ground it occupies is nearly one acre and a quarter, an immoderate space for the sepulchre of one individual, even allowing that the members of his family shared a portion of its extent."

At Hermontis, a short distance south of Thebes, are the ruins of a small temple, consisting of a colonnaded court with portico and sanctuary, and some distance beyond this, more extensive remains at Esneh, or Latopolis, but the only portion uncovered is a portico of considerable pretensions. Passing by several monuments more or less remarkable, we arrive at Edfou, or Apollinopolis Magna, the temple of which has already been described; and beyond this, at Ombos, where are ruins of two temples, one of which is remarkable for having a double entrance, and two sanctuaries side by side. In our way to the islands of Philöe and Elephantina, we would stop for a moment at Syene to notice the quarries of granite from which a great portion of the stone for building was supplied, previous to the working of the quarries near Philöe. The islands of Philöe and Elephantina are rich in remains, but more especially the former, which we accordingly select for illustration. Denon says:—

"As soon as I could set foot in the island (Philöe) I began first by going over all the inner part, to take a general survey of the various monuments, and to form a kind of topographical chart, containing the island, the course of the river, and the adjacent characteristic scenery. I found a convincing proof that this group of monuments had been constructed at different periods, by several nations, and had belonged to different forms of religious worship; and the union of these various edifices, each of them in itself regular, and crowded together in this narrow spot, formed an irregular group of most picturesque and magnificent objects. I could here distinguish eight sanctuaries or separate temples, of different dimensions, built at various times, and the limits of each had been respected in the construction of the succeeding ones, which had impaired the regularity of the whole. A part of the additions to the original buildings had been made with a view of connecting the old to the new, avoiding, with great dexterity, false angles and general irregularities. This kind of confusion of the architectural lines, which appear like errors in the plan, produce in the elevation a picturesque effect, which geometrical rectitude cannot give; it multiplies objects, forms elegant groups, and offers to the eye more richness than cold symmetry can ever command. I was here able to convince myself of the truth of a remark which I had before made at Thebes and Tentyra, which is, that the mode of building with the ancient Egyptians was, first, to erect large masses, on which they afterwards bestowed the labour of ages in the particulars of the decoration, beginning their work with shaping the architectural lines, proceeding next to the sculpture of the hieroglyphics, and concluding with the stucco and the painting. All these distinct periods of work are very obvious here, where nothing is finished but what belongs to the highest antiquity; where, as a part of the subordinate buildings which served to connect the various monuments, had been left in many particulars without finish, without sculpture, and even incomplete in the building. The great and magnificent oblong monument exhibits these different periods of workmanship; it would be difficult to assign any use to this edifice, if the presence of certain monuments representing offerings, had not pointed it out to be a temple. It has, however, the form neither of a portico, nor of a temple; the columns which compose its outer circumference, and which are engaged in the wall only half their height, support nothing but an entablature, and a cornice without roof or platform; it only opened by two opposite doors, without lintels, which made a straight passage through, in a longitudinal direction. As it was doubtless built in the later period of the Egyptian power, it shows the perfection of art in the highest purity; the capitals are admirable in beauty and execution; the volutes and the foliage are gracefully waved, like the finest Greek architecture, and are symmetrically diversified like those of Apollinopolis, that is to say, differing from the contiguous capitals, and similar to the corresponding ones, and all are exactly kept within the same parallel."

This group of buildings is 800 feet long and 420 feet broad, and it is almost entirely covered with the most stately monuments of different ages. The front is a rampart wall, to serve as a protection against the rising waters of the Nile. The entrance to the temple was approached by a magnificent double range of columns around a court 250 feet long, behind which were rooms for the priests. The pyramidal môles are each 47 feet long, 27 feet thick, and 75 feet high; two rows of gigantic hieroglyphics adorn them, representing five of their grand divinities; there are likewise other figures of priests, &c.; on each side of the door (which is 26 feet high) is an obelisk 18 feet high, and a sphinx 7 feet long. Behind is a court 80 feet long, and 45 feet wide, also flanked by galleries of columns. On the right, behind the columns, is a suite of cells 10 feet deep, and on the left a private dwelling, composed of a portico at each end, and of three rooms of various dimensions, communicating one with another, and opening to the porticos; this is the only building that Denon ever saw of the kind. Two other môles serve as the portal to the most beautiful and regular part of the edifice; this is a species of portico, decorated by 10 columns and 8 pilasters 4 feet in diameter, as magnificent as they are elegant; the columns and walls are covered with sculptures, the ceilings are either painted in astronomical tables, or with white stars on an azure ground. Beyond this again was the secret part of the temple, 60 feet by 30, divided into four rooms, one leading to the others; in these remote chambers it is supposed that the sacred birds and reptiles were kept.

"Besides this vast enclosure, in which these numerous temples were connected and grouped together by dwellings for the priests, there were two temples standing apart; the larger of the two I have already spoken of, the smaller is one of the most beautiful that can be conceived, in perfect preservation, and so small, that it almost gives one the desire of carrying it away. I found within it some remains of a domestic scene, which seemed to be that of Joseph and Mary, and suggested to me the subject of the flight into Egypt in a style of the utmost truth and interest."

We have now described several of the principal monuments belonging to this style of architecture, from which may be formed a very fair idea of the Egyptian method of arranging and adorning their temples. We have not touched upon the pyramids, although the subject can scarcely be said to be completed without some description of them; we have, however, already extended this article to a somewhat inconvenient length, and would rather defer their consideration to a later period, than treat them here in a summary and insufficient manner. The same reasoning applies to the description of the sphinxes, and such like. We refer the reader, therefore, to the articles under the heads Pyramid and Sphinx.

The subject we have been treating of is one of very considerable interest, and, although not of direct practical utility to the architect, is yet well worthy his careful consideration.

Egyptian-Hall, or Banqueting-Rooms. *See* Œcus.

Egyptian Pyramids. *See* Pyramids.

EIDOGRAPH, an instrument for copying designs, invented by Professor Wallace, of Edinburgh. The eidograph is an improvement on the pentagraph in common use, is much more correct, and can be used for purposes to which the latter cannot be applied.

EIDOLON, a likeness, image, or representation.

ELBOWS of a Window, the two flanks of panelled work, one under each shutter, generally tongued or rebated into the back, so that the two elbows and the back form a lining round the three sides of the recess.

ELEOTHESION, the anointing-room, belonging to the palestræ, called by the Romans *unctuarium*. *See* Palestræ.

ELEVATION, an orthographical projection, made on a plane perpendicular to the horizon. In architecture, as buildings are constructed with vertical faces or fronts, the plane of delineation is generally chosen parallel to a side, in order that the measure in every direction may be readily obtained. What is generally called a section, partakes as much of a geometrical projection or elevation, as a section. By the elevations and plans, all the measures of an original object may be ascertained, whether the lines or arrises represented be horizontal, vertical, or inclined. In orthographical projections, all straight lines perpendicular to the plane of delineation are projected into points, and all straight lines parallel to the plane of delineation, are projected into straight lines of equal lengths, and are alike situated with regard to the plane of delineation, as the straight arris in the original object is with regard to the naked face of the wall. Therefore, whatever lines are perpendicular to the elevation, they will be represented by points, and whatever arrises are parallel to the elevation, they will be represented by lines parallel to the original. *See* DESIGN.

ELIZABETHAN ARCHITECTURE. *See* TUDOR ARCHITECTURE.

ELLIPSIS, or ELLIPSE, in geometry, a conic section formed by cutting a cone entirely through the curved surface, neither parallel to the base, nor making a subcontrary section; so that the ellipsis, like the circle, is a curve that returns into itself, and completely encloses a space. See the definitions under the word CONE.

One of the principal and most useful properties of the ellipsis is, that the rectangle under the two segments of a diameter is as the square of the ordinate. In the circle, the same ratio obtains, but the rectangle under the two segments of the diameter becomes equal to the square of the ordinate:

Problem 1.—*The two axes of an ellipsis being given to describe the curve.*

Method I.—*Figure* 1. Let A C be the greater axis, DG the lesser, cutting each other in the centre H; and if with the radius A H, or H C, from the point B, an arc E F be described, it will cut A C, at E and F, the foci; fix two pins at E and F; take a thread equal in length to A C, and fix one end of it to E, and the other to F; then keeping a pencil at the point D, move such point forward in the same direction, so that the parts D E and E F may continue to be stretched during the motion, until the describent D come to the point whence it began to move.

Method II.—*Figure* 2. Find the foci E and F, as before; between E and F, take any point, 1; with the radii A 1, 1 C, and the centres E and F, describe arcs cutting each other at G, as also at H; then G and H are points in the curve; in the same manner, with the same radii, from the centres F and E, find the intersections I and K. In like manner, if any other point, 2, be taken between E and F; four other points, L, M, N, O, will be obtained, and thus as many more as will be requisite for drawing the curve by hand.

For by the construction of the ellipsis, E D + D F, (*Figure* 1) is equal to E C + C F, = E F + 2 F C; also E D + D F = F A + A E = E F + 2 A E; therefore E F + 2 F C = E F + 2 A E: consequently A E is equal to F C; hence E D + D F = E F + 2 A E = E F + 2 F C: that is, the sum of the two lines drawn from the foci, to any point in the curve, is equal to the transverse axis.

Method III.—*Figure* 3. *To describe an ellipsis with the ellipsograph, or trammel, as it is called by workmen, the axes* A B *and* C D *being given in position, bisecting each other in the centre* E.—In any piece of material, contained between any two parallel planes, cut two grooves, at right angles to each other, in one of the planes; then provide a rod with three pins, or points, so that at least two may be moveable, and in a straight line with the third: let H F G be the rod, with the points F and G moveable; making H G equal to the greater semi-axis; then placing the grooves over the axes, and putting the points F and G in the two grooves, move the point H round, keeping the point F upon the greater axis, A B, and the point G upon the lesser axis C D, until the describent H come to the point where the motion commenced; and the figure so described, will be an ellipsis. The trammel, used by artificers, consists of two rulers, with a groove in each, so fixed that both grooves may be in the same plane, and at right angles to each other, and that the opposite sides of the cross may be in a plane parallel to those of the grooves. The rod above, is a bar with two moveable cursors, the fixed end is made to hold a pencil, and each of the other two an iron point, made to fill the groove, but capable of sliding freely.

Method IV.—*Figure* 4. *Given one of the axis,* A B, *and an ordinate,* C D, *to describe the ellipsis.*—Bisect A B at I for the centre; through I draw E F, parallel to C D; with the distance I A, or I B, from the point D, describe an arc, cutting I F at G; draw the straight line D G H, cutting I A at H; then if H D G be conceived to be an inflexible line or rod, the points H, G, D, remaining at the same distance in respect to each other; and if the point H be moved in the axis A B, and the point G in the axis E F, while the describent D, is carried round the centre, I, until A come to the point whence it began to move; a curve D B E A F, will be described, which will be an ellipsis.

Demonstration.—*Figure* 5.

$$LF, \text{ or } BK : FG, \text{ or } DB :: LC, \text{ or } AB : CD;$$
$$\text{Therefore, } BK^2 : DB^2 :: AB^2 : CD^2;$$
$$BK^2 : BK^2 - DB^2 :: AB^2 : AB^2 - CD^2.$$
$$\text{But } BK^2 - DB^2 = BK + BD \times BK - BD = DH \times DK$$
$$\text{and } CD^2 = CL^2 - DL^2 = AB^2 - LD^2.$$
$$\text{Consequently, } BK^2 : DH \times DK :: AB^2 : DL$$

which is a most principal property of the ellipsis, but the demonstration which accompanies the following method, is quite general, for every two diameters.

Method V.—*Figure* 6. *A diameter,* K H, *and an ordinate,* D L, *of an ellipsis being given, to describe the curve by a continucd motion.*—Bisect K H at I, and through I, draw A I A, parallel to D L; draw D E C, and K D, at right angles to A A; from L, with the distance K B, describe an arc, cutting I A at F; draw L F C; through the points C and I, draw M N; then if the point C be moved in M N, and the point F in A A, the point L will describe the curve of an ellipsis.

Demonstration.

$$\text{For the triangles } LFG, \text{ and } LCD \text{ are similar } \therefore \quad LF : FG :: LC : CD;$$
$$\text{But because } FL = BK, FG = DE, \text{ and } LC = AI, \quad KB : DE :: AI : CD;$$
$$\text{Again, by similar triangles, } IKB, \text{ and } IDE \quad KB : DE :: KI : DI;$$
$$\text{Therefore, by equality of ratios} \quad KI : DI :: AI : CD;$$
$$\text{By duplication} \quad KI^2 : DI^2 :: AI^2 : CD^2;$$
$$\text{By division} \quad KI^2 : KI^2 - DI^2 :: AI^2 : AI^2 - CD^2.$$
$$\text{But } KI^2 - DI^2 = (KI + DI) \times (KI - DI) = DH \times DK;$$
$$\text{and } CD^2 = LC^2 - LD^2 = AI^2 - LD^2.$$
$$\text{Therefore by substituting } DH \times DK, \text{ for } KI^2 - DI^2, \text{ and } AI^2 - LD^2, \text{ for } CD^2;$$
$$\text{In the last analogy we have} \quad KI^2 : DH \times DK :: AI^2 : LD^2,$$

a well-known property of the ellipsis.

The method for describing an ellipsis, having two conjugate diameters given, may be found in the Marquis de l'Hospital's *Treatise of Conic Sections*, translated by Stone. But the author of the *Architectural Dictionary* has chosen to give the description and demonstration from a diameter and double ordinate instead of two conjugate diameters, as being more readily applied in perspective. It is strange, that this useful method has been neglected by all English writers that have fallen in our way. This property was discovered by the author, and demonstrated by him, many years before he met with the above work, in endeavouring to find out methods for describing the perspective representation by continued motion.

Method VI.—*Figure* 7. No. 1. Let A B be the greater axis, bisected in C, by the lesser semi-axis C D; take two rulers, C E and E F, of equal length, equal to the sum of the semi-axes C D and C B, moveable upon each other at E, and the end C of the rule C E, moveable upon the centre of the ellipsis. Make the part F G of the ruler, F E, equal to the semi-axis C D; now suppose C E and E F to coincide with each other, and with the axis C D; then move the point F from C, in the direction C B, until the describent G arrive at B: the point G will then have traced the quadrant D B of the ellipsis. The other quadrants will be described in the same manner, by reversing and inverting the rulers.

Figure 8.—Another variation of this: Let A B be the greater, and C D the lesser semi-axis, as before; take the straight line H I, equal to the greater semi-axis, A C or C B; from I H cut off I K, equal to the lesser semi-axis, C D, and divide H K into two equal parts at I; then place the joint rule C E F in the following manner, viz., make C E and E F each equal to H L, or L K; the part C E being moveable round the centre, C, of the ellipsis, and the two rules C E and E G being moveable round E; now let C E and E G coincide with C D, and the point F to coincide with C, and consequently G with D; then move the point F towards A, keeping it in the semi-axis C A; and when C E and E F come in the same straight line, the point G will have described the quadrant of an ellipsis; the lesser axis (*see Figures* 7 and 8) is equal $2 \times$ F G, and the greater $= 2 \times$ C E $+ 2 \times$ E G.

Demonstration.—*Figure* 7, No. 2. Draw G I parallel to C F, cutting C E at I, and draw E L perpendicular to C F, meeting C B at L; produce C E to H, and make C H = C B; join H G, and produce it to K.

Now by the general demonstration, accompanying the article CYLINDER, we have C B^2 : C D^2 : : A K $\times$ K B : K G^2; but by the property of the circle K H^2 + A K + K B; therefore C B^2 : C D^2 : : K H^2 : K G^2; consequently C B : C D : : K H : K G, a property of the ellipsis.

But C E is the half sum of the two axis, and C I, or F G, equal to the lesser axis; then I E, or E G, is equal to the difference between the half sum of the two semi-axes and the lesser semi-axis; therefore I E = half the difference between the two semi-axes, and I H = the whole difference; consequently I E = E H.

Then because I G is parallel to C F, we have E C : E F : : E I : E G; but E C = E F; therefore E I = E G; and because E I = E H, E G is also equal to E H: then since the angle E P G is a right angle, the angles P E G and E G P, are together equal to a right angle; but the angles E G H and G E P are alternate; therefore E G H = G E P; add to each of these equal angles, the angle E G P, then will E G H + E G P = G E P + E G P equal to a right angle; consequently I G is parallel to C K, and the triangles C K H and I G H are similar.

Therefore C H : C I : : K H : K G; but C B = C H, and C D = C I; C B : C D : : K H : K G, the above property of the ellipsis.

Method VII.—*Figure* 9. Find the foci E and F, as in Methods I. and II. let the ends E and F of two rules F I and E K be moveable, the one round E, and the other round F, and let each be equal in length to A B, the greater axis, intersecting each other at E; let the ends I and K be connected by a bar, I K, equal in length to E F, so as to be moveable round the points I and K; then if the point I or K, be carried round G, the whole instrument will be in motion, and the point A will describe the curve of an ellipsis.

Demonstration.—Join E I; then, because the triangles I K E and I F E have the two sides, I K and K E, equal to the two sides E F and F I, and the base I A common to both, the angles I K E and I F E are equal; therefore the sides I H and H E are equal; therefore I F = A B = E H + H F, which is a property of the ellipsis.

Method VIII.—Another method will be found under the article CONE, by the equal divisions and intersections of straight lines.

Method IX.—*Figure* 10. *To find any number of points in the curve.*—On the transverse axis, A B, describe a semicircle: take as many points in the circumference of the semi-circle, as may be necessary for constructing the elliptic curve; draw straight lines perpendicularly to the axis cutting it, and let one of these lines, C D, pass through the centre; let E F be any other perpendicular, cutting the axis in F, and let C G be the lesser semi-axis; find the point H, so that F H may be a fourth proportional to C D, C G, F E, and the point H will be in the curve of the ellipsis required: in the same manner, a point may be found in each of the other perpendiculars. The finding of points in the curve by this method being entirely in proportion, the whole may be very readily obtained, by making I K = C D, I L, equal to the lesser semi-axis of the ellipsis; join K L; on I K make I *l*, *e m*, I *n*, equal to the perpendiculars; draw *l o*, *m p*, *n q*, parallel to K L, cutting I L, at *o*, *p*, *q*; then I *o*, I *p*, I *q*, are the ordinates of the ellipsis, to be applied respectively upon the perpendiculars, from the greater axis. This may very easily be described by means of the proportional compass, or the sector.

Method X.—*Figure* 11. Let A B be the greater axis, C D the lesser semi-axis. On the diameter A B, describe the semi-circle A E B, and with the radius C D describe the semicircle F D G; take any number of points, *h*, *i*, &c. in the circumference A E B, and draw *h* C, *i* C, &c. cutting the semicircle F D G, at *k* and *l*; from the points *h*, *i*, &c. draw lines *h m*, *i n*, &c. perpendicularly to A B; also from the points *k*, *l*, &c. draw lines *k m*, *l n*, &c. parallel to A B; then the points *m*, *n*, &c. are in the elliptic curve. When the points for half the curve are found, the corresponding points for the other half will be readily obtained, by producing the perpendiculars to the other side of C B, and making the ordinates on the one side equal to those on the other.

Method XI.—*Figure* 12. *Any two conjugate diameters,* A B *and* C D, *being given, to describe an ellipsis through points found in any diameter, taken at pleasure.*—Through D draw P Q parallel to A B; from D draw D F, perpendicular to P Q; make D F equal to E A, or E B, upon F; with the distance F D, describe the circle *n* D *k*; through the centre, E, draw the lines P E N, *t* E M, *s* E L, indefinitely cutting the tangent P Q, at P, *t*, *s*, &c.; join P F, *t* F, *s* F, &c. cutting the circle *n* D *k*, at the points *n*, *m*, *l*, &c.; also join E F, if necessary, and draw *n* N, *m* M, *l* L, &c. parallel to it, cutting the diameters N N, M M, L L, &c. at N, M, L, &c. and these points will be in the curve of the ellipsis required: if the diameters are produced to the opposite sides, at N, M, L, &c. and the distances E N, E M, E L, &c. are made respectively equal to their opposite corresponding distances E N, E M, E L, &c.; then the points N, M, L,

ELLIPSIS.

PLATE I.

Fig. 1.

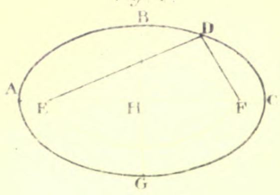


Fig. 2.

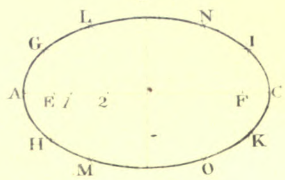


Fig. 3.

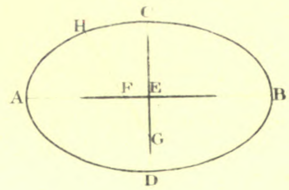


Fig. 4.

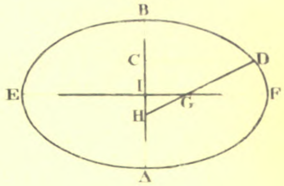


Fig. 7. Nº 2.

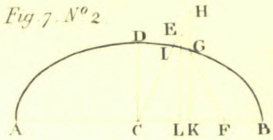


Fig. 5.

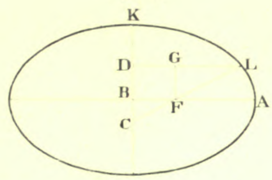


Fig. 6.

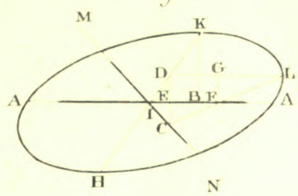


Fig. 7. Nº 1.

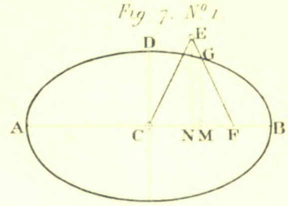


Fig. 8.

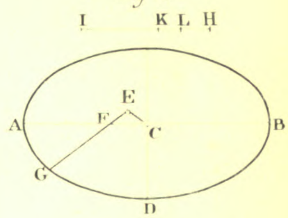


Fig. 9.

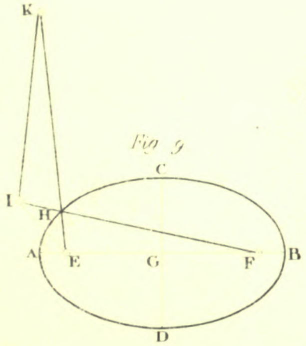


Fig. 10.

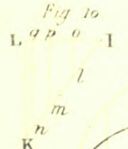


Fig. 10.

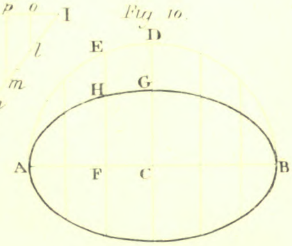


Fig. 11.

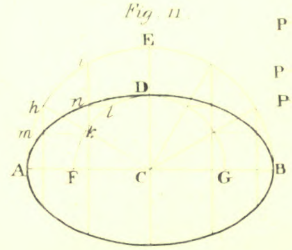


Fig. 12.

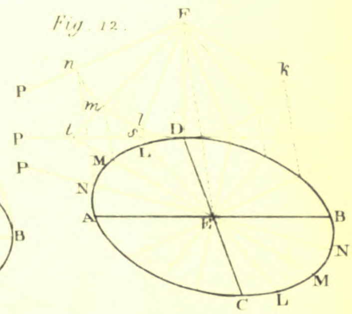


Fig. 13.

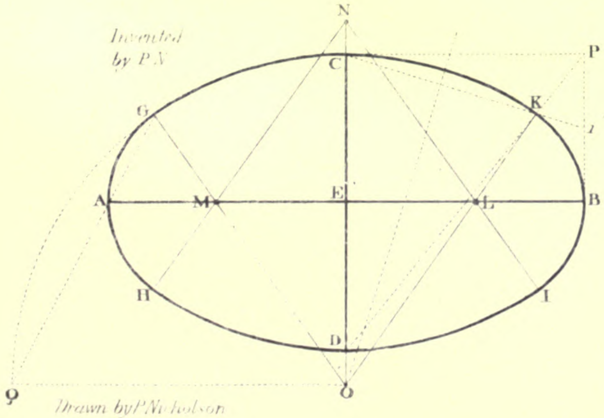
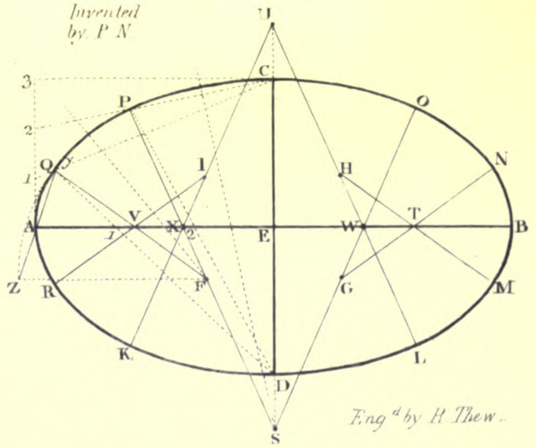


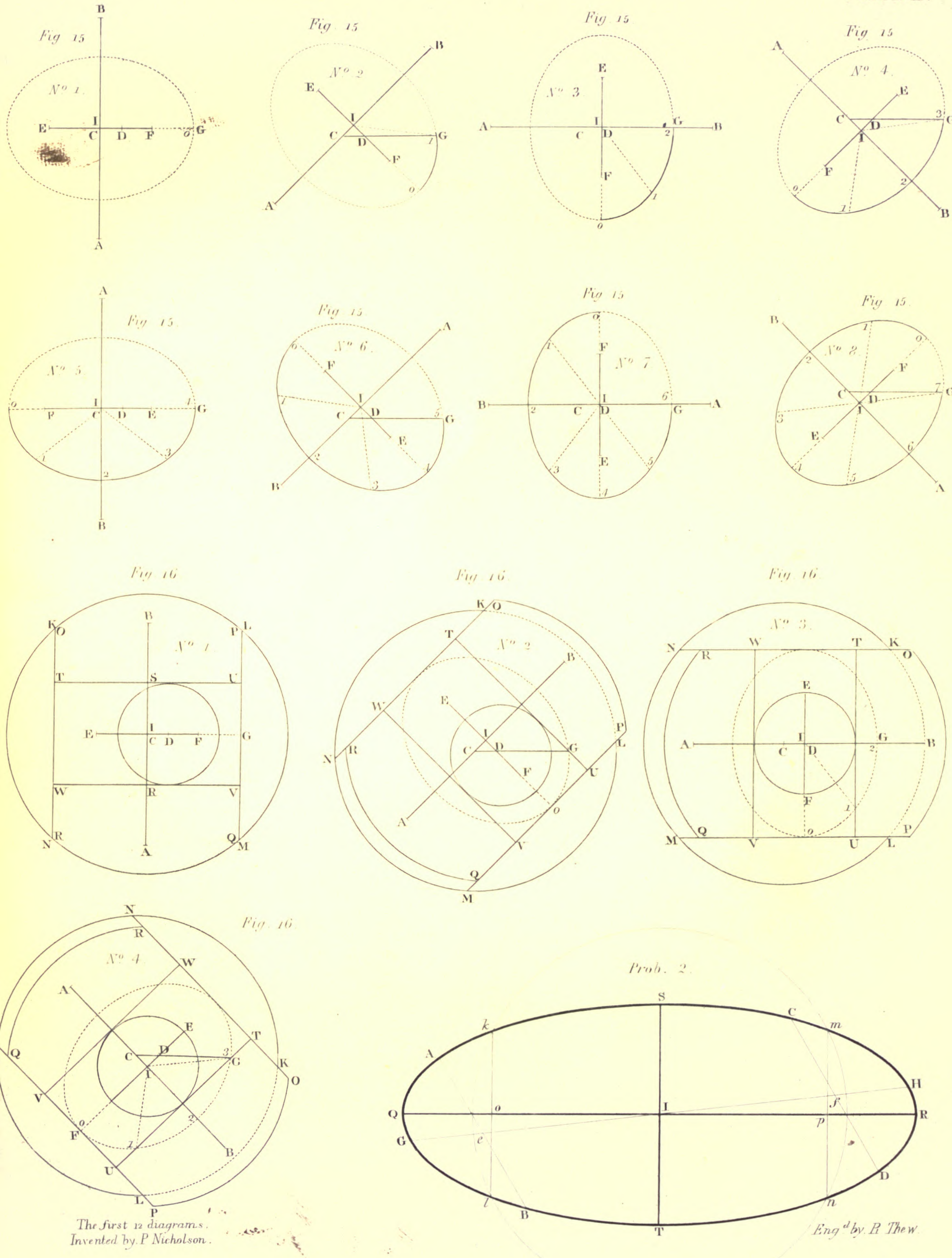
Fig. 14.



Drawn by P. Nicholson.

Eng.d by R. Thew.

ELLIPSIS.



The first 12 diagrams.
Invented by P. Nicholson.

Eng.d by R. Thew.

on the under side of the diameter A B, will also be in the curve.

This method may be very easily applied in perspective: by having the representation of a diameter of an original circle perpendicular, and that of another parallel to the picture, we have a diameter and double ordinate: the diameter of the ellipsis, or representation, is the diameter of the circle perpendicular to the intersecting line of its plane; thus it is only finding the conjugate diameter, and drawing as above.

Figure 13.—*The axes* A B *and* C D *of an ellipsis being given, to describe its representation by means of circular arcs.*—Draw B P parallel and equal to E C; bisect it at 1; draw 1 C, and P D, cutting each other at K; bisect K C, by a perpendicular meeting C D at O; on O, with the radius O C, describe the quadrant C G Q; through A and Q draw Q G, cutting the quadrant at G; draw G O, cutting A B at M; make E L equal to E M, and E N equal to E O; from O, through M and L, draw O G and O K; from O, complete the arc G K; from N, with the same radius, equal to the distance N D, describe the opposite arc H I; from M with the radius M G, describe the arc G H, at the extremity of the longer axis; and lastly, from L, with the same radius, equal to L B, describe the opposite arc K I; then A G C K B I D H A is the representation required, made to pass through eight points in the curve.

Figure 14.—*To find the representation of an ellipsis, by means of circular arcs, passing through twelve points in the curve (a more accurate method than the former) the axes* A B *and* C D *being given.*—Draw A 3 parallel to E C; divide it into three equal parts; draw 2 *c* and 1 *c*; divide A E also into three equal parts, and through the points 1, 2, draw D Q and D P, cutting the former in Q and P. Bisect C P by a perpendicular, meeting C D, produced at S; and join P S, cutting A E at X; make E W equal to E X, and E U equal to E S; draw P X S, O W S, K X U, and L W U. Bisect P Q by a perpendicular, meeting P S at F, and draw Z F parallel to A B. With the radius F Q describe the arc Q Z, cutting F Z at Z; join Z A, and produce it to meet the arc at Q Z, at *y*: join *y* F, cutting A B at V; make X I equal to X F, also W H, and W G, equal to X F; make E T equal E V, and draw I V R, H T M, and G T N; then, with the centre S, and distance S C, describe the arc P O; with the centre U and distance U D, equal to the former, describe the opposite arc K L; with the centres I, F, G, H, describe the arcs K R, P Q, N O, and L M; and, lastly, with the centres V and T, describe the arcs Q R and M N, at the extremity of the longer axis; and A C B D is the representation passing through the twelve points A, Q, P, C, O, N, B, M, L, D, K, B, as required.

This method differs so little from a true ellipsis, that it may be used in preference to any instrument for describing the curves of very large arches of bridges, and in finding the joints of the stones, as was the practice of the celebrated French engineer Perronet.

Another method of describing an ellipsis, by means of an instrument, constructed upon the principle of the oval turning lathe.—As we have never seen any investigation of this method, upon simple principles, the Author offers the following to the public, which has only been given in his *Mechanical Exercises.*

Definition.—If there be any plane figure, and two inflexible straight lines at right angles to each other; and if the plane be fixed to an axis at right angles thereto; and if the two inflexible lines be made to coincide with the plane, and be so moveable on its surface, that one of them, which we shall call *the primary line*, may always pass through two fixed points in the plane, and through the point where the plane is intersected by the axis; and if the other transverse line be made to pass or slide along a given point, which is not attached to the plane, but would remain stationary, even though the plane were in motion; and if a secondary plane be fixed to the inflexible lines parallel to the primary plane: then if the axis be carried round while the point in the transverse line is at rest, the primary plane will also be carried round, and every point in it will describe the circumference of a circle: the secondary plane will likewise be carried round, and perform its revolutions in the same time as the primary plane and the axis, but being immoveably fixed to the rectangular lines, they will cause it to have both a progressive and retrogressive motion, in the direction of the primary line, in each revolution; and, lastly, if another point at rest be held to the surface of the secondary plane while in motion, it will either describe an ellipsis, a circle, or a straight line. Hence the describing point will always be at the same distance from the centre, or point where the axis intersects the primary plane.

The eccentricity of the ellipsis, or the difference of the axis, will be double the distance between the stationary point in the transverse line and the axis.

Instead of the stationary point, a circle may be placed with its centre in this point, and its plane perpendicular to the axis, and instead of the inflexible line moving backward and forward upon two fixed points in the plane, the diametrically opposite parts of the circumference may always touch a pair of parallel lines on the revolving plane.

Illustrations.—*Figure* 15. Let A B and E F, No. 1, 2, 3, 4, 5, 6, 7, 8, be the two inflexible lines intersecting each other in I, at right angles, and let C D be the two fixed points. Let A B be denominated *the primary line*, and E F *the secondary line*, and let the lines A B and E F at right angles, taken as a whole, be called *a transverse;* also, let C represent a primary point, and let the describing point be taken at O, in the line drawn through C D produced; now, in all positions of the chuck, the primary line A B is always upon the point C, and E F upon D. Having premised this in general, suppose, before the machine begins to start, that E F, No. 1, the secondary line, coincides with E G, and the point G with *o*, *o* being in the plane of the figure to be described; then because A B always passes through C, the points I and C will be coincident, A B being then at right angles to E F. Let us now suppose the motion to commence, and let it perform an eighth part of a revolution, as at No. 2, the describing point G, still remaining in the same position with respect to C and D, viz., in the right line C D G; then the point *o* will be at a distance from the point G, and a part, G *o*, of the curve will be described by the fixed point G, and the point I will be above the line C D G; now let the motion proceed, and describe another eighth, as at No. 3, then, the point *o* being always in the line E F produced, E F will be at right angles to the fixed line C D G, and A B coincident with C D G and the point which was last at G, will now be at I. In like manner, when another eighth has been performed, as at No. 4, the point *o* has performed three-eighths of a revolution, the point 1 is in a line drawn from the point C perpendicular to the fixed line C D G, and the point 2, which was at G, in No. 3, is situated between 1 and G. In this manner, by continuing the motion, the whole curve will be generated. No. 5 shows the curve when half a revolution has been described; No. 6, five-eighths; No. 7, six-eighths, or three-quarters; and No. 8, seven-eighths.

Here it may be proper to observe, that the angles performed by the revolution of the machine, are very different from the corresponding angles, formed by lines drawn from the centre of the ellipsis to the describing point, and to the extremity of the curve at its commencement.

From what has been said, it is easy to conceive, that the operation of elliptic turning is nothing more than that of the ellipsograph, or common trammel, with this difference, that in the operation of turning, the ellipsis is described by moving the plane, and keeping the point steady, but in forming the curve by the ellipsograph, the plane of description is kept steady, while the point is in motion. The transverse A B E F is the same as the grooves in the trammel-cross, and the line C D G the trammel-rod: here the cross and plane of description move round together, but fixed to each other, and the trammel-rod C D G is held still or immoveably confined: in the trammel, the board and cross are fixed together, and held while the trammel-rod C D G moves with the points C and D in the grooves.

To set this machine, therefore, it is only to make C D equal to the difference of the axes.

Figure 16.—No. 1, 2, 3, and 4, show the relation between the foregoing diagrams and the chuck. Let K L M N be the face of a board representing the plane, which is fixed to the axis of the machine; and let O P Q R be another board, made to slide in the board K L M N: each two points, O and K, L and P, M and Q, N and R, coinciding at this moment, K L M N will therefore represent a wide groove in the board; as this groove may be of any width, we may conceive the breadth to be very small, or nothing; it may therefore be represented by a groove, or by the line A B parallel to K N and L M, and in the middle of the distance between them. Instead of supposing the point D always moving backward and forward on the line E F, we may suppose a circle, or the end of a large cylindric pin, moving in a very wide groove, T U V W, across the slides O P Q R. Now, all the differences between these diagrams and those in the former Plate, are only wide grooves in place of lines passing longitudinally through the middle: for the line A B is always conceived to move reciprocally from one side to the other of the board K L M N; and it is the same thing whether one straight line slide longitudinally upon another fixed line, or whether a bar of any breadth move in a groove of the same breadth, or whether a straight line in reciprocal motion always pass through two fixed points.

No. 1, shows the chuck, as in the first diagram of the last Plate: No. 2 as No. 2, No. 3 as No. 3, and No. 4 as No. 4, of the said Plate. Any farther explanation is conceived to be unnecessary.

Problem 2.—*An ellipsis*, A B D C, *being given, to find the transverse and conjugate axes.*

Draw any two parallel lines A B and C D, cutting the ellipsis at the points A, B, C, D; bisect A B at *e*, and C D at *f*; draw G *e f h*, cutting the curve at G and H; bisect G H at I, which gives the centre; from I, with any radius that will cut the curve, describe a circle, *k l n m*, and join *k l* and *m n*; bisect *k l*, or *m n*, at *o* or *p*, and draw Q *o* I *p* R, meeting the curve in Q and R: then Q R is the greater axis; draw S T at right angles therewith, meeting the curve in S and T, and S T will be the lesser axis.

Problem 3.—*Any diameter*, A B, *being given, and an ordinate* C D, *to find the conjugate diameter of the ellipsis.*

Draw C I perpendicular to A B; bisect A B in F, and draw F H parallel to C D; on F, with the distance F A, or F B, describe the semi-circle A I B, cutting C I at I; make A E equal to C I, and draw E G parallel and equal to C D; through G and A, draw A H, cutting F H at H, then F H is the semi-conjugate diameter.

This problem is useful in perspective, in the representation of the circle: for, having the representation of a diameter of the circle perpendicular to the intersecting line, and the representation of a diameter of the circle parallel to it, the former representative diameter of the circle will be a diameter of the ellipsis, and the latter will be a double ordinate of the same; find the conjugate diameter by this problem; then, having the two conjugate diameters, the curve may be described as in *Method* XI; or the axis may be found as in the next problem, and thence this curve described.

Problem 4.—*Any two conjugate diameters*, A B *and* C D, *being given, to find the axis.*

Through D draw E F parallel to A B, and D I perpendicular to E F; make D I equal to M A, or M B; with the radius I D describe from I the arc *g* D *l*, and join I M, which bisect by a perpendicular, meeting the tangent E F at N; with the distance N I describe from N a semi-circle, E I F; join E M and F M, which produce to H and K; and join I *g* E and I *l* F; parallel to I M, draw *l* L and *g* G, cutting H E and K F at G and L; make M H equal to M G, and M K equal to M L; then will G H and K L be the two axes required.

In like manner, if G H had been a diameter, its conjugate would have been thus found: produce H G to E, and join E I; draw E V at right angles to E I; then draw *g* G, and complete the rest as before.

This problem may be readily applied in perspective; for, by the last problem, two conjugate diameters will be found, and having the two diameters, the axes may be found by this, and the curve be described geometrically by an elliptic compass, or by traversing the curve with an ivory, pasteboard, or strong paper slip.

Problem 5.—*An ellipsis and its foci* F *and* G *being given, to draw a tangent through a given point*, H, *in the curve.*

Join F H and G H, and produce the latter to I; bisect the angle I H by the straight line L H, and L H is a tangent to the curve.

This problem is very useful in masonry, for finding the joints of elliptic arches. Thus, find a tangent in the curve, at the lower end of the joint, and from the point of contact, draw a line perpendicular to the tangent; and the line thus drawn will be the joint.

Problem 6.—*Two conjugate diameters*, A B *and* C D, *and the centre*, H, *being given, to draw two tangents to the ellipsis, from a given point*, E, *without the curve.*

First, let the point E be in D C, produced; make H I equal to H C, and join I E; through C draw C K, parallel to I E, cutting H A in K; make H L equal to H K, and through L draw F G parallel to A B; find the extreme points F and G, by *Problem* 3, and draw E F and E G, which are the tangents required.

But if the point E be in neither of the diameters, A B or C D, when produced, draw a line from the given point E, through the centre, so as to be terminated by the curve; and the portion thus intersected will be a diameter; then find a conjugate to this diameter, as in *Problem* 4.

This problem will be very useful in the perspective representation of a cone, for drawing the contour of the sides with the utmost exactness; the diameters being found by the preceding problem.

Problem 7.—*To describe an ellipsis similar to a given one* A B C D, *through a given point*, P, *having the same centre, and the axes in the same lines.*

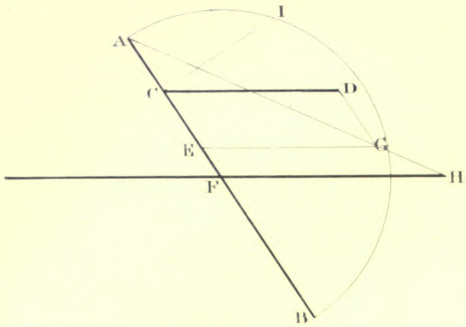
If the two axes, A D and B C, are not given, find them as in *Problem* 4; and the point E, where they intersect, is the centre; through the given point P, draw F E, to meet the curve in F; join A F and F B; parallel to F A draw P G cutting A E at G; and parallel to F B draw P H, cutting E B at H; then will E G be the greater semi-axis, and E H the lesser semi-axis.

Problem 8.—*Through the angular points*, A B C D, *of a given rectangle, to circumscribe an ellipsis, which shall have its axes in the same ratio as the sides of the rectangle.*

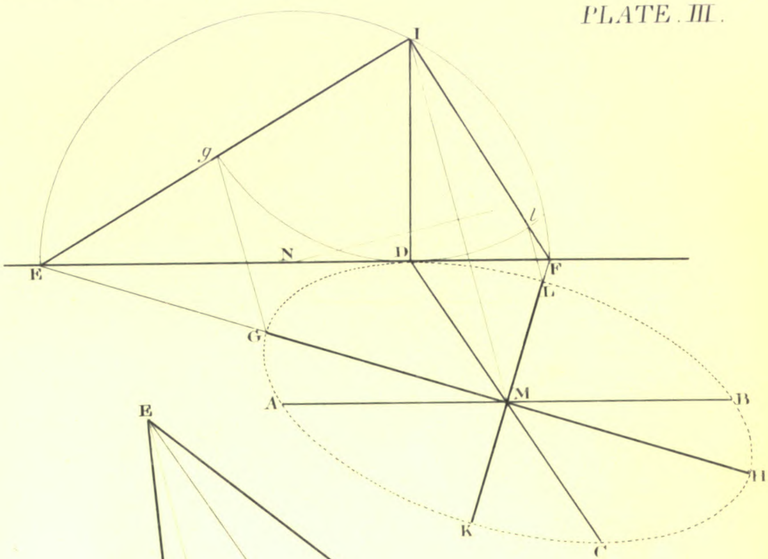
ELLIPSIS.

PLATE. III.

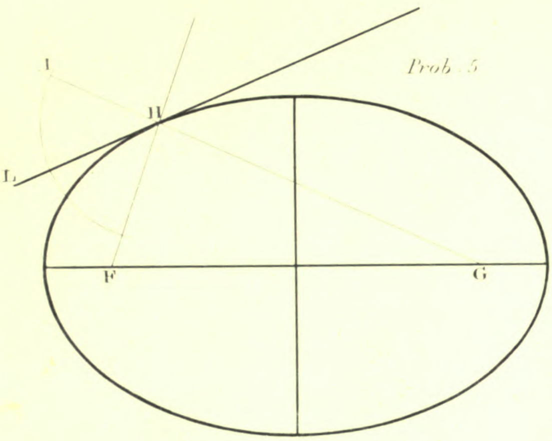
Prob. 3.



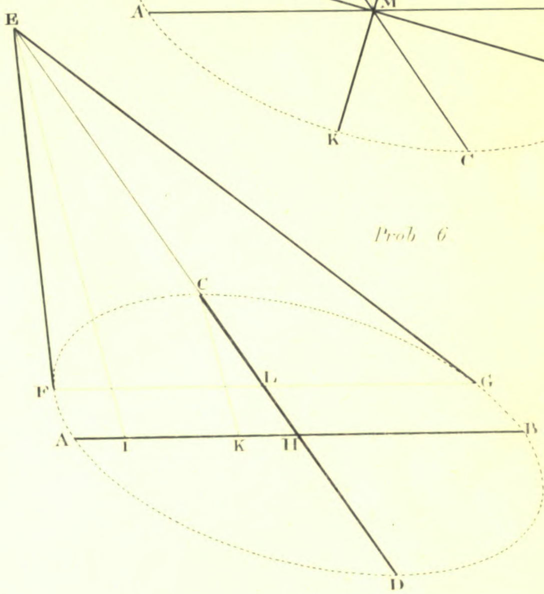
Prob. 4.



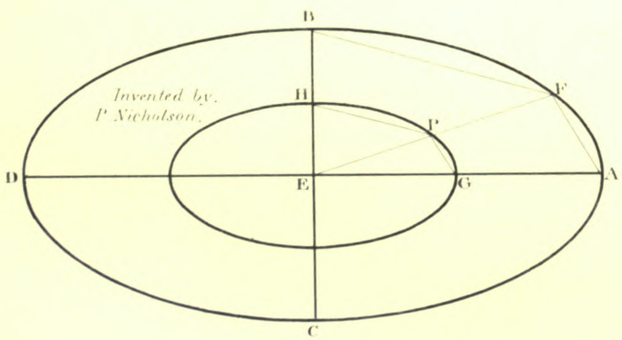
Prob. 5.



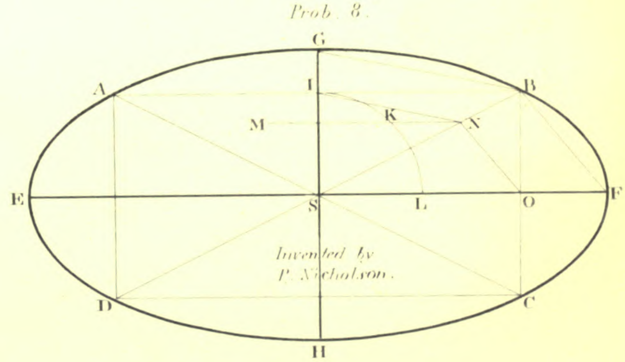
Prob. 6.



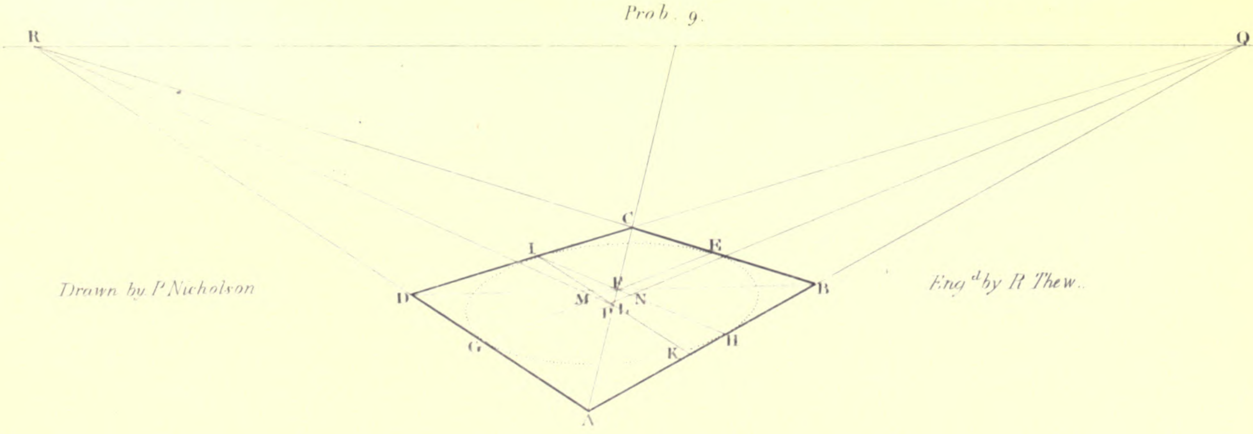
Prob. 7.



Prob. 8.



Prob. 9.



Drawn by P Nicholson

Eng^d by R Thew.

Draw the diagonals A C and B D, cutting each other at S, the centre; through S draw E F and G H, respectively parallel to A B and A D; upon S, with the radius S I, equal to the half of A D or B C, describe the quadrant I K L, cutting E F at L; bisect the arc I K L at K, and through K draw M N parallel to E F, cutting the diagonal B D at N; join I N, and through B draw B O parallel to it, cutting G H at O, and make S H equal to S O; join N O, and through B draw B F parallel to it, cutting E F at F; make S E equal to S F, and E F and G H are the two axes; then the curve may be described by any of the methods shown in Problem 1.

Problem 9.—*A trapezium,* A B C D, *being given, to inscribe an ellipsis therein.*

Produce the sides B A and C D to Q; also the sides A D and B C to R; draw the diagonals A C and B D, meeting each other at F; through F draw R I H, cutting the sides of the trapezium at I and H; also, through F draw Q E G, cutting the other two sides of the trapezium in E and G; bisect I H at N, and E G at M; draw Q N P and R M P; join I P, to which produce K: make P K equal to P I; draw G L parallel to C D, cutting I K at L; then I K is a diameter bisected by P, the centre, and L G is an ordinate.

This problem might have been constructed, as in the *Principles* (see Vol. I. *Problems* XVIII. XIX. and XX.) by having one of the points of contact given; but it is here much simplified, and reduced into one problem, by which it is much better adapted to perspective.

Problem 10.—*To find the area of any segment of an ellipsis.*—Let t = the greater axis,
c = the lesser,
y = D H, the ordinate,
and x = A D, the abscissa.

Then by the property of the curve, we have $y = \frac{c}{t} \times x\,(a x - x^2)^{\frac{1}{2}}$ but $\frac{c}{t} \times \dot{x}\,(a x - x^2)$ is a fourth proportional to t, c, and $\dot{x}\,(a x - x^2)^{\frac{1}{2}}$ for $t : c :: \dot{x}\,(a x - x^2)^{\frac{1}{2}} : \frac{c}{t} \times x\,(a x - x^2)^{\frac{1}{2}}$; and since $\dot{x}\,(a x - x^2)^{\frac{1}{2}}$ is known to be the fluxion of the semi-segment of the circumscribing semi-circle A E B, (see the article SEGMENT;) therefore, as the transverse axis, or the diameter of the circumscribing circle, is to the conjugate, or diameter of the inscribed circle, so is the area of the semi-segment of the circle to the area of the elliptic segment A H D; but the ordinate F D of the circle is to the ordinate H D of the ellipsis, as the diameter of the circumscribing circle is to the diameter of the inscribing circle; therefore, circular and elliptic segments upon the same base, and between the same parallels, are to one another as their bases, when the greater axis of the ellipsis is equal to the diameter of the circumscribing circle.

It is therefore evident, that, whether we know the specific measure of the greater axis of the ellipsis, or the diameter of the circumscribing circle, or not, we still can obtain the area of the elliptic segment, by a circular segment; provided it be known, that the greater axis of the ellipsis is equal to the diameter of the circle. In architecture, this circumstance is frequently known: suppose, for example, that in a groin, one side is the segment of a circle, and the other the segment of an ellipsis; it follows, from the construction of the groin, that both the vertical diameter of the circular side, and the vertical axis of the elliptic side, are equal; and therefore, if the width of each side of the groin, which is the chord of its arc, be given, and the height of the arch, we have nothing more to do than to find the area of the circular section or side, and the area of the elliptic side will be found by the rule of proportion. For practical use, take the following rule:

First.—*To measure the circular segment.*—To two-thirds of the area of the base, multiplied by the height, add the cube of the height, divided by twice the base of the segment, and the sum is very nearly the area of the circular segment; then *To find the area of the elliptic segment,* say, As the chord of the circle is to the chord of the ellipsis, so is the area of the circular segment to the area of the elliptic segment.

Example.—What is the area of the elliptic end of a groin which rises 5 feet, and extends at its base 15 feet, supposing the base of the circular end to be 18 feet?

$2 \times 15 = 30$, twice the length of the segment.

18	5
15	5
90	25
18	5
3)270	3,0)12,5
90	4.166, &c.
90	

180 two-thirds of the product of the base and height.
4.166 cube of the height, divided by twice the base.

184.166 area of the circular segment.

Then 18 : 15 : : 184.166
15
920830
184166
18)2762490(153.471 the area of the elliptic segment.
18
96
90
62
54
84
72
129
126
.30
18
12

To have wrought this example according to the series, would have been too operose for practical purposes.

The above method for finding the area of the segment of a circle, was discovered, or invented, by the author, in the year 1794, and published in his *Principles,* in 1795.

It is evident, that whatever takes place in the segment, must also occur through the whole curve; therefore, in an ellipsis having its greater axis equal to the diameter of a circle, it will be, As the diameter of the circle is to the lesser axis of the ellipsis, so is the area of the circle to the area of the ellipsis.

Example.—What is the area of an ellipsis, the greater axis of which is 24, and the lesser 18?

```
      24
      24
      ——
      96
     48
    ————
     576
   .7854
    ————
    2304
   2880
  4608
 4032
 —————————
 452. 3904 the area of the circumscribing circle.
```

Therefore 24 : 18 : : 452.3904

```
        18
   ————————
   36191232
   4523904
   ————————
24)8143.0272(339.2928 the elliptic area.
   72
   ——
    94
    72
    ——
    223
    216
    ———
      70
      48
      ——
      222
      216
      ———
        67
        48
        ——
        192
        192
        ———
```

But the proportion of 18 to 24, is as 4 to 3: therefore the above might have been considerably abridged; we were, however, desirous of working the operation at full length, as would unavoidably happen in case of incommensurable numbers, in order to compare it with the following operations.

Now let us try whether we cannot find a more practical rule for the area of an entire ellipsis, than that above.

Let $p\,d^2$ be the area of a circle circumscribing an ellipsis, where

$p = .7854$, and $d =$ the diameter of the circle or greater axis of the ellipsis,

and $c =$ the conjugate, or shorter axis;

then we have $d : c : : p\,d^2 : \frac{p\,d^2\,c}{d} = p\,d\,c$ the area of the entire ellipsis; we have therefore the following neat rule.

Multiply the two axes together, and the product by .7854, and this second product will be the area.

Suppose now, for the sake of comparison, that we take the former example, viz., the greater axis 24, and the lesser 18.

```
    24
    18
   ———
   192
   24
  ————
   432
 .7854
 —————
  1728
 2 160
34 56
302 4
——————
339 . 2928 area of the ellipsis.
```

In the same manner, may the half, or the quarter, be found, viz., by multiplying the two dimensions together, and the product by .7854.

Example.—In a semi-ellipsis upon the greater axis. Let the greater axis be 24, as above, and the lesser semi-axis 9, the area is required.

```
 24          .7854
  9            216
———          ——————
216          4 7124
             7 854
           157 08
           ————————
           169.6464 = the area of the
```

semi-ellipsis, which is half of the entire area before shown.

Example in a quadrant.—Let the greater semi-axis be 12, and the lesser semi-axis 9, the area is required.

```
 12          .7854
  9            108
———          ——————
108          6 2832
            78 540
           ————————
           84. 8232 the area of the quad-
```

rant of the ellipsis, being one quarter of the area of the entire ellipsis, in the foregoing example. The area of an ellipsis is a mean proportional between the area of the circumscribing and inscribing circle.

For $p\,t^2$ is the area of the circumscribing circle; and $p\,c^2$ is the area of the inscribing circle:

Now $p\,t^2 : p\,t\,c : : p\,t\,c : \frac{p^2\,t^2\,c^2}{p\,t^2} = p\,c^2$; and therefore the proposition is manifest.

To find the periphery of an ellipsis.

Let $a =$ the greater semi-axis A C;

$c =$ the lesser semi-axis;

$x =$ the distance C D from the centre, the abscissa;

$y =$ D H, the ordinate;

$z =$ E F, the arc:

then will A D $= a - x$ and D G $= a + x$, therefore A D $\times$ D G $= a + x \times a - x = a^2 - x^2$.

Then by the property of the ellipsis,

A C^2 or C B^2 : C G^2 : : A D $\times$ D B : D H^2; that is

$$a^2 : c^2 : : a^2 - x^2 : y$$

consequently $y^2 = \frac{c^2}{a^2}(a^2 - x^2)$

and therefore $y = \frac{c}{a}(a^2 - x^2)^{\frac{1}{2}}$

and $\dot{y} = \frac{-c\,x\,\dot{x}\,\frac{1}{2}}{a(a - x^2)}$ Therefore $\dot{z} = (\dot{x}^2 + \dot{y}^2)^{\frac{1}{2}} = \frac{\dot{x}\,(a^2 - \frac{a^2 - c^2}{a^2} \times x^2)^{\frac{1}{2}}}{(a^2 - x^2)^{\frac{1}{2}}}$; but by substituting d for $\frac{a^2 - c^2}{a^2}$ in this last expression we obtain $\frac{\dot{x}\,(a^2 - d\,x^2)^{\frac{1}{2}}}{(a^2 - x^2)^{\frac{1}{2}}}$ for the value of $\dot{z}$. But

$$\frac{\dot{x}\,(a^2 - dx^2)^{\frac{1}{2}}}{(a^2 - x^2)^{\frac{1}{2}}} = \frac{a\,\dot{x}\left(1 - \frac{d\,x^2}{a^2}\right)^{\frac{1}{2}}}{(a^2 - x^2)^{\frac{1}{2}}} = \frac{a\,\dot{x}}{(a^2 - x^2)^{\frac{1}{2}}} \times \left(1 - \frac{d\,x^2}{a^2}\right)^{\frac{1}{2}}.$$

Then by throwing the factor $\left(1 - \frac{d\,x^2}{a^2}\right)^{\frac{1}{2}}$ into an infinite series, we obtain $\dot{z} = \frac{a\,\dot{x}}{(a^2 - a^2)^{\frac{1}{2}}} \times \left(1 - \frac{d\,x^2}{2\,a^2} - \frac{d^2\,x^4}{2.\,4\,a^4} - \frac{3\,d^3\,x^6}{2.4.6\,a^6} \&c.\right)$ But the fluent of $\frac{a\,\dot{x}}{(a^2 - x^2)^{\frac{1}{2}}}$ is equal to the corresponding arc, E F, of the circumscribing circle. Therefore, taking A equal to the circular arc, we obtain the fluent of $z = \text{A} - \text{B}\frac{d}{2\,a^2} - \text{C}\frac{d^2}{2.4\,a^4} - \text{D}\frac{3\,d^3}{2.4.6\;a^6}$ where $\text{B} = \frac{a^2\,\text{A} - x\,(a^2 - x^2)^{\frac{1}{2}}}{2}$, $\text{C} = \frac{3\,a^2\,\text{B} - x^3\,(a^2 - x^2)}{4}$, $\text{D} = \frac{5\,a\,\text{C} - x^5\,(a^2 - x^2)^{\frac{1}{2}}}{6}$ &c., but when x becomes $= a$, then $(a^2 - x^2)^{\frac{1}{2}} = 0$, consequently the values B, C, D, become only as follows, viz.,

$$\text{B} = \frac{a^2}{2}\text{A}$$

$$\text{C} = \frac{3\,a^2}{4}\text{B} = \frac{3\,a^2}{4} \times \frac{a^2}{2} \times \text{A} = \frac{3\,a^4}{2.4}\text{A}$$

$$\text{D} = \frac{5\,a^2}{6}\text{C} = \frac{5\,a^2}{6} \times \frac{3\,a^2}{4} \times \frac{a^2}{2} \times \text{A} = \frac{3.5\,a^6}{2.4.6}\text{A}$$

These values being substituted in the above series, give the quadrant $z = \text{A} \times \left(1 - \frac{d}{2.2} - \frac{3\,d^2}{2.2.4.4} - \frac{3.3.5\,d^3}{2.2.4.4.6.6}\right)$ &c. Now by putting $\text{B} = \frac{d}{2.2}$, $\text{C} = \frac{3\,d^2}{2.2.4.4}$, $\text{D} = \frac{3.3.5\,d^3}{2.2.4.4.6.6}$, &c. we obtain $z = \text{A} \times \left(1 - \frac{d}{2^2} - \text{B}\frac{1.3.d}{4^2} - \text{C}\frac{3.5.d}{6^2} - \text{D}\frac{5.7.d}{8^2}\right)$ &c. Therefore, to find the circumference of an ellipsis, we have the following

RULE. Multiply the circumference of the circumscribing circle by the sum of the infinite series $1 - \frac{d}{2^2} - \text{B}\frac{1.3.d}{4^2} - \text{C}\frac{3.5.d}{6^2} - \text{D}\frac{5.7.d}{8^2}$, &c.

Example.—Required the periphery of an ellipsis, the transverse axis of which is 50, and the conjugate 40, then will $d = 1 - \left(\frac{40}{50}\right)^2 = 1 - \left(\frac{4}{5}\right)^2 = 1 - \frac{16}{25} = 1 - .64 = .36$

Therefore 2) .36 = d

2) .18

.09 = $\frac{d}{2.2}$ = A
1

.09
3

.27
.36 = d

162
81

4) .0972

4) .0243

.006075 = A $\frac{1.3\,d}{4.4}$ = B
3

.018225
5

.091125
.36 = d

546750
273375

6) .03280500

6) .00546750

.00091125 = B $\frac{3.5\,d}{6.6}$ = C
5

.00455625
7

.03189375
.36 = d

19136250
9568125

8) .0114817500

8) .00143521875

.00017940234375 = C $\frac{5.7\,d}{8.8}$ = D
7

.00125581640625
9

.01130234765625
.36 = d

6781408593750
3390704296875

.0040688451562500

10) . 0040688451562500

10) . 0004068845156250

. 00004068845156 25 = D $\frac{7 . 9 d}{10 . 10}$ = E
9

. 0003661960640625
11

. 0040281567046875
. 36

0241689402281250
120844701140625

12) . 001450136413687500

12) . 000120844701140625

. 0000100703917617 1875 = E $\frac{9 . 11 d}{12 . 12}$ = F
11

. 000110774309378 90625
13

33232292813671875
11077430937890625

. 001440066021925781 25
. 36

00864039613155468750
43201980657773 4375

4) . 000518423767893281 2500

7) . 000129605941973320 3125

7) . 0000185151345676171875

. 00000264501922394531 25 = F $\frac{11 . 13 d}{14 . 14}$ = G

Therefore, these terms collected, are as follow :

A = . 09
B = . 006075
C = . 00091125
D = . 00017940234375
E = . 00004068845156 25
F = . 0000100703917617 1875
G = . 00000264501922394531 25

Therefore . 0972190562062981640625 = the sum of the negative terms, which therefore being taken from 1.
. 0972190562062981640625

leaves . 9027809437937018359375 for the sum of the series.

Therefore . 90278 0943
50

45.1390 47150
3.1416

270 8342 8290
451 3904 715
1 8055 6188 60
4 5139 0471 5
135 4171 4145

141.8088 3052 64400 = the periphery of the ellipsis required.

But as this rule would be much too laborious for practice, we must content ourselves with some easy method of approximation: It will be very serviceable, however, in comparing the results obtained by such approximations, in order to ascertain the degree of dependence that may be put on them. Let us therefore try the following Rule, for the periphery of the whole, the half, or the quadrant of the curve.

RULE.—Multiply the square root of the half sum of the squares of the two axes by 3.1416, and the product will be the circumference, nearly.

Example.—Let the greater axis be 50, and the lesser 40, as before: the entire periphery is required.

50	40
50	40
2500	1600
1600	

2) 4100

20.50 (45.27692, the root.
16

85) . 450
425

902) . 2500
1804

9047) . 69600
63329

90546) . 627100
543276

905529) . 8382400
8149761

9055382) . 23263900
18110764

.5153136

45.2 7692
3.1416

271 6 6152
452 7 692
1 8110 7 68
4 5276 9 2
135.8307 6

142.2419 7 1872

The above, though agreeing only in the two first places of figures, is sufficiently near for most practical purposes in measuring; the difference in four places of figures is only four more than the truth.

The investigation of this rule is as follows:
Let t = the greater axis,
and c = the lesser,

then $p\left(\frac{t^2 + c^2}{2}\right)^{\frac{1}{2}}$ expresses the rule;

out $p\left(\frac{t^2+c^2}{2}\right)^{\frac{1}{2}} = p\,t\left(\frac{1}{2}+\frac{c^2}{2\,t^2}\right)^{\frac{1}{2}}$

and since $d = 1 - \frac{c^2}{t^2}$

we have $\frac{c^2}{2\,t^2} = \frac{1-d}{2}$

therefore $p\,t\left(\frac{1}{2}+\frac{c^2}{2\,t^2}\right)^{\frac{1}{2}} = p\,t\left(\frac{1}{2}+\frac{1-d}{2}\right)^{\frac{1}{2}} = p\,t$ $\left(1-\frac{d}{2}\right) = p\,t\left(1-\frac{d}{2^2}-\frac{d^2}{2^3.4}-\frac{d^3}{2^4.8}-\frac{5\,d^4}{2^5.16}\right)$ &c. = the periphery; but the true periphery = $p\,t$ $\left(1-\frac{d}{2^2}-\frac{3\,d^2}{2^2.4^2}-\frac{3.3.5d^3}{2^2.4^2.6^2}\right)$ &c. Now this series agrees with the former in the first and second terms, and differs in the third only $\frac{d^2}{64}$; the rule is therefore an approximation.

The rule now delivered is still too long for practical uses; let us therefore try the following:

Rule.—Multiply the half sum of the two axes by 3.1416, and the product will be the periphery, nearly.

Example.—The same still as the preceding, viz., 50 and 40.

50	3.1416
40	45
2)90	15 7080
	125 664
45	
	141.3720 the periphery.

This rule is exceedingly easy, and sufficiently near for all practical purposes, where the eccentricity of the ellipsis is not very great. It gives the periphery nearly as much below the truth as the preceding rule is above; and, consequently, where great accuracy is required, if the result be found by both methods, the half sum will be exceedingly near. To show this by an example:

The result by the first rule	142.241971
The result by the last rule	141.3720
	2)283.613971
The half sum of both	141.806985

which is very near the truth, as it agrees in five places of figures with the result by the series.

ELLIPSOGRAPH, an instrument usually constructed of brass, for describing a semi-ellipsis at one movement of the index. *See* Ellipsis, *Problem* 1, *Method* 3.

ELLIPSOID, a solid, generated by revolving a semi-ellipsis round either of its axes. This solid is understood by some to be the same as spheroid. *See* Spheroid.

Elliptic Arch, a portion of the curve of an ellipsis, employed as an arch. This curve has some advantages over circular arcs, in bridge-building, as it leaves a greater space at the haunches for the passage of vessels, and, consequently, saves a considerable quantity of materials in the construction.

Elliptic Compasses. *See* Ellipsograph.

Elliptic Conoid, the same as Ellipsoid.

Elliptic Winding Stairs, a winding stair, having an ellipsis for its plan. *See* Stairs and Winding Stair.

EMBANKMENT, a large body, mound, or bank of earth, constructed or thrown up in different ways, according to circumstances. Embankments are of various kinds, according to the purposes for which they are designed, as Railway Embankments, which carry a line of railway over valleys and low ground at the elevation required for the level of the rails; Canal Embankments, for confining the water of a canal or reservoir, or upon which a canal or aqueduct is formed; and Embankments constructed with the view of guarding, protecting, and defending lands on the borders of the sea, rivers, and lakes, from being inundated and injured by them, and for reclaiming lands from the sea.

We shall treat first of the latter description of embankments. These are of different kinds and forms, according to the nature of the situations and the materials of which they are constituted. In embanking against the sea and large rivers, where the slopes next them are naturally gentle and easy, they are mostly of the earthy description, being well put together, and covered on the surface with turf cut from the tough sward of the land in the neighbourhood; but in cases where the banks, borders, and shores, are steep and bold, they are usually of a more hard and solid nature: as of stone, brick, gravel, sand, shells, and other similar substances, laid closely in some sort of tenacious material, such as clay or mortar, and other matters of the same quality. Timber is also frequently employed in their construction, in a variety of forms.

In works of this sort, very much depends upon the form in which they are constructed, and the nature and management of the materials made use of. In respect to the first it may be remarked, that banks of these kinds are commonly constructed with too narrow bases for the heights which are given them; from which circumstance, the sides which are opposed to the effects of the water become too steep and upright; consequently, in cases of high tides or floods, they are utterly incapable of resisting their weight, which has equally a lateral and downright pressure. Besides this, there is another disadvantage attending this method of forming them, which is, that the floods, as well as the tides, in ebbing and flowing, have a more continued action on one part than would be the case, if the slopes were more gentle and gradual: consequently, they have a much greater tendency to break down and destroy the superficial parts of the banks. With some variations in the forms, most of the embankments in this country are, however, made in this way. They may succeed in some particular instances; but, in general, it is found that breaches are frequently taking place in them, from the effects of the sea or floods, which are not capable of being filled up or repaired without considerable difficulty and trouble; and which, if suffered to continue even for a short space of time, endanger the whole embankment.

The common form of embankment is shown at *Figure* 1, and the improved form pointed out at *Figure* 2.

The angles or slopes of these sorts of works are made very different in various cases; but that shown in the above figure seems, in general, well calculated for the purpose of resisting the impression of heavy tides, or the waters of floods. The greater breadth they have, in proportion to their height, the more effectual they must be in resisting the power of the waters which come upon them. In regulating the heights of embankments, it is necessary to ascertain the greatest depth of water at the highest tides or floods; making the summits of them about two feet higher than the points to which they rise at such times. By some, a less height than this above the highest mark of the tides or floods has, however, been considered sufficient; but it is always proper to be on the safe side, as the consequences of an overflow are very serious.

In forming embankments with stones, or other similar materials, which, as has been seen, is essential in bold steep banks or shores, it is necessary that they be laid in proper materials, and be closely jointed next the sea, or the rivers, so as to be fully capable of resisting the entrance of water. Great care is requisite in doing this, or the bank will not stand, for the water, insinuating itself between the openings, will sink down among the stones, softening and loosening the clayey or earthy matters underneath, by which portions of them will be forced out and washed away. Hollows being formed in that way below, the stones naturally sink down; and the waters, rushing into the cavities with considerable impetuosity, quickly displaces others, and the whole embankment is soon destroyed. This very frequently takes place with the heads thrown across rivers, and such paved or causewayed banks as are formed with the view of protecting and preserving bold and open shores. Such shores are especially liable to be undermined and carried away by the washing operation of the waters which come against them. In order to render the embankments perfectly secure in such cases, they should be laid with good mortar, and be pointed with a strong cement. A good coat of gravel, in some cases of this kind, is even found far superior to paving with stones.

It sometimes happens that rivers, near their mouths, form shallow estuaries, and occupy much ground which might be usefully employed. In this case, an entirely new outlet may sometimes be made, through which the river may at once discharge itself into the sea; and the whole course will, probably, be soon filled up by the deposition of soil and mud brought in by the tides; for it is the current which clears the channel, and when this is taken away the channel soon fills up. In the course of a short time the old mouth of the river will be so filled up as scarcely to admit the tide; and an embankment across it may lay a large fertile track of land quite dry.

In constructing embankments of the quay, or other similar kinds, a mortar formed from powdered unburnt lime-stone and coarse sharp sand is employed; the whole being pointed with puzzolana earth, by which they become as solid as rock, and fully resist the effects of water. The lime of particular sorts of lime-stone is found more proper for forming this sort of mortar-cement than that of others: thus, that found at Dorking, in Surrey, is supposed to constitute the most durable substance of this kind of any in the kingdom; and has been employed in many works near London. And an excellent sort of lime-stone, for the same purpose, has likewise been discovered near Worsley, in Lancashire, which is there termed *Sutton lime*.

An excellent cement for this use, which hardens under water, may be composed by having four parts of blue clay, six of the black oxide of manganese, and nine of carbonate of lime, submitted to a white heat, and then well incorporated with sixty parts of sand, and as much water as may be necessary to form it into a mortar. *See* CONCRETE.

It is invariably found, in examining the shores of the sea, and the banks of rivers, that such as have easily and gently declining slopes from their beds to their borders or banks, and those which are formed in a steep upright manner, of rocky materials, such as are shown at *Figures* 3 and 4, are the least exposed to injury from the effects of the waters: the two former being the most secure when spread over or coated with good coverings of sand or gravel, or uniformly turfed over quite down to the water-side with the sward of a tough old pasture. The strength and firmness of their banks are in proportion to the extent of the slope; and their durability depends on that of their being made uniform on their surfaces, both in respect to hardness and smoothness: as, in the former case, from the great length of slope, the flows and decreases of the waters act more momentarily on their different parts, and their greater weight renders their banks more firm; while, in the latter case, by the equality of their surfaces, the power of the water is rendered the same on one part as another, and no obstacles are left for the producing of eddies, or other means of forming holes or breaks in them.

In the latter, or those of the bold, upright, rocky kind of banks, their strength chiefly depends on the resistance of the large quantity of materials by which they are backed, and not on the manner in which they are disposed, as in the former case; and their durability, on that of the uniform compactness of texture in the parts opposed to the effects of the waters: as, where these have fissures in them, or are softer in some parts than others, the waters are liable to enter and break down the banks in time, according to the particular nature of the cases.

It is, therefore, of importance, that the modes and forms of embankment, which are thus naturally presented, should be improved upon by art. It is evident, that if a cut were formed behind the embankment, as in *Figure* 5, at the letter *x*, the shores or banks, though, in this case, as it were, detached from the land, would be found equally strong, and capable of resisting the pressure of the waters, as in their original state. Hence, if a mound or bank were formed, and placed out at the distance of one, two, or three miles from the shore or other embankment, within the bed of the sea or other waters, as at *y* in the same *Figure*, it would be equally capable of resisting them as in the former instance, and not more liable to be broken down by their pressure than in its former station; and would also defend them as completely from the intermediate space of land, as it did before from the narrow trench. Consequently, on this principle, vast tracts of land may, in different parts of the kingdom, be obtained by judicious embankments.

Though the shores of bold steep coasts may not afford examples equally capable of being followed with advantage as the above, they nevertheless suggest useful hints for the purpose of defence, in cases of bold, abrupt, broken shores, constituted of earth, or of that material and rocky substances intermixed. It readily presents itself to the mind, that the raising a good perpendicular stone wall against such banks, renders them nearly as strong and lasting as those formed by nature of steep solid rocky bodies. This sort of walled bank is exhibited at *Figure* 6; but though this method may be practised, in cases of the above kind, with great advantage, it is not, by any means, applicable in general to rivers; as, with them, the waters, during the periods of floods, stand in need of room to spread, which is the great use of giving their banks a sloping form; while, in this way, it would have the effect of doing more injury than was the case before. The increased rapidity of the current, caused by its being so confined, doing greater damage to the banks. Instances may, however, happen in which it may be had recourse to with propriety, in defending a part of the bank of a river, without giving it a sloping direction, or for protecting one part of a bank at the risk of that which is opposite to it; but well-constructed piers, in such cases, are preferable, and attended with less expense to maintain. But instead of these, art may suggest one that may answer in some respect more perfectly; as, in place of bringing together such a mass of earthy or other substances, as may be proper for constructing such banks as are shown at *Figures* 1 and 7, it may be more advantageous to have one formed, such as is shown at *Figure* 8, the side of which, next the water, forms, with the base, an angle of about 45 degrees. This will be capable of bearing all the weight or pressure of water that can possibly be brought upon it, equally well with that of *Figure* 1, except that the operation of the tides would break the superficial part of the side next the sea, unless prevented by coating it with some durable substance, such as paving stones, bricks, or other similar materials.

Banks of various kinds, between this and the first natural kind, may be invented, differing only in the degree of inclination which they have towards the sea; that which slopes in the highest degree, as *Figure* 1, having the surface covered over with sand or gravel; and that which has the least slope, as *Figure* 8, may be covered with pavement; the different intermediate slopes being protected by materials which have a quality between the two, such as coarse gravel, chalk-stones, brick, and sand. The embankment, shown in *Figure* 9, is wholly constructed of a sandy loam deposited upon a soil of the same quality; but as it would not, for some time after being formed, be sufficiently impervious to water, a column of clay is carried upright in the middle, from the clayey substratum of the soil underneath, as is shown at *x x*, in the section. This is called *Puddling*.

In cases where the shores are of a very sandy nature, embankments may be made wholly of a sort of wicker-work. Thus three or four rows of paling are put down, of different heights, and the vacant spaces between them well filled, by forcing in furze, brush-wood, or even straw, as represented at *Figure* 10. These substances, by detaining the mud and sand, as the tide passes through them, or during high floods, soon forms a sort of embankment, such as that shown in the above representation. It should afterwards be covered with some plant, which is capable of binding and giving it solidity, such as the *elymus arenarius*. An embankment, so constructed, would continue, during extraordinary tides, to retain still larger quantities of the sandy materials, until, ultimately raised above the range of the highest floods, a safe bank would be formed. By banks formed in this way, large quantities of land might be gained in a very few years, in different parts of the rivers Severn, Humber, Frith, &c.

In all cases of embankment, however they may be formed, tunnels and sluices of a proper kind, with valves towards the sea or rivers, must be occasionally placed, according to circumstances, so as to permit the water that may be collected within to pass away, and that of the sea or rivers, to flow up, with different intentions in the view of improving the land.

The utility of projecting points is very considerable, in different cases, on the sea-coasts and rivers, in defending the bays and inlets of the former, as well as guarding the banks of the latter, by diverting their streams or currents to the opposite sides. Hence arises the formation of piers, which become highly beneficial in defending embankments, as well as the borders of rivers and brooks. In the first of these cases, they may generally be constituted and coated over with the same sort of material as that of which the embankment is formed; while, in the latter, they should be formed of some sort of stony matter, being constructed in such a way as to decrease in every direction as they advance outwards, as represented in *Figure* 11. In each of these cases, they are, however, capable of being constituted of brush wood, secured by means of stakes, often with more perfect success. And it frequently happens, that a simple rude wicker-work fence, of not more than three or four yards in length, may be fully sufficient for the purpose. Embankments formed of stone, unless constructed in the manner represented at the above figure, are apt to cause eddies below them; while those formed of brush-wood cannot have this effect.

It is obvious, that considerable attention must be required in deciding the most proper situations for constructing this sort of projection in, and the distances to which they should extend into the rivers; as a too extended projection may be highly dangerous to the opposite bank, and of course do harm, instead of being beneficial; while not carrying them out sufficiently far may prevent the effect which is wanted. In cases where piers are to be formed of stone, as in rivers where the bottoms are of a rocky nature, the plan represented at *Figure* 11, is a good one, as it will scarcely cause any eddy, and be nearly similar to that of the wicker-work, in the effect which it produces. Different works of these several kinds have been constructed in the northern parts of the island with much success.

Proper Materials for Embankments.—It will be obvious, that different sorts of materials may be made use of in different situations and kinds of works of this nature, with more advantage than others, both in so far as duration and expense are concerned.

Those steep upright embankments, which are constructed with the view of protecting bold shores, or coasts, and the banks of particular rivers, may probably be best formed of good brick, rubble, or ashlar work, in the manner of a wall, as seen at *Figure* 6, in the Plate, the materials being laid in the strongest mortar that can be made. But where this is not the case, they may be built in the common way, and pointed with puzzolana earth, or what is termed the Roman cement, prepared by Messrs. Parker and Co., London. Concrete has been used most successfully and extensively for the purpose of embankments, as we have shown under that article.

The different kinds of sloped embankments may be formed either with common earthy materials, clay, mud, or a mixture of these several different substances; and any other matters which are capable of uniting into a solid, firm, compact mass, may be had recourse to for the same purpose. Where the sides next the sea or other waters form angles of from 20 to 30, or even 35 degrees with their bases, they may be coated with sand, the shells from the sea, or coarse gravel from the borders of the shores. And stones, broken down to uniform sizes of a few pounds in weight, may be employed in a similar manner. Where none of these substances can be procured in sufficient abundance, a method practised in Holland, of covering them with such perishable materials as mats, reeds, straw, bark, and others of the same nature, may be had recourse to; but these are obviously disadvantageous, as requiring very frequent renewal. They might likewise be protected by a low fence of brushwood fixed in an erect manner all along at the bottom of the bank, of an equal height, as tending to break off the violence of the waves. Another method might also be employed, which is that of covering the whole front of the bank with brushwood, either made into bundles, or in the manner of wicker-work, or fixed down in a neat manner by means of long poles and strong hooked stakes. And farther, they may be laid in the form of a causeway, with stones in moss, or covered with wicker-work applied upon the mossy material when spread out over the bank. Many other modes also may be adopted under particular circumstances.

In all cases where the sides and slopes towards the sea constitute angles of from 35 to 45 degrees with their bases, as in *Figure* 8, recourse may be had to stones of the flag kind, as coverings, which should be jointed with cement mortars formed in some of the ways we have mentioned above. And where these sorts of stones cannot be provided, if clay can be found, proper kinds of bricks may be made, and used in the same way as the stones. Where the slopes or inclined planes are from 40 to 45 degrees, it is frequently more cheap and economical to have them covered with stones of about six or eight pounds in weight, applied to the thickness of a foot and a half, or nearly two feet; or these may be used on a bed of common moss of three inches, or of peat-moss of the flow kind, of six inches in thickness, spread upon the banks, only to the thickness of six or eight inches. Stones of these kinds may likewise be formed into a sort of causeway, or be laid in strong clay, and their surfaces jointed with lime or a strong cement mortar, which has the property of quickly hardening, and of enduring the operation of the air and tides, which alternately act upon it.

There may likewise be cases in which it may be the most advantageous practice to have the sides next the sea or rivers protected by coverings of wood only, in which case, larch may be the most proper, or such others as are durable, having their surfaces covered over with pitch and some sort of sharp sand. And old sail-cloth, or oil-cloth pitched and coated over with sand in the same manner, or even thin plates of metals, have been suggested as useful in particular instances.

In a paper read before the Institution of Civil Engineers in May, 1841, the Hon. Mr. Stewart gave a very interesting account of the application of peat to the purpose of building "sea walls." The author described some embankments constructed with it on the estates of his brother the Earl of Galway, to reclaim various portions of land, to the amount of many hundred acres, and stated that it had been found to answer extremely well, for several reasons, the most prominent of which were, that the blocks of peat, when well rammed down, grew together, thus forming a complete "puddle" wall; and that from its spongy nature it was not liable to crack in dry weather like clay, when any portion of it was in water, as moisture was in that case drawn up to all parts of it.

It is evident that great quantities of land might in many situations be obtained from the sea and large rivers, by the forming of proper embankments. Some notion of this may indeed be formed by a careful examination of such lands as lie along their shores and banks, by ascertaining the distances to which the waters ebb out at common tides, as it is found by experience, that at least one-half of the extent of land, thus uncovered in any particular situation, may be gained; hence, throughout the whole kingdom, it could hardly be estimated at a less quantity than from two to three millions of acres, but it is probably much more than even the last quantity, if it were capable of being ascertained with any degree of accuracy or correctness.

Importance of embankments.—When the extent and the value of the lands which are capable of being gained by these means are fully considered, there can be no doubt of their being of the greatest consequence to the interests of the country. It has been well remarked by a late writer on this subject, that there are numerous places in the kingdom where vast improvements may be effected by the judicious application of these means. Vast tracts of land of the best kind may not only be gained from the sea, but likewise from the large rivers and lakes, besides the beneficial consequences which must necessarily arise from the prevention of such rivers from overflowing their banks, and injuring the level grounds in their vicinity by such inundations. In some cases, it is supposed, that by raising a bank of only three or four feet in height, at a very small expense, some thousands of acres might be prevented from being overflown, the crops from being carried away, and much other mischief from being produced. In other instances, the forming of very trifling banks might be the means of obtaining much extent of country, which in its present state is of but very little value; yet so indifferent are people in general about improvements of this description, that though immense tracts are year after year overflown, and the most dreadful devastations committed, they have recourse to no means of prevention; nay, even though the sea itself, says the writer, as if to rouse them from their inaction, presents to their view twice every twenty-four hours, large tracts that might by proper means be made of very great value, yet these repeated invitations are disregarded, and no attempts are made to possess what might, in many cases, be so easily and so advantageously acquired. It is certainly extraordinary and unaccountable that the acquiring of distant possessions should be eagerly sought after, and considered of so great importance to us as a nation, when the addition of land in our own country by the reclamation of it from the waters, must be in every point of view so much more valuable.

The acquisition of additional territory at home should, therefore, be more attended to, and have more expense bestowed upon it than has hitherto been the case. In particular situations, indeed, a few active and enterprising persons have taken advantage of the opportunities which have been presented; as in the counties of York, Lincoln, Cambridge, and others, many hundred thousands of acres have been gained by embankments. In Norfolk, too, a considerable extent of land has been gained in this way. In the neighbourhood of Chester, the River Dee Company have likewise gained several thousands of acres from the sea, which have since been divided into different beautiful farms, the whole of which pay in rent more than 2,000 pounds per annum. And in Holland the whole country has, in a great degree, been obtained by these means.

It is stated by Mr. Beatson, in the second volume of *Communications to the Board of Agriculture*, that large sums have been expended in some places by individuals with a view of guarding against inundations, but, owing to the embankments they have made being injudiciously placed, and as badly constructed, the desired effect has not always been produced, particularly in the northern parts of Cheshire, on the banks of the river Mersey, where works of this kind have been thrown up at a great expense, which, from the manner of their being placed, may, in some cases, by confining the course of the river, do more harm than good. By the appearance of that part of the country, so far as he could judge from the cursory view he had of it, it seemed to him that the inundations from that river might have been effectually prevented at a much easier rate, if a proper method had been taken at first; but from a certain ill-judged and mistaken tenaciousness of property, the embankments are constructed so close upon the sides of the river, that, in many places, it is confined to a space not more than 20 yards over. Owing to this, and to an aqueduct across the river, with only one arch instead of two, which it ought at least to have had, the water sometimes, in great floods, rises, he was informed, to the height of about 20 feet above its ordinary level, and overflows the embankments, although now, by frequent additions, they are about that height. Instead of 20 yards, had these embankments been 80 or a 100 yards distant from each other, and the river widened in the narrowest places, one-third or one-fourth of their present height would have been quite sufficient. They would have been much easier made, and less liable to damage by the floods; a great deal of money also would have been saved, not only in the first construction, but in keeping the banks afterwards in repair. The space of ground between the embankments and the river thus left, would have produced the richest pasture, or meadow-hay, by its frequent manurings with the fertilizing particles left upon it, when flooded by the swelling of the river; and in those places, if any, that are unfit for pasture or hay, willows or other aquatics might have been planted to great advantage;

and thus it might have been of more value perhaps than at present, while the interior grounds would have been more effectually secured from the ravages of sudden floods. Notwithstanding the general indolence shown in most parts of the country, respecting the acquisition of land by embanking, and the seeming aversion that most people have to engage in such undertakings, there have been, however, some ingenious and enterprising projectors, whose ideas upon that subject have soared far beyond the bounds allotted to common understandings. From the speculations of such people, the most important advantages are sometimes produced; and surely the man who is possessed of a speculative turn of mind, and who considers no obstacles insurmountable, is a much more useful member of society than he who is perpetually starting difficulties against every new project, and is for having all things remaining *in statu quo*, that is, for leaving the world as he found it.

The idea of reclaiming land from the sea, for example, would have appeared to a torpid genius of this kind, as a matter too visionary for sober-minded men. A thousand difficulties would have started up at such a proposal; and obstacles, which to a more expanded mind, would seem perfectly practicable to overcome, would have presented to him impediments insuperable.

What would such anti-projectors think of proposals to exclude the sea entirely from extensive bays, many miles across, and exposed to the full sweep of the winds and the waves? Such was the proposition to carry a railway embankment across Morecambe Bay, and the estuary formed at the mouth of the Duddon, the embankments on Lough Foyle in Ireland, and other similar works.

That there are many large tracts of land in different parts of the kingdom, both on the sea-coasts and on the sides of lakes and rivers, easily attainable, there cannot be the smallest doubt. It is, therefore, an object worthy of the attention of those who are so fortunate as to possess property of this nature, to have it ascertained by persons of experience in such matters, how far the acquisition of additional portions of land may be adequate to the expense which it may be necessary to incur in procuring it. But embankments are important in other views than those of gaining ground by them. When rivers are concerned, one material advantage is the deepening of their courses, by which vessels of greater burden than they admitted formerly, may be permitted to navigate them.

And farther, as embankments become more frequent on the borders of rivers and sea-shores, the intervening distances may become a sort of bays, in which accumulations of shell, mud, sand, gravel, and other matters, may take place by the influx of the tides; and these, however difficult they may be at first to embank, will in time be as easy to perform the work on, as the natural bays and creeks are at this period. In this way many rivers, which in their present state are eight or ten miles in width at their junction or influx with the sea, may in the course of years be reduced to less than half these distances. Consequently, such embankments would be equally beneficial to the proprietors of land, and the merchant or manufacturer, as many rivers would become more easily navigable, and those obstacles which interrupt their mouths be wholly removed.

In embanking against the encroachments of the sea, it is necessary to ascertain, with great accuracy, the maximum height to which the water rises; the methods of doing this have been already shown. But as new works of this sort, especially where the banks are large, are liable to subside too much, it may be a proper precaution to take the levels frequently for some time after they are completed, in order to guard against any mischief which might arise in this way. Where the banks are low, this is not, however, so necessary, as in higher ones, as the settling is always more or less according to their height; in low banks it will of course be very little. In the making of such embankments, it is scarcely possible to lay down any general rule in regard to their size or dimensions, as these must be directed by situation and circumstances, under the management of an expert engineer. In cases where the embankment to be formed is to exclude the sea from a piece of low marshy ground, over which it only flows at spring-tides, the work is easy, and capable of being accomplished at no great expense. But where it is intended to reclaim a portion of land which is covered every tide, in some bay or creek, or on the sides or windings of some large river in which the tide ebbs and flows, the business will be in some degree more difficult, according to the depth and rapidity of the current of the water. And where it is proposed to exclude the sea from an exposed situation at the mouth of a river, or in a bay, or inlet, which is uncovered every tide, the operation will be the most difficult and expensive of all, according as it is exposed to prevalent winds, and the depth of the water to be resisted. Each of these situations, therefore, requires a different method of management.

The business of embanking against the sea, when at any considerable distance within high-water mark, is not only the most tedious, but at the same time the most difficult; as, when the materials are not very good and the work not well performed, the force of the water at every flowing of the tide will quickly undo all that has been effected, especially if the soil be of a sandy nature, as is often the case in such situations. If it be a strong clay, as is sometimes the case in marshy places, there will be the less risk of its being washed away. In sandy situations it has been advised by some to lay bundles of straw or reeds well fastened down, or any other impediment, to hinder the soil from being carried away by the ebbing tide. Where a sufficient supply of good strong turf cannot be had, other expedients may be tried; but where such turf can be provided, as is the case in most marshy situations, and where the embankment required is not to exceed the height of four or five feet, it is best to finish the slope with good turf as expeditiously as possible, as the work proceeds; that is, supposing the length of 30, 40, or 50 feet or yards of it can be completed in a tide, it is better to finish that length to its intended height, than to trace out or begin a greater extent than can be finished before the tide returns, by which a great deal of the soil might be carried away, and much of the work demolished, which is not so likely to be the case when the slope is finished. Turf which contains the roots of bent or rushes is very good for this use.

In commencing a work of this kind, however, the first thing to be done is to strike out the intended line of it, setting out the breadth at the base, also the width of the excavation or trench to be made in the inside, from which most of the materials that compose the bank are to be taken: this trench serving also as a drain to keep the grounds within dry. There should also be trunks or sluices at different parts of it, to shut off themselves against any external water, and to open when the tide ebbs, to let out any water from within. The width of it should be proportioned to the quantity of materials required from it, for the raising of the embankment, as eight, ten, or fifteen feet wide, and three or four feet deep, leaving a *berme*, or space, between the edge of the trench and the inner bottom of the embankment. If the soil be strong, one foot or eighteen inches will be sufficient for this purpose; but if loose or sandy, three or four feet at least will be required. The more easy and gradual the external slope is made, the less sudden the resistance against the sea will be, as has been seen above, and of course the embankment be less liable to injury; this slope should therefore be formed according to the exposure of it to the winds and tides: a contrary opinion has, however, been held by some engineers, and the formation of upright walls properly faced has by them been considered better adapted to resist the action of the water. *Figure* 12, is supposed to be a section of an embankment in which the base or horizontal line *g h* should at least be three times the perpendicular height *h i*; but *l m*, the inside slope, need not be more than three-fourths of the perpendicular height, that is, nine inches for every foot of rise. The inside slope should be faced with turf likewise, laid with the green side downwards, as in common sod walls. Some expert sodders can finish this sort of work extremely neat by setting the sod on edge, according to the slope intended to be given, and with proper mallets and beetles ramming the earth hard behind, which consolidates the work as it advances, and tends to render it durable. As soon as the first or lower course is finished, the upper edge of the sods is pared with a sharp knife quite even, by laying a rule to them, and then they go on with the second course, which they finish in the same manner, and thus proceed until the whole height is completed, which, when properly finished, has a smooth and beautiful appearance, not a joint between the turfs being seen. Where turf is used in covering the outside slope, it should all be laid with the grass uppermost, as already noticed, and be well beaten down with a flat sod-beetle for the purpose, and in order the better to secure them, it may be proper to drive small stakes, about eighteen inches in length, through every sod. In cutting sods for this use, they should be taken up in a careful manner, and be all traced by a line of the same breadth; their edges being cut as even as possible, that they may make the closer joints, which will tend very much to their security, until they are grown properly together. In laying the different courses of such sods, care should also be taken that the joints of the one be covered by the other, in the manner that good brickwork is made.

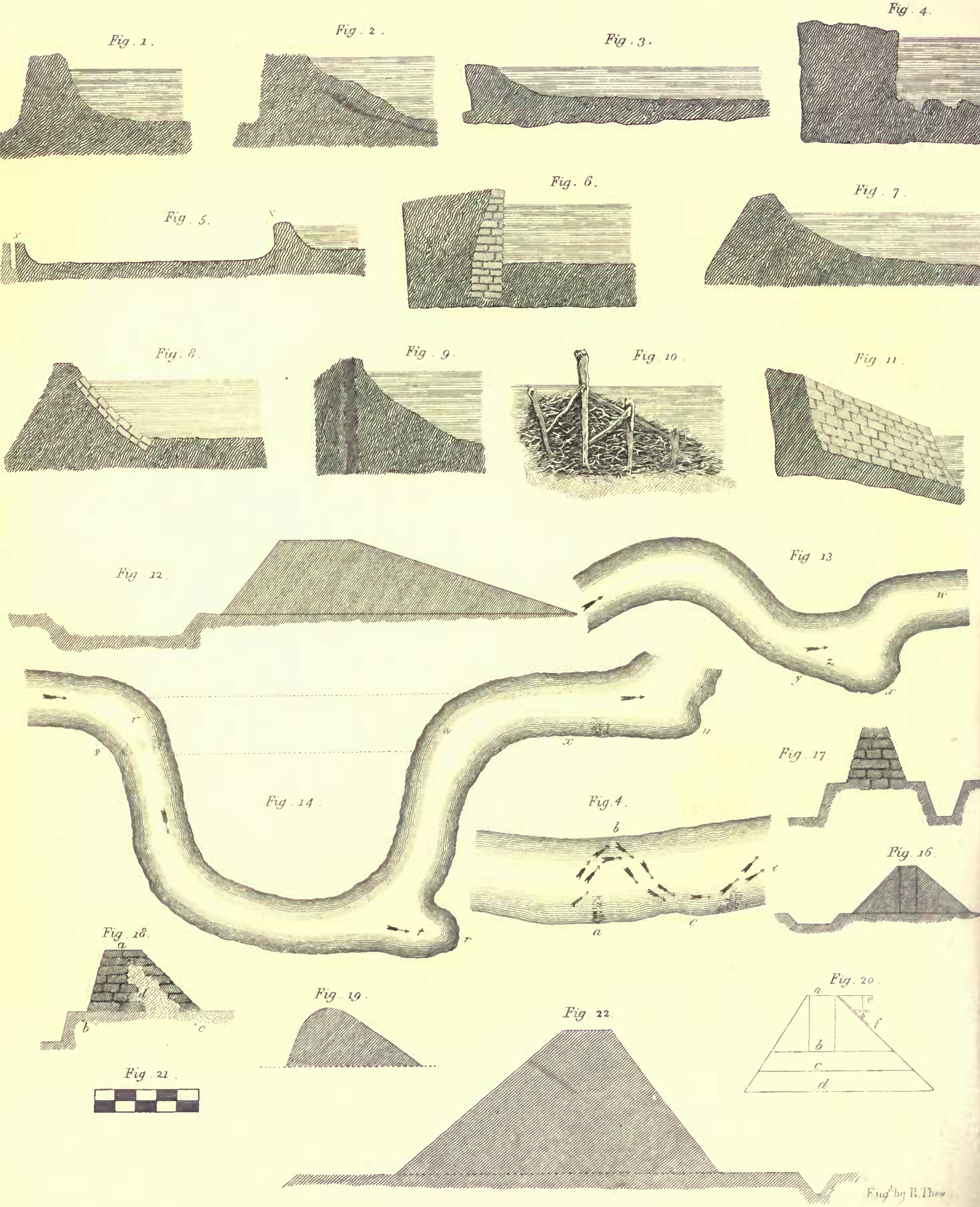
Where it is proposed to reclaim a piece of land, upon which the sea ebbs and flows every tide, to a greater depth than in the foregoing case, as in a creek, or on the side of a large river, a different mode of proceeding must be pursued, according to the soil, and the nature of the materials to be employed. Where plenty of stones can be readily procured, a bank may be formed of them, with a mixture of clay, either by means of land-carriage, or, which in some instances is better, by conveying them in flat-bottomed boats, or punts, and throwing them over-board until the bank is formed. Where stones cannot be easily had, clay, or other materials proper for the business, may be thrown in, in sufficient quantity, in the same manner, with perhaps nearly equal success. It is supposed that most of the embankments in Holland were formed in this way, the clay dug from the canals being made use of for the purpose. In either case it is requisite to fix up strong poles before the work is begun, as guides for laying down the materials. Proper sluices must likewise be laid in suitable direction for taking off the back-water when the tide ebbs, under the inspection of the engineer. Much, in all cases of this sort, depends on a skilful engineer, who is capable of suggesting and contriving various means of facilitating the business, and of obviating the difficulties that may arise in its execution. A person of real genius is often capable, by his different contrivances, of rendering the accomplishment of a great undertaking comparatively easy, which to others would be almost impracticable, or carried on at such a heavy expense as to counterbalance the advantages to be drawn from it. In cases of the kind just noticed, he might suggest the erection of stages or platforms, in such a manner as to carry on the work at all times of the tide, which would be an immense saving, as the delays caused by the tides in this sort of business are both tedious and expensive. Waggons might likewise be contrived in such a way as to carry on such platforms large quantities of materials at once, which could be easily emptied and filled; and at the same time be drawn by machinery, in such a manner as to save much labour and expense, both in carriage and tidework.

There is another species of sea embankment, which is, perhaps, the most important of any; as there are few estuaries, or mouths of rivers, in which large tracts of land may not be gained by it. The shoals or flats formed at the entrance of such rivers, are mostly composed of the richest and most fertilizing particles, brought down from the towns and circumjacent country through which they pass. Such shoals and flats may, therefore, under proper management be in most cases readily converted into the most fertile plains. In these situations the first object is that of collecting the whole river into one stream, and preventing its overspreading a wider extent than is merely sufficient for its discharge; or it may be better, perhaps, to alter its course altogether, and cause it to be discharged at some other outlet. It has been found by experience, that where the course of a river is changed in such a manner as to make it discharge itself into the sea at a different place to that where it did before, the former place will in a few years, by the continued accumulation of sand and mud brought in at every tide, be so choked up, and raised above its former level, as to form of itself, in the course of time, a bank, that with a very little assistance, will exclude the sea; for as the current of the river before carried away all that sediment which the motion of the waves naturally stirred up, from its being now removed, it is obvious that all or most of the muddiness will not only be carried farther up the old channel of the river, but a great part of it be deposited there as the tide recedes. It has been found that in spring-tides and particular winds, this sediment is deposited in larger quantities than at other times, and on making a perpendicular cut in the ground under reclamation, the different layers are found to be so distinct, that those made at spring-tides can be easily distinguished from the rest. This curious fact is well deserving of the attention of all those who have lands situated at the mouth of rivers, as there may in many such situations be considerable tracts gained at a very light expense. But though this fact may exist in some places, as has been proved by experience, nevertheless it is supposed that the effect cannot be the same in all situations. Where there is a great extent of flat or muddy shores, the motion of the waves will no doubt stir up the mud and sand, and carry great quantities of them along with the current on the flowing of the tide; and when the tide ebbs, though some of the lighter particles will be carried away again, yet it is reasonable to suppose the heavier ones will be left behind. If the shores are bold and rocky except just near the entrance of the river, there will be less of this mud; but on such shores there can, indeed, be little or no occasion for embanking, unless perhaps in some creeks, narrow at the entrance and spreading out wide above. If the sea were excluded from such creeks, a great deal of land might probably be gained.

In the marshland district of the county of Norfolk, lying between the rivers Wyn and Ouse, immense tracts of the most rich land, such as is composed of the muddy depositions left by the tides and floods, which is there called *silting*, have been obtained by means of embanking. This kind of work has sometimes been undertaken by the tenants on a low piece of marsh, in consideration of having the land free for twenty-one years. But in these cases the banks have often been very

EMBANKMENTS

PLATE .



Engd by R. Thew

imperfectly made, not having cost more than forty shillings a rod. And those which were constructed by the landlords were indeed frequently but little better, being mostly deficient in not having slope enough given them towards the water. Count Bentinck, and his son, who succeeded him in the estates, undertook the drainage of the marsh lands upon a scale never practised in that part of the island before, and by their successful operations have increased the old estates by more than 1,000 acres.

The base of the embankment, in this case, is about 50 feet, the slope to the sea 36 feet, forming an angle, of about 25 or 30 degrees. The crown is 4 feet in width, and the slope to the fields 17 feet, in an angle of about 50 degrees; the slope towards the sea being very nearly turfed over. The first expense incurred in forming this bank was £4 per rod, but a very high tide coming before it was finished, not only made several breaches, but occasioned an additional height and slope to be given to several different parts, in order to bring it to the dimensions mentioned above, all of which made the gross expense to amount to about £5 the rod. The whole cost was something more than £5,000. The expense of the houses, farm buildings, and other things, was about as much more, for five new farms, which was a greater expense than was necessary, as the land would have let as well in two or three as five farms. Supposing, therefore, the expense at £10,000 and the new rental at £1,000 a year, it is just 10 per cent for the capital laid out. The expense here, however, seems to have run too high, when the necessary repairs of the bank are taken into the account. The representation, given at *Figure* 22, in the Plate, fully explains the nature of the embankment formed in this case.

In another new embankment, in which 273 acres of marsh land, and 18 of bank, were gained, the men were paid 4s. 6d. a floor of 400 cubical feet, finding wheeling planks, barrows, trussels, &c. When it is thus formed, the front slope is sodded, for which they are paid in addition 4s. a floor of 400 square feet, earning from 5s. 6d. to 7s. a day, and there is some little further expense necessary for beating it down in a firm manner. The whole of the expense of the bank, sluice, and every thing else, was about £3,300. The land was immediately offered to be rented at four pounds an acre for four years, or three pounds an acre for six years; which, in the former case, would amount to £4,368 in that length of time, or 1,000 guineas more than the whole of the capital laid out on the undertaking.

On this coast the operation of *silting* up, or raising the surface of the marsh-land by the repeated depositions of muddy matters from the sea, is performed in a more rapid manner than in many others; and the little hollows and creeks are found from experience to silt up much faster where the tide-waters are speedily taken off by proper cuts and channels formed for the purpose, than where the contrary is the case.

One of the most extensive reclamations of land in England, is the large tract of country known by the name of the Great Bedford Level. This great expanse of rich and fertile country is bounded by the high lands of the counties of Norfolk, Suffolk, Cambridge, Huntington, Northampton, Lincoln, and the Isle of Ely, and contains upwards of 300,000 acres of fen-land, beyond which are about a dozen very large marshes also similarly reclaimed. The drainage of the whole level is effected by innumerable dikes and drains of all sizes communicating with, or gathered together into three great channels, forming the main outfalls into the sea. One of these outfalls is at Boston, in Lincolnshire; one at Wisbeach, in Cambridgeshire; and the other at Lynn Regis, in Norfolk.

In Holland, however, is exhibited the most prominent illustration of the successful redemption of land from the sea; and probably in no part of the world has it been carried to so great an extent. Indeed, the whole country has been rescued, as it were, from the waves of the ocean, and has been secured and held only by the constant care and superintendence of the persevering conquerors.

There is little doubt that the inhabitants of Holland were obliged, in the first instance for their own preservation, to erect barriers against the encroachments of the sea. On the invasion of their country by the Danes and Normans, the latter soon discovered the superiority of these lands to those adjacent to them, and at once applied all their energies to the proper reclaiming of so fertile a property. Thus, by the steady perseverance of ages, has Holland become pre-eminent for the extent of her drainage works, though the manner in which their embankments are constructed is very far from equal to similar works executed in this country. It is said by those who have made it their business to examine the mode of making these banks, that in those made of stone, the materials are not economically distributed, but are heaped so confusedly on each other, as not only to weaken the bank, but occasion great waste. They have, however, a very ingenious method of facing their banks where there is a scarcity of stone, with straw, formed into ropes, about an inch or two in thickness, laid in regular courses. These courses fit closely together from top to bottom, and are fastened down to the bank with wooden *falks*.

In Ireland the attempt to bring into cultivation the immense tracts of bogs or flats partially covered with water, a few years ago attracted the public attention; and a board of commissioners was appointed to inquire into the nature and extent of the bogs in Ireland, and the practicability of reclaiming them.

These commissioners have published reports containing much interesting and instructive matter, exhibiting the present state of the wastes in certain districts, and evincing clearly the practicability of converting them at a comparatively small expense, into rich arable and pasture land.

On the north and west coasts of Ireland there are a great number of deep bays or inlets of the sea, presenting great facilities for embanking. Amongst these the estuaries called Lough Swilly and Lough Foyle, in the counties of Donegal and Derry, seemed to offer to some enterprising speculators a tract of land peculiarly adapted for embanking.

Sir John Macneill having been consulted on the scheme for the drainage of these loughs, employed Mr. J. W. Bazalzette to make the necessary surveys for the purpose, and the latter has furnished to the Institution of Civil Engineers a valuable paper on the subject from which the following observations have been extracted.

Lough Foyle is described by Mr. Bazalzette, as not entirely insulated from the Irish Channel, but as having a narrow mouth communicating with it. Above this mouth the waters spread over a wide tract of land, and then again contract into a narrow channel. The effect of the tide rising through so small a passage has been to scour the *narrows*, and throw up the deposits on the sides of the Lough. By the accumulations of years these deposits have at last become immense banks of rich alluvial soil extending for some miles and covered only at high water. To reclaim this land it was proposed to construct an embankment or sea-wall, a little below low-water mark, for fourteen miles in length, by which about 25,000 acres of land would be enclosed.

Lough Swilly is less extensive than Lough Foyle, but presents greater difficulty in the construction of the works, from the scarcity of the necessary materials. It is wider at its mouth (which opens into the Western Ocean,) than in any other part, and in its whole extent is extremely exposed to the winds. It was proposed to construct here three embankments, the first 1,100 yards, the second 1,133 yards, and the third 633 yards in length. The position of these banks being fixed by careful measurements and soundings, the proposed method of formation was as follows :

Each bank was to be 4 feet in perpendicular height above the highest spring-tides, which here rise to 18 feet : and to have a slope on the sea-face of 3 to 1, except in the most exposed part, where the slope was to be 4 to 1. The materials available for the work were stone, clay, earth and gravel, taken from the adjoining lands, and the banks were to be faced with rough stones on both sides, laid as close as possible with the edge outwards, in courses not exceeding 4 feet in height. In the centre of each bank was to be built a culvert of masonry, with proper sluices and flood-gates. These culverts were to rest on a foundation made by driving piles into the soil, which from its alluvial character could not be depended upon in itself. The sluices being self-acting, the drainage would be effected in the following manner. At high water, it being supposed that the whole of the *slob* (as it is termed in Ireland,) is covered on the receding of the tidal water, the sluices would shut of themselves, retaining the water within the banks. When the flood-tide came on, the pressure on the sluice-gates from within, would prevent their opening to admit it, and the retained water would soon evaporate, leaving the rich slob dry, and to be in a short time fit for agricultural purposes.

The extent of the slob thus enclosed by these three walls would be about 2,000 acres, and the value of it may be estimated by the fact that a large quantity of land has already been reclaimed near this part of the Lough. This land now lets at £5 per acre, and is considered the richest soil in the neighbourhood. Indeed, in every case, where a proper selection of land has been made, and the works performed judiciously, similar success has been the result.

It has been remarked by Mr. Beatson, whose observations on this subject we have before noticed, that in the lakes or *mires* of the north, and the *Loughs* of Scotland and Ireland, the business of embanking is both simple and easy. In these situations the waters generally subside during the summer months, rising considerably in winter, and whenever the season is very wet. In particular cases the extent of surface which is overflown in the winter season, so far exceeds that which it covers during the summer, that it would be an object, and sometimes a considerable acquisition, to confine the water within its summer boundaries, or to cut off some of its parts. To accomplish this the principal outlet must be carefully examined, and be considerably widened and enlarged; which will prevent the water from rising so high as was formerly the case. Where the levels will not admit of much depth being had, or where the ground is of a rocky nature, and would of course be difficult and expensive to deepen, the breadth should be increased as much as possible, and all obstacles cleared away, that the water may run freely in a shallow stream. Where it is required to ascertain with exactness, or, to fix with certainty, the future limits of the water, a section of the greatest quality running out during a flood should be taken. Suppose this section, for example, be 10 feet in width and 4 feet in depth, by making it 40 feet in width, the same quantity of water will not rise above 1 foot : consequently, by this means alone, 3 feet in height will be gained all round the lake, which, in case of embanking it, would be a great object. During the summer season, when the water is lowest, is the most proper time for carrying on these, as well as other embankments. When, however, any materials are to be brought from a distance, they may be laid down, or prepared at other seasons, with the exception of turf, which should always be used as soon as possible after it is cut. The manner of constructing embankments of this kind may be sufficiently understood, from what has already been said in the other description of embankments: observing, however, as a general rule, that when the materials on the spot will answer the purpose, they should invariably be made use of, although at the expense of digging a trench larger and deeper than would otherwise be necessary. It should constantly be attended to, in executing all sorts of embankments, that the greatest care be taken to make them perfectly firm and solid, by continually beating them, and examining them carefully, during the whole of the time they are in a state of being formed.

The following account of embankments on the Continent, is taken from the "Dictionary of Terms of Art," part of the very useful rudimentary treatises published by Mr. Weale.

"On the banks of the Po, two sorts of dykes are used to prevent the river from overflowing during the winter, or the flood season. They are called 'in froldi,' when immediately upon the banks of the river, and 'in golene,' when at any considerable distance, as it is sometimes found advisable to allow the river to spread over a large surface of the adjacent valley, either for the purpose of admitting it to deposit the mud in suspension, or to allow it to lose its torrental character. The maintenance of the works of these dikes is confided to the government engineers, who are under the control of a syndicate of the proprietors of the property most liable to be affected by inundations. When the river passes from one state to another, as from Piedmont to Modena, a mixed commission is charged with the joint superintendence.

"The Haarlem lake, besides the very remarkable steam-engines described by Mr. Dempsey, merits observation for the extensive works executed for the defence of the land, and for the canals reserved for the navigation. The enclosure dike is 50,000 metres long, or rather more than 31 miles. It has two outfall dikes, which serve for the navigation, 9,000 metres, about 5½ miles ; one half of which is 40^{m} (131 feet 2 inch) wide at the bottom or floor line ; the other 43^{m} 20 (141 feet 10 inches.)

"The ordinary tides are at the flux, 2 feet 4 inches above the scale or datum line at Amsterdam ; at the reflux 2 feet 8 inches below the same datum : the difference between high and low water is then, on the average, about 5 feet. With violent winds from the N. W., however, the tides rise sometimes 6 feet 6 inches above the average. The tides of the Y, near the lake, are $+ 16^{c}$ (or 6½ inches) and -23^{c} (or 9 inches), giving a total variation of 1 foot 3½ inches.

"The estimated cost of reclaiming the 18,000 hectares, was 8,000,000 of florins, or £667,000 English, nearly about £13 per acre. Previously to undertaking this colossal work, the Zind Plas, of 4,000 hectares superficial, (nearly 11,500 acres) had been reclaimed at a cost of 3,000,000 of florins, or £250,000 ; not far from £22 per acre. The heights of the enclosure dike are + or — the datum line at Amsterdam, or the mean level of the sea in that port.

Embankment of the flooded part of the Amsterdam and Haarlem railway.—The bottom part consists of treble ranges of fascines, tied down by longitudinal poles 1 metre apart from centre to centre, and 0.25^{c} diameter; two double stakes at each end of the poles, and two ties in the intermediate distances. The interstices of the fascines and the space between the rows, are filled in with sand. The upper part, forming the encasement for the ballast, is made of three rows of treble fascines, well staked and wattled together.

"A core of sand or clay, faced with step fascines, is made up to low-water mark. Upon this a bed of rushes, fastened down by stakes and wattles, is laid; and the upper portion of the bank is faced with fascines of a regular slope of 1 to 1."

Embankments against rivers may be divided into two kinds; namely, such as are for preventing their encroaching on the adjacent lands, and for protecting those lands and the neighbouring level country from being overflown, when the water rises above its ordinary level. It may be remarked, that where the course of a river is a straight line, or nearly so, it hardly ever makes any encroachment upon its banks, unless, perhaps, in very large rivers, when they rise above their common level, either owing to an increase in the waters, or to their being, in some degree, affected by the tides. In either case, the waves occasioned by a strong wind, where the river is wide, will moulder away the banks on that side upon which it blows, unless prevented in proper time. This may be done either by securing the bank properly with stones, or by driving a row of long piles pretty close together at a little distance from the shore, the piles being of such a length, and so driven, that their tops may be always above the highest rise of the water. It is surprising the effect that piles driven in this manner have in resisting the power of the waves in such situations.

Some years ago, when Mr. Beatson was on duty as an engineer at a fort near Portsmouth, built on a point of land much exposed to the sea, the waves made such havoc, that the walls on that side were constantly giving way, although built in the most substantial manner; and having bulwarks of large heavy stone besides, to protect the foundation: however, all would not do; those bulwarks were soon knocked to pieces, and several times the wall itself. At length it was proposed to drive a number of piles at about 40 or 50 yards from the fort. These piles were 12 or 15 inches in diameter, and driven about one diameter from each other nearly in a straight line, parallel to the wall where the waves did so much damage. They were driven into the ground with a pile-engine till perfectly firm, perhaps 8 or 9 feet deep, and about 2 feet or the top of them left above the level of high-water mark. After this was done, the wall received no farther injury, the space between the piles and the fort being always perfectly smooth, however tempestuous the waves might be without. The same simple method might, it is supposed, sometimes protect the banks of large rivers, if exposed to the waves, when other methods might fail.

But it is suggested, that the most common cause of rivers encroaching on their banks, is the resistance occasioned by a sudden bend. In flat countries, apt sometimes to be overflown, where there are any such bends or windings in the rivers, it would be of great advantage to straighten the course as much as possible; for, as every impediment or obstruction will naturally cause the water to rise higher than it otherwise would do, and as such bends have that effect, consequently, in the time of a flood the waters will overflow a greater extent of country, and to a greater depth, than if the river had a free and uninterrupted course straight forward. If the windings of the river cannot be altered, and encroachments are making on some part of the banks, it must first be considered, whether the force of the water can be driven to another place where no injury can be done. If, for example, a river is encroaching on its banks at *x*, *Figure* 13, a jetty of stone, a little way up the river, in the direction *y z*, would throw off the current towards *w*, and might totally prevent any farther encroachment. On the river Nith, in Dumfriesshire, it is stated, that a good deal has been done in this way by Mr. Millar, of Dalswinton, a gentleman of the most enterprising genius and most liberal mind, who has paid more attention, and laid out more money, in making important and useful experiments, than almost any other private individual. The course of the river, where Mr. Millar has been carrying on his operations, is said to be nearly as shown at *Figure* 14, by *r s t u;* at *t*, it was encroaching most rapidly, and seemed inclined to take a new course towards *v*, which would have destroyed some very fine land, and done a great deal of mischief in that part of the country. To prevent this, Mr. Millar made a large cut, about 400 yards in length, from *w* to *r*, and threw in a great quantity of stones quite across the river at *s*, to direct its course in a straight line from *r* to *w*. This had, in a great measure, the desired effect, by totally preventing its progress at *t*, but now it began to encroach on its banks at *u*. He at first endeavoured to prevent this by driving in, at a considerable expense, a number of piles at a little distance from the bank, and wattled them with willow branches, &c., thinking thereby to protect the bank. The piles were driven in with heavy mallets, apparently firm into the ground; they continued so for some months, till a heavy fall of rain came on, which swelled the river, undermined the piles, and carried them all away. But, indeed, it is in vain to think of piles doing any good in such a situation, unless firmly driven in by a pile-engine; for it is not possible to drive them in properly with mallets; this must have been the cause of their giving way so soon. The piles not succeeding, Mr. Millar was resolved to try another plan; several of his adjacent fields being covered with an immense quantity of stones, he ordered them to be gathered and thrown into the river, so as to form a jetty at *x*, a little way above the injured bank. Being obliged to go from home about that time, and to leave the execution of the work to some country-people, they carried out this jetty too much at right angles to the stream. It had not, therefore, the desired effect, but rather made the matter worse than before; for, if a jetty is carried out at right angles, as at *a*, in *Figure* 4, the current will be forced from *a* to the opposite side of the river at *b*, and from thence it will rebound towards *c*, more violently that it did before. But if a jetty be placed obliquely, as at *d*, it will force the current gradually towards *e*, in which position one jetty may do more good than several placed improperly at right angles. Mr. Millar was, therefore, under the necessity of making other jetties in this way, and at length had the satisfaction to find that they answered the purpose intended. Those he made laterally formed a sort of convex slope, the convexity being parallel to the current. Strong planks were also firmly set on edge among the stones, their ends pointing towards the river, so that if ever any current came so rapidly as to move any of the stones, it must move them all in a body the whole length of the plank. Perhaps this precaution was unnecessary; for although stones are thrown into a river loose in this manner, the slush, sand, &c., that come down the river will soon fill up all the cavities, and render it as firm and solid as a regular-built wall. Mr Beatson has been the more particular in this description, he says, in order to show the errors that Mr. Millar at first fell into, and the great expense they occasioned, whereas, had he been on the spot himself, and got the work executed as he intended, it would have saved a great deal of unnecessary labour as well as money.

It is stated by the same writer, that the next sort of embankments against rivers, are those to prevent them overflowing their banks, and inundating large tracts of country. This may be considered as the simplest and easiest of all sorts of embanking, if judiciously executed. It is, therefore, the more inexcusable to see, in some places, extensive tracts of the richest meadows completely overflown by every flood, for want of them.

Two ordinary-sized rivers rise no more, even in the greatest flood, than five or six feet above their common level, unless when they meet with some considerable interruption or confinement in their course. But if interrupted or confined, they will rise twenty feet or more, as is the case with some parts of the river Mersey, already mentioned. If, for example, a given quantity of water is six feet deep, when running over a space twenty feet wide, it is clear, if that space were only made ten feet wide, the water would rise to twelve feet, and if it were made forty feet wide, the same quantity of water would only rise to the height of three feet. It is, therefore, of great consequence, in preventing inundations, to give the river as much width as possible, by widening every narrow place. All kinds of obstructions should also be removed, whether occasioned by windings, shoals, stones, trees, bushes, or anything else. In some cases this may even preclude the necessity of embanking; but where embanking is necessary, let the banks by all means be at a sufficient distance from each other, to contain with ease, between them, the largest contents of the river in great floods. The distance and height of the banks may easily be ascertained by measuring a section of the river when at its highest, or when the flood-mark is visible. By not attending to this, a great deal of money has been thrown away on the embankments on the river Mersey, and after all they do not effectually answer the intended purpose; a great part of the country being still overflown every time the river rises to any considerable height.

Where a sufficient distance is allowed between the embankments, their height need not exceed from four to six feet. If irremoveable obstacles are in the way, which cause the river to rise higher, the banks must be higher in proportion. In either case, however, the slope of these kinds of banks on each side may be equal to its perpendicular height, and the breadth on the top about one-third of that height, which, supposing the bank six feet high, the base would be fourteen feet, and the breadth of the top two feet, as shown at *Figure* 16, in the Plate.

The materials for making these banks should be taken as much as possible from the sides of the river, which will have the double effect of widening the river and forming the embankments; and there should be a trench on the inside (from which materials may also be got) with some sluices, as formerly directed, to drain off any water from within; also sluices to let in water from the river, if required, which would very much fertilize the meadows, if properly laid out for that purpose.

Such farms as are situated on the borders of rivers are frequently, it was observed by a late writer, liable to much injury and inconvenience from them: 1st. From part of the soil being carried away in times of flood. 2nd. From their overflowing their banks. 3rd. From their flowing back in times of flood into the channels of the rivulets and streams that conduct the water from the more elevated and distant grounds to the rivers, whereby these rivulets and streams are made also to overflow their banks.

In respect to the first, the danger of the soil being carried away in time of floods, it is increased or decreased according to circumstances, as the form of the banks, the nature of the soil, the rapidity of the river, and the quantity of water that lodges on the margins of the banks, or falls over them into the river. Where the banks of a river are perpendicular, especially if the soil be of a rich mouldering nature, the danger of part of them being carried away by floods is much greater than where they slope gently from the surface of the field to the bed of the river, as has been already fully seen.

Where that is not the case naturally, they ought to be moulded into that form by art; as when a river, in place of being confined in its progress, has a power of efflux and reflux, the damage to be apprehended is inconsiderable, compared with what is likely to happen when, being restrained within too narrow limits, it is constantly struggling for an extension of space. Where the soil is rich free mould, and the under stratum, opposite to the greatest force of the water, sand or gravel, this struggle never fails to be attended with bad consequences. If the soil and subsoil be one entire mass of clay or strong loam, and the current of the river does not press more upon one part than another, a most substantial improvement may be effected by sloping the bank, so that the declivity may be one foot in three or four from the surface of the field to the bed of the river. This some may object to, as sacrificing a certain portion of valuable land; but it should rather, it is thought, be considered as a premium paid for the insurance of the remainder, than as a total loss. If gravel, mixed with small stones, can be conveniently procured, spreading these materials on the sloping bank to the depth of eight or ten inches, and till beyond the flowings of the river, will prove a good security against farther damage; and if the bank be planted thick with any sort of willow, especially the Dutch willow, it will in a short time become an impenetrable fence, while the annual cuttings of wood will soon be equal to the heritable value of the land thus apparently sacrificed. Where no gravel can be procured, the new sloped bank should be immediately covered with well swarded turf, pressed down as hard as possible, either with the back of a spade, or with wooden mallets. If this be done in the beginning of summer, and willows planted the following autumn, the improvement will be both effectual and permanent. In case the river run with extraordinary violence against any one particular part of the bank, it may be necessary to make a fence or bulwark of stone in the front of that place; the best way of doing which, is, in place of building a wall, to drop the stones in a careless manner, but so as they may lie close together on the sloped bank, as already suggested.

This is a much more secure mode of fencing, if the bank be made with sufficient declivity, than any stone wall that ever was built for the purpose, and while it is the most secure, it is also the least expensive; but care should be taken to lay the stones all the way from the bed of the river, till considerably beyond where the river flows in common. Where the soil is of a strong adhesive nature, and the under stratum is sand or a pebbly gravel, it becomes in a much greater degree necessary to slope the banks. The water, when rushing violently along, has a powerful effect in undermining the bank; so that the soil, having nothing to support it, naturally gives way, and frequently in such quantities as to occasion very serious loss both to proprietors and tenants. In all such cases, the slope should be made much more gradual than where the soil and subsoil are of the same quality, and such as will nourish aquatic plants. The banks, having been sloped according as circumstances require, a thick coat of gravel, mixed with small stones, where such can be procured, should be laid on, so as to form a kind of natural beach, over which the river, when in flood, may have power to extend itself at pleasure. Should it be difficult or impossible to procure such materials as are proper for forming this best of all defences, strong thick sods should be placed on the surface, in the manner before directed: these, if laid on in spring, or early in summer, will have time to unite, and to become one compact body before the autumnal floods (which are those whence the greatest danger is to be expected) begin to flow. If the subsoil be of a nature unfavourable to the growth of willows, such sods as are full of the roots of rushes should be made choice of in preference to all others; as, where these plants thrive and spread over the surface, it becomes in a great degree impenetrable by water, even in great floods, and when the river runs with considererable violence and rapidity.

The directions above given will, it is supposed, be found more or less practicable and useful according as the river on ordinary occasions runs with greater or less rapidity. In level, or nearly level districts, all that is necessary is to secure full scope for the rivers to overflow their usual bounds without interruption; when that is secured by either of the methods before mentioned, floods, unless very violent, seldom do any material damage to the banks of rivers in such situations. It becomes in many cases extremely difficult to fence rapid running rivers in such a manner as to prevent part of the banks from being carried away by inundation. Sloping the banks would be attended with no good consequences. Even strong bulwarks made of stone are often swept away by the overpowering flood. A method has, however, been suggested, of fencing the sides of a rapid running river, which has been practised with success, after several other attempts had failed: it is by means of a sort of large baskets, provincially termed *creels*, formed of hazel, willow, &c., into a kind of open network, which being placed along the bottom of the banks, are filled with stones. This is a very simple, and by no means an expensive expedient; and as these baskets may be made to contain two or three tons of stone, it can only be on few occasions, and in very particular situations, that a basket, containing such a weight, can be displaced or carried away. Such a mode of fencing as this, it is imagined, would prove effectual in many parts of Scotland and Wales, where the rivers run with uncommon rapidity. Owing to inattention, or rather to not being aware of the consequences, much damage is often done to the banks of rivers in level districts, especially if the banks be perpendicular, and of a considerable height, by allowing the land-floods to fall over them into the river. As the water from the furrows approaches the bank, it is frequently stopped in the furrow of the head ridge, which becomes for a time a kind of reservoir; the consequence of which is, that a considerable proportion of water sinks and filters through the earth, which being thus softened and swelled, is more easily undermined and carried off by the river. Sometimes little cuts or openings are made for the furrows across the head ridge, for the purpose of conducting the rain-water into the river; here, again, the consequences are equally bad. Whoever will examine the bank of a river where this mode of management is adopted, and it is very common, will observe, that at every one of these cuts or openings a little creek is formed, in consequence of the bank having been more softened, and by that means having become a more easy prey to the river when in flood. To prevent these evils, it is necessary, besides sloping the banks, to devote a part of the lands adjoining, to the breadth of 20 or 30 yards, for instance, either to pasturage or the growth of trees, and to form a drain at a proper distance from, and parallel to the bank, for the purpose of collecting and carrying off the water from the furrows. Were this done, and were the water from this drain conducted into the river by conduits formed a little above its ordinary level, much land, which is annually lost by neglecting this simple precaution, would be saved, and preserved in a proper state.

In the second case, it is evident that injuries, although of another nature, are often sustained by farmers, from rivers overflowing their banks. Sometimes the farmer is prevented from sowing his field; at other times the crops of grain and grass are greatly injured, by being covered for a considerable time with water; and at others again, the whole produce of the year, the hay and corn crops, are swept away. To prevent evils so complicated, and so serious in their nature, is certainly the business of every man, who, from the situation of his farm, has reason to apprehend, that, without using proper precautions, he may be subjected to such visitations. These damages can only happen in level tracts, where the banks of the rivers are low, and where the course is not of sufficient breadth to contain the water in time of flood. Some people, although very improperly, raise mounds of earth close to the top of the bank, and of a height exceeding that to which the river can be expected at any time to rise. These mounds, from being placed so near the river, are unable to resist the pressure of the water, and by giving way, frequently admit a current into the fields, which proves much more injurious in its course than if no mound whatever had been erected. Were a mound of earth formed on the side of the drain, proposed to be made for carrying off the land-water, and were that mound well sloped on the side towards the river, it would be the most secure and effectual guard against rivers doing injury to the adjoining lands, of any that could be adopted. By these mounds being placed at a distance from the river, the force of the stream would be much lessened, and the natural boundaries of the river greatly enlarged; as, in proportion as the mounds are removed from the centre of the current of the river, in like proportion will they become more secure, as being less liable to violent pressure. The propriety of erecting these mounds at a proper distance must, therefore, be sufficiently evident; as, when mounds are erected near the top of the bank, which can only be owing to ill-judged parsimony, they form as it were a part of the bank, and are liable to be undermined and swept away. Whereas, when they are placed at the distance of 20, 30, or 40 yards, they serve rather as a boundary to confine the overflowing waters which glide along the bottom, than as a barrier to prevent the encroachments of an impetuous river during the time of floods.

In regard to the third case, it is observed, that farmers who possess lands in low situations often sustain damage from rivers, in time of flood, by their flowing back into the channels of the rivulets and streams that conduct the water from the more distant and elevated grounds to the rivers, whereby these rivulets and streams are made also to overflow their banks.

The only precaution that can be adopted, in such a case, or at least the one which appears to have the greatest probability of answering the purpose, is to erect mounds at a distance from the banks, and of a size proportioned to the quantity of water, which, from the cause now mentioned, may be supposed at any time to stagnate in these channels. This may be done at a very trifling expense either in money or land. If the proprietors do not choose to ornament the country and improve their own estates, by planting trees on the borders of the rivulets and streams, the farmers may so construct these mounds, as that they may become fences to their arable fields, while that portion of the farm, necessarily and properly cut off for the protection of the remainder, may be devoted to pasturage.

Several different embankments of a successful kind have been effected in the northern parts of the kingdom. An important work of this nature was some years since executed on the estate of Lord Galloway, situated on the mouth of the river Cree, near Cree-town, by his lordship's tenant, Mr. Thomas Hannay, who states, in the third volume of the "Farmer's Magazine," that at the time he entered on the farm, upwards of 100 Scottish statute acres were regularly flooded by the highest spring-tides, excepting about three months in summer, when the tides were lower. They were seldom, however, covered above the depth of one or two feet, and never above four or five. Eighty acres of the above consisted of a rich sea marsh, or *ings*, as they call them there, almost a true level, excepting where hollows were formed by the egress and regress of the tides, and the passage of fresh water from the higher grounds; and about 4 or 5 acres, which were about 16 inches lower, being a younger marsh, and nothing but what they call ink-grass growing upon it; other grasses, such as clover, rib-grass, &c., grew on the rest of the marsh, forming a very beautiful close cover in the summer. The other 20 acres were on an average about 18 inches higher; consequently the sea did not cover them so often. It had formerly been ploughed, but not for about 20 years past. Last time it was in corn, it was flooded immediately after being sown, which rendered the crop almost entirely useless, and deterred former tenants from ploughing it again. Mr. Hannay began to bank this field in the autumn of the year 1798, by making a dike along the side opposite to the river, in a direct line facing the east. This dike was made, at an average, about 3½ feet high, and 6 feet broad at bottom, and 20 inches at top, built after the same manner with that mentioned below. He enclosed, along with the said fields, he says, 4 acres of the marsh adjoining, by making a dike 5 feet high, and 5 feet in bottom, almost wholly of solid feals or sods, with a very little stuff, properly beat, in the heart of it, which makes an excellent fence, and promises to be a very durable one. This dike, together with two small drains, one on each side of it, about two feet deep, cost 3d. per yard. The division-dikes of the whole marsh, which now, divided into 4 parts, are all built after the same manner, only that there is no loose stuff in the heart of some of them, but all of solid feal, jointed like bricks, as may be seen at *Figure* 17, which represents an end view, or section of it. This dike, meant as a permanent fence, answered as a temporary bank, and enabled him to plough that field in spring, 1799, although the bank round the whole marsh was not finished till the winter following. He sowed oats on this field, and, considering the badness of the season, had a very good crop; particularly so on that part which had not been ploughed formerly. On farther consideration, he altered the plan of the bank round the marsh, (which extends in a circular direction facing the north) by making it, at an average, about four feet and a half high, and allowing about two feet in the base for one in height, as at *Figure* 18, where *a b c* represents an end view, or section of it, every small span representing the section of a feal or sod; *a b* shows the inside of the bank, with the green side of the feal down; *b c* the base; *a c* the side next the water, with the green side of the feal out, (which adds greatly both to the strength and beauty of the bank;) and *d* the heart of the dike, made up with stuff properly compressed with a rammer. The stuff was taken from a ditch, in the inside of the bank, leaving a casement of a foot, which ought to have been three at least; and, where the ground is of a sandy nature, more; as the fresh water, running in the inside, was likely to undermine the bank, had he not prevented it, by cutting a new drain, and filling the old one with the stuff cast from it. The only creek worth noticing, through which the bank passed, was about 40 feet wide and 9 feet deep, in the bottom of which a wooden pipe, with a stopper, was laid through the bank.

There are now about 50 acres of the same kind of marsh-land adjoining his; and also about 100 acres on the other side of the river, banked in, all nearly in the same manner as represented in the figure. The bank on a farm on the side of the river opposite to his, was made almost a complete wreck, by an extraordinary tide, owing to its lying quite exposed to the south-west winds, which always send up the highest tides; but on his side, though suffering some injury from the same high tide, he was not affected by those winds, as they blew right over the bank. In his opinion, the bank on the other side of the river, in order to be durable, would require to be 30 feet broad, and 8 feet high, covered with feals, with the green side out; and that no stuff should be lifted within 6 or 7 feet of it, the ground being of a sandy nature. It might be made after the form shown at *Figure* 19. The whole of this turned out most excellent land, and continues to produce to this day some of the finest crops in that part of the country.

Another improvement of the same nature was accomplished on what in Scotland is termed *carse land*, on the farm of Netherton of Grange, belonging to James Peterkin, Esq., by Mr. John Hoyes, his tenant. The work was undertaken under an agreement with the proprietor, to allow one year's rent, of £195 sterling, with the farther allowance of ameliorating the farm-houses to the extent of £150 more. The method adopted for carrying on the operations was this:—After looking over the carse, and marking out the line or dike, the length of which is 1,400 yards, mostly in a right line, except an angle at the distance of 300 yards from the west end, and a segment of a circle at about 250 from the south-east end, it was resolved to make the embankment 6 feet high in the highest part of the ground, and to allow 2 feet of breadth in the bottom of every foot in height, as seen by the draught of the mould at *Figure* 20. After taking the level of the carse, it was found that where the ground was low, and a good deal of it broken by runs of the sea and outlets for the water, the dike would require to be 8 and 10 feet high, to have it on a level at the top; so that the average would be 9 feet high. The embankment was built in the following manner: It was begun on the highest ground, near the west end, and two moulds set up at the distance of 70 or 80 yards; the height, 6 feet, by 12 broad in the base; the slope on the outside 6 feet, on the inside 4 feet, and the breadth at the top 2 feet; the sides made up with feal from the broken ground on the outside of the dike, which were laid with the grass-side down, two feal deep on each side of the dike; the outside feal of the first course with the ends out and in, and the other running along; the next course, the outside feal running along, and the outside out and in, and so on alternately, each course consisting of a head and runner; the body of the dike being made up of the carse ground from which the feal had been cut, and packed down by men with beaters. When this was brought to the height of 4 or 5 feet, another piece was begun, leaving an intermediate space, where there were any water-runs, for the egress of the tide: this was found necessary, to draw off the water from the low parts of the carse, which would have been filled up in spring tides; and, by coming in at the end and over the high ground, would have been prevented from getting out by the dike, if it had not been done in that way; so that the embankment was all in detached pieces, till it was brought near the height. These intermediate spaces were then filled up, between the fall of one and rise of next spring-tide, after laying down wooden pipes with stoppers in the dike, to carry off the sink-water. In carrying on the work, they had in some places to cross over lakes and runs made by the tides, which required vast quantities of materials, the dike being in some places upwards of 10 feet high, and 22 broad in the base; the greatest part of the dike being 16 to 18 feet broad. There was one lake of 150 feet in length, and 50 feet in breadth, filled up with earth, clay, and sand, to the height of 5 feet; on which the dike was then built. This forms a mound, on the outside of the dike, of 15 or 16 feet broad; and through this there are pipes laid, to carry off the sink-water. A stream of water was also turned by the west end of the farm, by cutting a canal, which conveyed the water through the embankment there, by means of an outlet built of stone, with a sluice on the inside, raised to the level of the running water, and a folding door on the outside, to be shut by the spring-tides. At this place, a road, that formerly led to Findhorn at low water through the carse, is carried over the top of the dike, by making a mound of earth at each side, with a gradual approach and descent.

In *Figure* 20, *a*, is the breadth of the dike at the top, when finished; *b*, the breadth of dike at the bottom, being twelve feet, when it is six feet high; *c*, the breadth when eight feet high; *d*, the breadth when ten feet high; *f*, the slope on the sea-side of the dike, which is always equal to half of the breadth of the bottom: the inside slope, and breadth of the dike at the top, is equal to the other half; and *e* is the plumb-rule in a frame, made to apply to the mould or dike: the intention of it was, to find if the dike was kept on the proper slope, where a line could not be applied from one mould to another, as in a round or turn, or when the moulds were obliged to be taken down; but this one only answered for the sea-side, another being used for the inside, to fit its slope." *Figure* 21, is a scale of the mould, one-eighth of an inch to a foot.

A curious, useful, and highly ingenious method of embanking, and preventing the waters of the tides from soaking through the porous banks, made in the fen-lands, and low marshy grounds, was described by Mr. John Smith, in the fourth volume of "*Communications to the Board of Agriculture*," who begins by "concisely observing, that the great land of the fens is divided into three large levels; and that each of these levels is subdivided into numerous districts by banks: but as these banks are made of fen-moor, and other light materials, whenever the rivers are swelled with water, or any other district is deluged either by rain, a breach of banks, or any other cause, the waters speedily pass through these light, moory, porous banks, and drown all the circumjacent districts. The fens have thus sometimes sustained £20,000 or £30,000 damages by a breach of the banks, though these accidents seldom happen in the same district twice in twenty years. The water, however, soaks through all fen-banks every year, in every district; and when the water-mills have lifted the waters up out of the fens into the rivers in a windy day, a great part of the water soaks back through the porous banks, in the night, upon the same land again." And he adds, that "this water that soaks through the bank drowns the wheat in the winter, washes the manure into the dikes, destroys the best natural and artificial grasses, and prevents the fens from being sown till too late in the season. This stagnant water lying on the surface, causes also fen-agues, &c. Thus, says he, the waters that have soaked through the porous fen-banks have done the fertile fens more real injury than all the other floods that have ever come upon them."

Having been much concerned in fen-banking from his youth, he had some time since devised the plan which he now finds to answer so well; but found it difficult to prevail with any gentleman, who had a proper extent of this sort of land, to give it a fair trial. However, during the last autumn, he prevailed with a person in the parish where he lives to try it, which showed it to be equal to his highest expectations.

The improved method of embanking proposed by this gentleman, consists chiefly in this: that "a gutter is cut eighteen inches wide, through the old bank down to the clay (the fen substratum being generally clay;) the gutter is made near the centre, but a little on the land-side of the centre of the old bank. This gutter is afterwards filled up in a very solid manner with tempered clay; and to make the clay resist the water, a man in boots always treads the clay as the gutter is filled up. As the fen-moor lies on clay, the whole expense of this cheap, improved, and durable mode of waterproof banking costs in the fens only sixpence per yard. This plan was tried on a convenient farm, and a hundred acres of wheat were sown on the land. The wheat and grass lands on this farm were all dry, whilst the fens around were covered with water. This practice is, after all, nothing more than making a *puddle-bank*, well known to all engineers, or those engaged in forming canals.

The term embankment in canal-making is applied to any large mound of earth, either for confining the water of the canal or reservoir, or for carrying the former across a valley or low piece of ground. The method of constructing such embankments is nearly the same as in those for railways, except that in the former the sides have puddle-trenches formed near the canal, to prevent leakage.

The embankments on some of the great lines of railway in this country are of immense magnitude, on the London and Birmingham railway, for instance, the total of embankments amounted to about 11 millions of cubic yards. The following extracts from specifications for works of this kind will show the usual mode of construction.

"The whole of the embankment in this contract shall have slopes of two to one (that is to say) where the base of the slope is two feet, its height shall be one foot only, and they shall be thirty-three feet wide at the level of the red line in the section, neither more nor less.

"Each of the embankments shall be uniformly carried forward as nearly as the finished heights and width as the due allowance for shrinking of materials will admit of, and this allowance shall not exceed or fall short of the quantity deemed necessary by the engineer. In all cases, this must be carefully and strictly attended to, in order to avoid the necessity of making any subsequent addition, either to heights, or the width of the embankment, to bring them to their proper level and dimensions.

"The surface of the embankment shall be kept in such form or be intersected by such drains, as will always prevent the formation of pools of water upon them, and insure the embankment being kept as dry as possible.

"Whenever the material, teemed over the end of the embankment, shall not form the proper slope, it shall be carefully trimmed to its required form; and this operation must proceed at the same time with the end of the embankment, so as to obviate the necessity of any future addition of material to the sides of the embankment.

"As the embankments advance, and become consolidated, the slopes shall be carefully trimmed into planes having the proper slope, and be neatly covered with a uniform substance of turf, of not less than eight inches in thickness, and laid with the green sward outwards; the turf must be taken from the ground to be occupied by the base of the embankment, and cut square, so as to be laid on the slopes in the form of flags; and where the land is arable, the slopes of the embankment shall be covered with soil. It must be uniformly laid on, of the thickness of six inches, and sown with rye-grass and clover-seed, as soon as the proper season will admit of its being done, not less than one pound and a half of clover-seed, and one pound and a half of rye-grass seed, to be sown to each acre.

"When the material, brought to the embankment, consists of large lumps, they shall be broken into pieces of not more than six inches in diameter."

Expense of forming embankments.—This must obviously be very different in different situations and circumstances, according to materials and the price of labour, but though in general pretty considerable, it is seldom so high as is commonly supposed. It is probable, that in cheap districts, and where the materials are plentiful, the expense of forming an earth-bank, covered with sand or gravel, such as that shown at *Figure* 1, could not be less than from fourpence or sixpence, to tenpence or a shilling, the cubic yard. And such as have more steep and bold slopes, as from thirty-five to forty degrees, and are formed with pavement on the surfaces, cannot cost less than from ninepence to one shilling the cubic yard. One made on the plan of that shown at *Fignre* 6, could not be constructed for less than from twelve or fifteen to thirty pounds for every thirty-two yards. And one constructed of brushwood, in the same method, for soft ground, which will not admit of a wall, would not be lower than from sixpence or eightpence, to six or seven shillings for each foot forward in a lineal manner. In many situations, the ezpenses would, however, in all sorts of embankments, stand a great deal higher than these.

In some districts, embankments are formed by the rod and the floor, the former being from four to five pounds, and the latter about four shillings and sixpence, the workmen finding all sorts of necessary things for the business.

EMBATTLED BUILDING, a building with embrasures in the parapet, resembling a castle or fortified place.

Embattled Line, a straight line bent into right angles, so that if there be two sets of parts, the parts of each set may be in the same straight line, and parallel to the parts of the other.

Embattled Aronade, is partly the same as the Embattled Line, the difference consisting of a semi-circle raised in the middle of each part which forms the continuation of one of the straight lines, the semi-circle presenting its convexity towards the parts which form the other straight line.

Embattled Battled Line, a straight line bent into right angles, so that if there be three sets of parts, one set may be parallel to those of the other two.

EMBLEMATA, a kind of inlaid or mosaic work, used by the Romans in flooring, panelling, &c.

EMBOSSING, the act of forming work in relievo, whether it be cast, moulded, or cut with a chisel.

Embossing, in architecture, that kind of sculpture in which the figure stands in relief beyond the plane, or other surface from which it seems to rise. The several kinds of sculpture formed by embossing are, *low relief, mean relief,* and *high relief.*

EMBRASURE, an enlargement or splay of the aperture of a door or window, generally withinside the wall, for the admission of a greater quantity of light; when the wall is very thick, an enlargement is also made on the outside of the wall.

Embrasure, is also applied to the apertures of an embattled parapet. It is another term for the crenelles, or intervals between the merlons.

EMBROIDERY, the enrichment of woven fabrics by the introduction of devices in needlework. Embroidery was a kind of work very usually employed in ecclesiastical hangings, vestments, and the like, and, in such cases, is of the most gorgeous and elaborate description.

EMPLECTON, a kind of walling, used by the Greeks, and the Roman villagers, consisting of rubble masonry, with facings of wrought stones laid in regular courses. *See* Walls.

ENAMELLING, a method employed to enrich metal-work by the introduction of colour, much used in the works of the middle ages. Specimens of enamel of an early date are to be seen on the envelopes of Egyptian mummies, also in Greek and Roman work, &c.

ENCARPUS, sculptures of fruit or flowers, such as those employed in the decoration of friezes.

ENCAUSTIC, a term applied to paintings, in which the colours are fixed by means of heat. *Encaustic tiles*, are those in which coloured devices are introduced, the colours being burnt in during the process of manufacture.

ENCHASING, that mode of decorating metal-work in which the devices are represented in low relief.

ENDECAGON. *See* Hendecagon.

END-IRONS, otherwise *and-irons*, standards, usually of metal, and of various forms, used in fireplaces previous to the employment of coal for fuel, to support the logs of wood.

ENDS of a Stone, the two parallel sides, which form the vertical joints.

ENGAGED COLUMN. *See* Column.

ENGINE, *Pile*. *See* Pile Engine.

ENGLISH ARCHITECTURE, a term applied by some to the styles of Gothic architecture as developed in England. *See* Gothic and Domestic Architecture.

ENGLISH-BOND, in bricklaying, a disposition of bricks, wherein a course of headers succeeds a course of stretchers alternately. In the north, bricklayers frequently run three or five courses of stretchers to one of headers.

ENGLISH OAK, oak timber of the native produce of England. It is much used in the country for rustic buildings, and is particularly useful in the truss-posts of roofs, as being less liable to compression, and possessing a greater degree of tension, than fir.

ENNEAGON, a figure of nine sides and angles.

ENSEMBLE, (a French word, signifying *together*, or *one with another*, formed of the Latin *in* and *simul*,) the work or composition of a building, considered as a whole, and not in parts.

ENTABLATURE, (French, from the Latin *tabulatum*, a stage, or story,) that part of an order which is supported by the column or columns, and forms the covering or shelter to the edifice. It consists of three principal divisions, viz., the architrave, which rests upon the capitals of the columns; the frieze immediately above it; and the cornice at the summit. These divisions, according to Vitruvius, represent the principal timbers used in the roof of the timber-building, which he supposes to have been the origin and type of erections in stone. This subject has been already referred to under the title Doric Architecture. The entablature either finishes the whole edifice, or so much as has the order applied to it; and in strictness ought to terminate either in a level cornice, or in a pediment formed of two equally inclined cornices. This rule, however, was not always adhered to by the Romans: for in many of their buildings, we find the ordonnance crowned with an attic or blocking course. The edifices of Balbec and Palmyra were often finished in this manner; as were even some of the Grecian structures, after Greece had become a Roman province.

The general height of the entablature is equal to two diameters of the column; though some authors make the Doric entablature one-third of the height of the column; and the entablature of the Ionic one-fourth, and that of the Corinthian or Composite, each one-fifth of the respective columns. Vignola makes the entablature one-quarter of the height of the column, in each of the orders; but the former proportion of twice the breadth of the base agrees much better with the ancient Grecian examples than the other two. It must be recollected, that in ancient examples of the same Order, the height of the entablature is in some instances more, in others less, than two diameters. In the temple of Minerva, at Athens, which is one of the most chaste of the Grecian Dorics, the entablature is almost precisely two diameters of the column. In the Corinthian or Composite, where the column is ten diameters in height, the proportion found in some ancient examples of later date, one-fifth of the said height, is exactly two diameters of the foot of the shaft.

To find the proportions of the different parts of the entablature, divide the total height into ten parts, of which give three to the architrave, three to the frieze, and the remaining four to the cornice. This will stand as a general rule, but in the Doric order the proportions are somewhat different, the architrave containing two-eighths, and the frieze and cornice three-eighths each.

The entablature is also called *trabeation;* and by Vitruvius and Vignola, *ornament.*

ENTABLATURE, or ENTABLEMENT, is sometimes used for the last row of stones on the top of the wall of a building, whereon the covering rests. As this is frequently made to project beyond the naked of the wall, to carry off the rain, some authors call it, in Latin, *stillicidium,* or *drip;* but such an entablature does not stand out far enough, but permits the water to fall on the foot of the wall.

ENTAIL, a term used in the middle ages to designate all kinds of sculpture and carved decoration, but more especially applied to the more elaborate enrichment.

ENTASIS, the swell observable in the shafts of Grecian columns, and more particularly in those of the Doric order. Amongst the modern Italian architects, the practice has been carried to an absurd excess. Several methods of describing the curve will be found under the article COLUMN.

ENTER, (from the French *entrer,* to go in,) in carpentry and joinery, to insert the end of a tenon in the mouth or beginning of a mortise, previous to its being driven home to the shoulder.

ENTRESOLE, (French,) an intermediate story; a low floor introduced between two principal ones. *See* MEZZANINE.

ENTRY, (from the French *entrée,* a passage,) a door, gate, passage, &c., for admission into the interior of an enclosure, house, or apartment.

ENVELOPE, (French,) the covering of a portion of the surface of a solid, by means of a thin pliable substance, which comes in contact in all points or parts with such surface.

To develope the surface of a solid, is to find the envelopes that will cover its different parts.

A few examples of the developement of surfaces will be here given, and for further information we refer the reader to the article SOFFIT.

Problem I.—*To develope that portion of the curved surface of a cylindroid, which is contained between two parallel planes, and another plane passing through the axis at right angles with the parallel planes.*

Plate I. *Figure* 1.—Let M N L C be the plane passing through the axis, terminated at M C and N L by the parallel planes, and by the surface to be developed, at M N and C L; the four lines M C, C L, L N, N M, forming a parallelogram, M C, L N. Draw C A C_8 at a right angle with C L, and produce N M to A; then A C is one of the axes of the elliptic section, at right angles to the axis of the cylindroid. On A C describe the semi-ellipsis A B C, having its other semi-axis equal to that of the cylindroid; divide the curve A B C into any number of equal parts, say eight, and extend them from A to C_8, which coincides with the termination of the eighth part, marking the respective points as 1, 2, &c., at *e*, *g*, &c. Through the points of division, 1, 2, 3, &c., in the arc, draw the straight lines 1 E F I, 2 G H K, parallel to A M: also, from the points *e*, *g*, &c., draw lines *e f i*, *g h k*, &c., parallel to A. M. Transfer the distances, E F, G H, &c., to *e f*, *g h*, &c.; through the points M, *f*, *h*, &c., to C_8 draw a curve; and C_8 M N *l* will be the envelope required.

Problem II.—*To develope the surface of a cylinder contained between two other concentric cylindric surfaces and a plane, in such a manner that the axes of the two cylindric surfaces may cut the axis of the first cylinder at right angles, and that the plane may pass along the axis of the first cylinder, and cut the axes of the two cylinders at right angles.*

Figure 2.—Let A C L N be the plane terminated by the arcs A C and N L, which are the intersections of the concentric cylindric surfaces, and by the parallel straight lines A N and C L, which are formed by the curved surface of the cylinder intersecting the plane.

Proceed in every respect as in *Figure* 1, and the envelope will be obtained; the referring letters being alike in both *Figures.*

Problem III.—*To develope that portion of the surface of a cone contained between two parallel planes and a third plane, so that the axes of the code may be cut at right angles by the parallel planes, and that the third plane may pass along the axis of the cone.*

Figure 3.—Let A E F C be the plane passing along the axis, terminated at A C and E F by the parallel planes, and at A E and C F by the curved surface of the cone. A B C is a section of the cone, perpendicular to the axis. Produce A E and C F to meet in D; and with the radii D E and D A describe the arcs E G and A C; extend the semi-circumference of A B C on the arc A C, from A to C, and draw C G D; and A C G E will be the envelope required.

Problem IV.—*To develope that portion of the surface of a cone contained between two concentric cylindric surfaces and a plane passing along the axis, so that the plane may cut the common axis of the cylindric surfaces at right angles.*

Figure 4.—Let A I K C be the portion of the plane passing along the axis, and the arcs A C and I K the intersections of the cylindric surfaces; the straight lines A I and C K, the intersections of the conic surface. A B C is a section upon the chord A C. From D, with the radius D A, describe the arc A M; divide the semi-circumference A B C into any number of equal parts, and extend them upon the arc A M, from A to M, at the points 1, 2, 3, &c. to M: draw 1 D, 2 D, 3 D, &c. to M D included; also, through the points 1, 2, 3, in the arc A B C, draw lines perpendicular to A C, cutting it in as many points: from these points, draw lines to D, cutting both the concave and convex curves; from the points so cut, draw lines parallel to A C, cutting A D; then from the points of intersection, made by the parallels drawn from one of the curves, describe the several arcs drawn from the point D, to cut the respective straight lines. Proceed in the same manner with the other curve, and through the points so obtained, draw the two curves; and A M L I will form the envelope required. But to show more particularly how the successive points in the curve of the envelope are found, we shall only describe a single point, and the remaining points will be obtained in the same manner; thus, to find the point H in the envelope, draw 2 E perpendicular to A C, cutting it at E; draw E D, cutting the curve A C at F; draw F G parallel to A C, cutting A D at G; from the centre D, describe the arc G H, cutting 2 D at H, which is a point in the curve, as before stated; but by drawing the several systems of perpendicular lines, of lines going to a centre, and parallel lines, at once, much time will be saved in the operation.

Problem V.—*To develope the surface of a cuneoid contained between two parallel planes, and a plane passing along the axis of the cuneoid, so that the parallel planes may be perpendicular to the plane passing along the axis, the section of one of the parallel planes being given.*

Figure 5.—Let A B C D be the plane passing along the axis, terminated by the straight lines A D and B C, which are the intersections of the parallel planes, and by the straight lines A B and C D, which are the intersections of the cuneoidal surface. Let the section B E C, standing upon D C, be a semicircle, and, consequently, the section A F D formed by the other parallel plane, will be a semi-ellipsis of the same altitude.

Produce A B and D C to meet in G, divide the arc D E, which is the half of the semi-circumference, into any number of equal parts, say four, from the points of division, draw the perpendiculars 1 H, 2 I, 3 K, E L, cutting B C at H, I, K, L: draw G P perpendicular to A G; on G P make G *m*, G *n*, O *o*, and G P respectively equal to H 1, I 2, K 3, and L E; from the points *m*, *n*, *o*, P, as centres, with the respective distances G H, G I, G K, and G L, describe the arcs *h r*, *i t*, *k v*, and *l x;* extend the arc B 1, or 1, 2, which is the eighth part of the semi-circumference, from B to *h*, from *h* to *i*, from *i* to *k*, and from *k* to *l;* then drawing the curve B *h i k l*, will give the half of the envelope, which will coincide with the arc H E, when the semi-circle H E C is turned perpendicular to the plane, A B C D, upon its base B C: and since *l* P is the middle line, the other half, or counter part, will easily be found. To develope the elliptic edge, join *m h*, *n i*, *o k*, and P *l*, and produce them to *u*, *s*, *t*, *f:* transfer H U, I S, K T, to *h u*, *i s*, *k t*, *l f*, and through the points A, *u*, *s*, *t*, *f*, draw a curve A *u s t f*, which will be the envelope of the arc A F, the half of the semi-ellipsis A F D; then the counter part being found, will complete the envelope A B C *d* of the curved surface, standing over A B C *d.*

Problem VI.—*To develope that portion of the surface of a cuneoid terminated on two sides by a plane passing through the axis, and by two concentric cylindric surfaces whose axis is perpendicular to the plane given; given that portion of the plane terminated by the curved surface of the cuneoid, and by the intersections of the two cylindric surfaces; also, the semicircular section of the cuneoid.*

Figure 6.—Let A E and D G be the intersections of the cuneoidal surface, and the arcs A E B and E F G the intersections of the concentric cylindric surfaces.

Let D C be the intersection of the section, which is a semicircle, then find the envelope for the semi-circumference, as in the last problem for parallel planes; then the lengths of the intermediate lines contained between the base of the circular section, and the intersections of the cylindric surfaces, being transferred upon the corresponding lines from the semicircular envelope, will form the covering of the cuneoidal surface, as defined.

The reader will observe, that the two last constructions in *Problems* V. and VI., are only approximations near to truth; it is, we believe, impossible to find the true envelope by means of straight lines, or perhaps even to extend the true cuneoidal surface on a plane at any event, any more than that of a sphere, which can only be represented by means of projections. The only surfaces which can be extended on a plane, are those to which a straight edge will everywhere apply through a certain point, or in parallel directions to a given line; of this description are the surfaces of planes, cones, and cylinders: a straight line will apply to all parts of the surface of a cone through the vertex, and to all parts of a plane through any given point, and to all parts of the surface of a cylinder parallel to the axis.

The envelopes of all solids, to which a tangent plane to its surface parallel to the given plane will apply, have the same curvature or straight line at the edge, where the plane becomes a tangent, as the corresponding part of the edge of the given plane.

In describing the envelopes of solids, the whole or a portion of the section passing through the axis, is always supposed to be given, as also a section of the solid, making a given angle with the said plane, and the intersection in a given position.

If only a portion of the section passing along the axis be given, it is always supposed to be terminated by the same surfaces, which also terminate the surface to be covered.

The following is a more general method of finding the envelope of a solid by means of points.

In this description it will only be necessary to have the seats of three points given on the base, and the heights of the points on the cylindric surface from their seats. Let A B C (*Plate* II. *Figures* 1, 2, 3) be the part of the base of the cylinder, and A, B, C the seats of the three points; join A C; draw C E and A D perpendicular to A C; make A D equal to the height of the point above A, C E equal to the height of the point above C, and C F equal to the height of the point above the seat B; join E D; draw F G parallel to C A, and G H parallel to C E, cutting A C at H; and join H B; produce A C to I; divide the curve A B C into any number of equal parts; and extend those parts upon C I; through the points of division in the curve, A B C, draw lines parallel to B H, intersecting B C; from the points of intersection in A C draw lines parallel to G H, to meet D E; from the points of intersection draw lines parallel to A C; and from the divisions in C I draw lines parallel to C E, so as to intersect the other parallels last drawn; through the points thus found, draw the curve C I K E C, and it will be the envelope required.

Figure 1, is the case where the rectangular plane makes a right angle with the elliptic section:

Figure 2, that where the angle made by the rectangular plane and the elliptic section is acute:

Figure 3, where the angle formed by these two planes is obtuse.

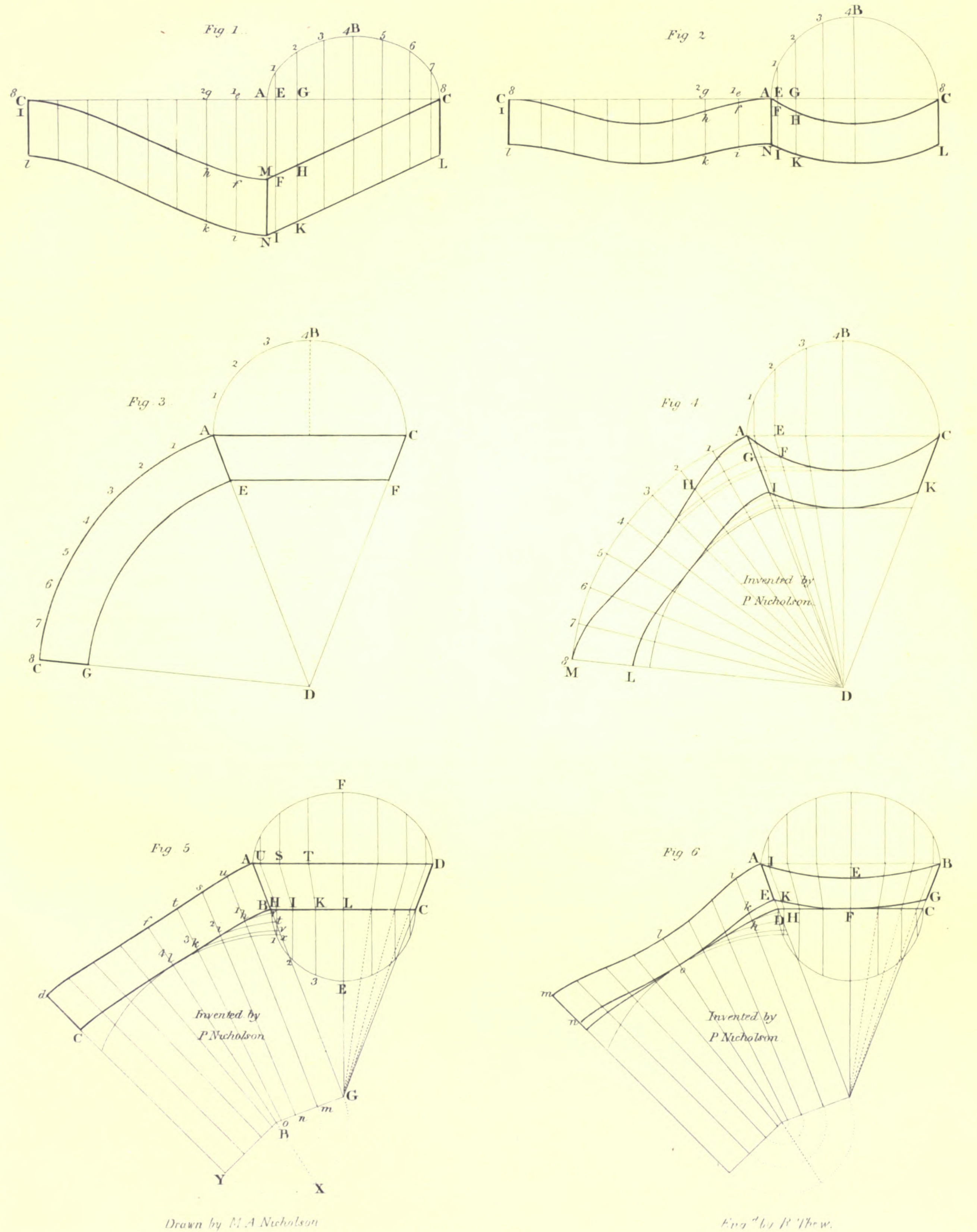
In *Figures* 2 and 3, D M E is the orthographical projection of the curve; with which the curve, E K, of the envelope would coincide. This is found by drawing parallels to G H through the points of division in the curve A B C, to meet the parallels of A C, as shown by the dotted lines.

EPHESUS, an ancient city of Ionia, formerly the metropolis of Asia Minor, now in ruins. The celebrated temple of Diana, in this city, was deemed one of the seven wonders of the world. In the time of Pococke, the remains of this renowned metropolis consisted of the temple of Diana; a circus; a gymnasium; a large theatre, and two of smaller dimensions; an odeum, or music theatre; a building, called the *Athenæum;* another, called the *Hypelæum*, of which there are yet considerable remains; with some vestiges of an aqueduct, and other fragments. A great part of the ancient walls are still entire, but in some parts the foundations only remain, from which it appears they were ten feet thick. Most of these vestiges are represented in Pococke's *Travels in the East.* The situation of this city was very favourable to the procuring of materials, being in the vicinity of Mount Lepre, which consisted of rocks of stone and marble, whose elevated situation afforded the means of an easy transit of the stones or blocks for building, to the site of the intended fabric.

EPICYCLOID, in geometry, a curve generated by the revolution of a point in the circumference of a circle, while it is moved round the circumference of another quiescent

ENVELOPES OF SOLIDS.

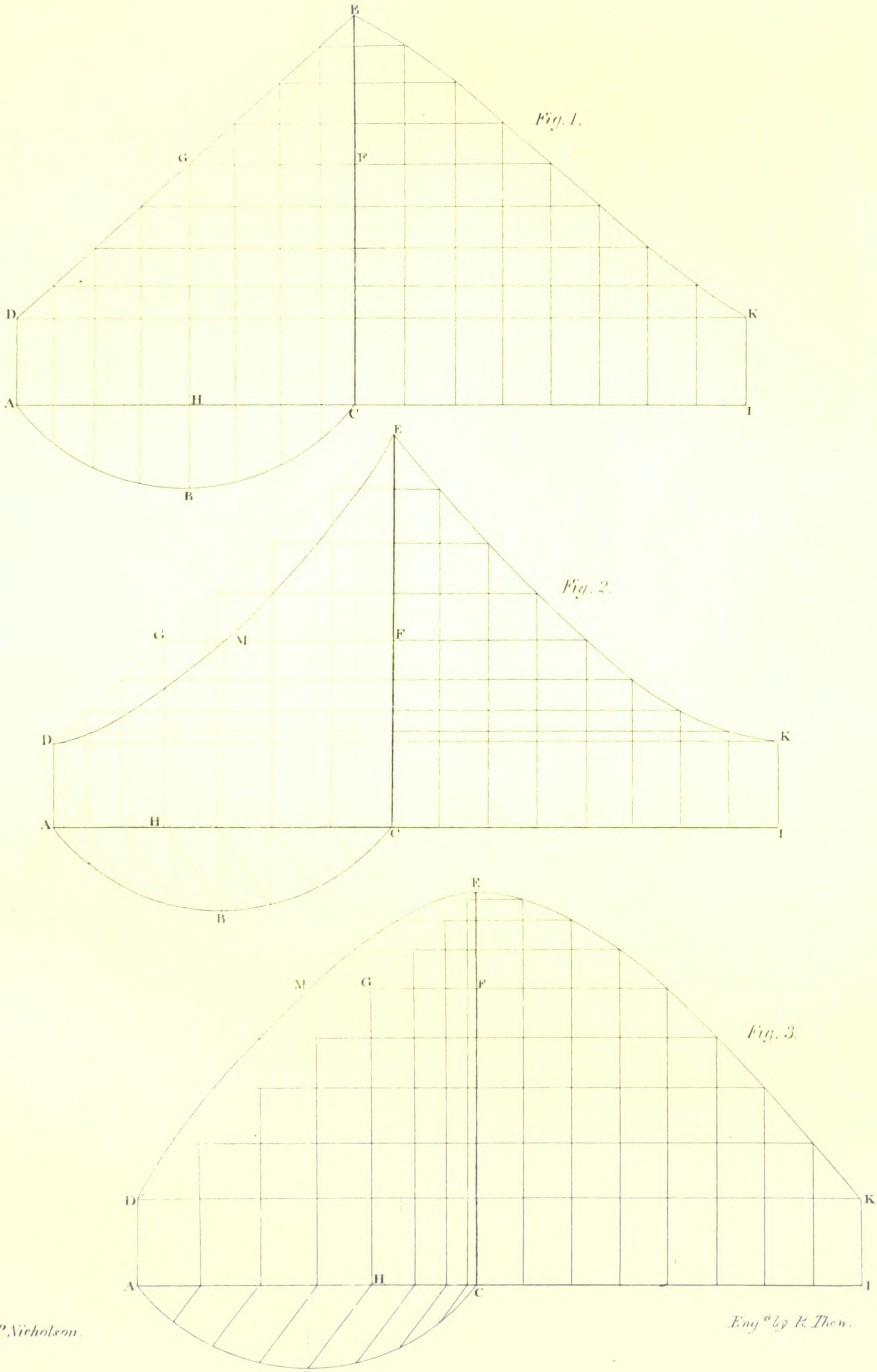
PLATE I.



Drawn by M. A. Nicholson

Engd by R. Thew.

ENVELOPE.



Drawn by P. Nicholson.

Eng.d by R. Thew.

circle in the same plane, so that in each circle, the distance between the point of contact at the commencement of the motion, and the point of contact at any instant while in motion, is equal one to the other. Hence if the circumferences are equal, all parts of the circumference of the moving circle will have been in contact with all the parts of the circumference of the quiescent circle.

If the generating circle proceed along the convexity of the periphery, it is called *an upper*, or *exterior epicycloid:* if along the concavity, *a lower*, or *interior epicycloid.*

The part of the quiescent circle which the generating circle moves along, is called *the base.*

The length of any part of the curve, which any given point in the revolving circle has described from the time of its first being in contact with the quiescent circle, is, to double the versed sine of half the arc, as the sum of the diameters of the circles, to the semi-diameter of the quiescent circle; provided the circumference of the moving circle be carried along the convex side of the quiescent circle; but if upon the concave side, as the difference of the diameters to the said semi-diameter.

Dr. Halley gives us a general proposition for the measuring of all cycloids and epicycloids: thus, the area of a cycloid or epicycloid, either primary, contracted, or prolate, is to the area of the generating circle, and also to the areas of the parts generated in these curves, to the areas of the analogous segments of the circle, as the sum of double the velocity of the centre, and the velocity of the circular motion, to the velocity of the circular motion. The demonstration hereof, *see Phil. Trans.* No. 218.

The areas of epicycloids may be determined by the following proportion: As the radius of the circle of the base is to three times that of the radius, together with twice that of the generating circle, so is the circular segment to the epicycloidal sector, or the whole generating circle to the whole area of the epicycloid.

As to the tangents, it is known from the time of Descartes, that a line drawn from any point to that of the base, which touches the circle, whilst this point is described, is perpendicular to the curve, and consequently to the tangent.

Maupertius, discussing this subject, conceived a polygon to revolve upon another, the sides of which are respectively equal; one of the angles described a curve, the periphery of which is formed of arcs of circles, and the area is composed of circular sectors, and right-lined triangles. He determined the proportion of the area, and of the periphery of this figure to those of the generating polygon. He also supposed those polygons to become circles, the figure described to become an epicycloid, and the above-mentioned proportion, modified agreeably to this supposition, gave him the area and periphery of the epicycloid. *Mem. de l'Acad.* 1727.

It does not appear that any writer published an account of epicycloids, before the celebrated Sir Isaac Newton, who, in the first book of his *Principia*, proposed a general, and a very simple method of rectifying these curves. After him, Bernouilli, during his residence at Paris, showed how, by means of the integral and differential calculus, to determine their area and rectification. The invention of epicycloids is, however, ascribed to M. Reaumur, the celebrated Danish philosopher, during his residence at Paris, about the year 1674. These curves appeared to him to be such as best suited the teeth of wheels, constructed so as to diminish their mutual friction, and to render the action of the power more uniform; hence he was led to consider them, and to this purpose they have been applied. However, M. de la Hire makes no mention of Reaumur, and seems to claim the merit of this geometrical and mechanical invention. But M. Leibnitz, who resided at Paris in 1674, and the two following years, says, that the invention of epicycloids, and their application to mechanics, was the work of this Danish mathematician, and that he was esteemed the author of it.

EPISTYLE, (from *επι*, *upon* *ςυλος*, *column*) in ancient architecture, a term used by the Greeks for what we call *architrave*, viz., a massive stone, or a piece of wood, laid immediately over the capitals of columns, from one to the other.

The epistyle is the first or lowest principal division of the entablature.

EPISTYLAR ARCUATION, a term applied to that method of building in which arches are thrown from column to column, instead of horizontal architraves.

EPITITHEDAS, (Greek *επι τιθημι*) a word used by the Greeks, to express the simæ, or cymatium, or crowning moulding of the entablature. By some the term is restricted to the upper member of a raking cornice.

EQUAL ANGLES, are those whose containing lines are measured by equal portions of equal arcs, described from the meeting of the two containing lines.

Equal Arcs. *See* Arcs.

Equal Circles, are those whose diameters are equal.

Equal Curvatures, are such as have the same, or equal radii of curvature. *See* Curvature and Curve.

Equal Figures, are those whose areas are equal, whether the figures be similar or not.

Equal Solids, are those which comprehend, or contain as much as the other, or whose solidities or capacities are equal.

EQUIANGULAR FIGURES, such as have equal angles.

EQUIDISTANT STRAIGHT LINES, are a series of parallels with equal intervals.

Equidistant Solids, are those whose intervals are terminated by parallel planes, at equal distances on the corresponding sides, comparing that of any two adjoining solids, with that of any other two adjoining solids.

EQUILATERAL (from *æquus*, equal, and *latus*, a side) having equal sides.

Equilateral Figure, that which has all its sides equal.

Equilateral Hyperbola, that in which the asymptotes are at right angles to each other.

EQUILIBRIUM, in mechanics, the equality of forces in opposite directions, so that they mutually balance each other; equipoise.

ERGASTULUM, among the ancients, a house of correction, or workhouse, where slaves, by the private authority of their masters, were confined and kept at hard labour for some offence. It was likewise called *sophronisterium.*

ESCAPE, a concave quadrantal moulding used to join two parallel members of different projections, as the shaft of a column with the fillet at its foot and junction with the capital.

ESCUTCHEON, a shield charged with armorial bearings. Decorations of this kind were much used in the later periods of Gothic architecture, carved on bosses, dripstones, spandrels, &c. The term is also applied to the metal plate on doors surrounding the key-hole, and to that from which the handle is suspended. Beautiful specimens, of excellent design and workmanship, are to be found in old mediæval buildings.

ESCURIAL, the palace or residence of the kings of Spain. The word originally signified a little village in Spain, situated in the kingdom of New Castile, twenty-two miles to the N. W. of Madrid. Here king Philip built a stately monastery, of the order of St. Jerome, held by the Spaniards as one of the wonders of the world. It was begun in 1557, and finished in about 22 years, at the expense of 6,000,000 of piastres. The plan of the work resembles a gridiron, in memory of St. Quintin, who suffered martyrdom with that instrument.

The king and queen had their apartments there, the other parts were possessed by the monks.

The length of this superb palace is an oblong 740 by 580 Spanish feet, besides 460, for what may be termed the handle of the gridiron. The height of the roof is 60 feet, and every angle has a square tower 200 feet in height. The west front has 200 windows, and that of the east 366.

The Escurial has a very fine church, crowned with a dome, which is 330 feet, supported by four rows of pillars, and paved with black marble; containing 40 chapels, and 48 altars. To this church, Philip IV. annexed a beautiful mausoleum, called the *Pantheon*, or *Rotunda*, built on the plan of the temple of that name at Rome. It is 36 feet in diameter, and incrusted with marble; in which the kings and queens of Spain, who leave any posterity, are interred; the rest being laid in another vault of the same church, together with the infants and other princes.

ESTIMATE, a calculation of the expenses of a building, or other parts thereof, by measuring the drawings with a compass from a scale, and calculating the amount upon materials and workmanship. *See* Brickwork, Carpenters' work, Joiners' Work, &c.

ESTIMATION, the act of estimating a building, *See* Estimate. A quick mode of estimating, or rather guessing at the expense of a building, is, to throw the whole into cubic feet, as if all the parts within the walls and roof were really solid, and calculating the whole at a certain rate per cubic foot; but this is so different in different places, and even in different times in the same place, that no certain ratio can be established: but where things are finished in the same way, in the same place, and at the same time, it frequently comes nearer to the truth than many real estimates, which are accepted far below value, in order to obtain the work. Though estimates sometimes come very near each other, yet the difference at other times is so preposterous, as to be one-fourth, or one-third of the whole amount, either owing to articles being overlooked, or to a difference of rates, or both.

ESTRADE (a French term, signifying a public road or highway) in building, a little elevation of the floor of a room, frequently encompassed with an alcove or rail, for receiving a bed; or sometimes, as in Turkey, it is only covered with fine carpets, for the accommodation of visitors of distinction.

ETRUSCAN ARCHITECTURE. The method of building practised by the ancient inhabitants of Etruria; from which it is supposed many of the peculiarities of Roman architecture took their rise, and the Tuscan order was borrowed. The origin and history of this people is involved in obscurity, as is also, to a great extent, their architecture. They seem to have been a mixed race, composed of Siculi or Umbri, of Pelasgi, and of a third race, of Lydian extraction, and to have attained to considerable eminence in the scale of nations, both in power and civilization. Although they had brought the arts to a great degree of perfection, we had, until recently, but little evidence of the fact; and, as regards their architecture, examples are still so scanty, as to afford us no precise notion of its character. We have no remains of temples, or other buildings of the kind; all such information is to be derived solely from their hypogæi or sepulchres, and the representation of buildings, to be found on the various utensils discovered therein. The remains above ground consist almost solely of ruins of walls surrounding the different cities, which remind us of the Cyclopæan erections at Tiryus and Mycenæ, consisting, as they do, of lofty heaps of stones of enormous size, fitted together in a compact form, but without either cramps or cement. Ruins of this nature exist at Cortona, Volterra, Fiesol, &c., in the first of which are some stones more than twenty-two Roman feet in length, and about five or six feet in height. The walls of Volterra are of a similar description. In the earliest examples, the stones are of an irregular polygonal shape, and in building were so laid as to have all their sides in close contact with the surrounding stones; remains of this kind of work are to be found at Cora near Velletri. Generally speaking, the stones were of rectangular form, and of various sizes, disposed in horizontal courses. There is at Volterra a gateway, called the Gate of Hercules, which has a fine arch composed of nineteen large stones. This leads us to remark, that the origin of the arch is very generally ascribed to Etruria, from whence it is said to have found its way into Rome. Be this as it may, the Etrurians were certainly aware of its principles, specimens of true arches and vaulting having been found in the remains, some of which are probably of early date. In a tomb at Cerœtri is a wall carried up somewhat after the shape of a Gothic arch gradually converging towards the top, but not meeting at the apex, a square channel being left between the two sides of the arch, which is covered over with a block of nenfro. This, however, is not a true arch, but is similar to those to be found in Egypt and Greece, the building to which it belongs is on all hands allowed to be of very great antiquity.

From the description of Etruscan temples given us by Vitruvius, we learn that they were of an oblong form, the length being occupied by three chapels, of which the central one was the principal. The façades were similar to those of Greece, adorned with columns, pediments, &c., and the latter with sculptures in terra cotta. From the same author we likewise learn, that their private houses were buildings of some importance, having external porticos and vestibules like those of Rome; indeed, it is supposed that the atrium was borrowed from them by the Romans. Amongst the structures for which the Etrurians were eminent, are their tunnels, canals, and sewers, for the purposes of drainage and irrigation; roads, fortifications, and other works of an equally useful character. Remains of a cloaca have been discovered at Tarquinii, in which the arch is employed, and which is altogether similar to that at Rome; and at Volaterra are the ruins of a subterranean reservoir, 24 Roman feet high, 56 long, and 29 broad.

We have now only to notice the sepulchral buildings; which form by far the principal portion of the remains, and are found in great numbers, fresh ones being constantly opened at the present day. They seem to have been equally as numerous as the cities, and it would appear to have been an universal rule, that each city should have a place of burial for its dead in its immediate vicinity. To such an extent is this the case, that a modern writer lays it down as an axiom, that wherever there stood an ancient town, there you will find a cemetery; and wherever you find a cemetery, there will have stood likewise an ancient city. These sepulchres are, however, not all alike, their forms and situation varying according to the geographical, geological, and other characteristics of the site; in some cases they are cut out of cliffs below the city wall; at others out of more yielding soil, and, in cases where requisite, lined with masonry on the inside. Besides these excavated sepulchres, we have some of a more primitive and less imposing character, being nothing better than graves sunk a few feet below the surface, and covered with unhewn masses of stone. They are very similar to the Druidical cromlechs; which fact would intimate some connection between the Celts and Etruscans. Again, we find tumuli, another form of sepulchral monument, which is common to all parts of the world.

Amongst the cemeteries which have been explored, that at Vulci is one of the more important, and this, like many others, was discovered by mere chance, and was found to contain a vast number of antiques of various kinds. Those of Norchia and Castel d'Asso, the façades of which are covered with sculpture, were discovered in 1810; those of Bomarzo and Orte from 1830 to 1837. Of still later date are the discoveries of Savona by Mr. Ainslie, and of several others by Mr. Dennis, who has published a very interesting work upon the subject. There seems to be no scarcity of such monuments, for new discoveries are being brought to light every year, and would lead us to suppose that vast tracts of country were completely undermined by them. The cemeteries vary in size, some of them being of very great extent, and laid out like a city in streets and squares. Each has its peculiar kind of tomb, the most simple of which consist of mere conical pits about eight or nine feet in depth, and six in diameter. Next to these come the tombs, with a simple doorway opening in the side of the cliff, and leading into a small vestibule about five feet square, with a shaft carried up from the roof to the ground above, the opening of which is frequently covered over with a large stone. The vestibule gives access to the tomb, which is an apartment from twelve to twenty feet square, cut out of the rock, and supported in the centre by a low massive quadrangular pillar, or in larger tombs by four or more similar piers, as is shown in Inghirami's plates. Sometimes the tomb is divided into two parts by a thick wall cut out of the rock, which forms a means of support in place of pillars. In the side-walls of the tombs, and sometimes in the piers and partition walls, are two or more tiers of long horizontal niches in which the bodies were placed. Tombs of this kind exist near Corneto, Ferenti, and Cervetri.

Cemeteries of more imposing character are to be seen at Castel d'Asso, and the places to which we have above referred; of the former we give the following description from a popular work of the day. "At Castel d'Asso the tombs rise upon each side of a narrow glen, facing each other like the houses in a street. Each tomb being detached, and the cliffs in which they are hollowed being hewn to a smooth surface, and formed into square architectural façades, with bold cornices and mouldings in high relief, they bear a strong resemblance to dwelling-houses, their façades extending the whole height of the cliffs, which in some places rise as high as 30 feet. In the centre of each façade is a rod-moulding, describing the outline of a door, in many cases having panels recessed one within the other. This, however, is but the false semblance of an entrance, the real one being in the lower part of the cliff, which having been left to project when the façade was smoothed down, has been hollowed into a kind of small vaulted antechamber, open in front. The form of these monuments, as well as of the false door in the façade, tapers upwards, and the front recedes slightly from the perpendicular. Along the top of the façade runs a massive horizontal cornice, but receding from the plane of the façade. On many of the tombs there are inscriptions, some of which are still legible, graven deep in the smooth surface of the rock above the simulated doorway. On the inner wall of the little entrance-chamber, and immediately below the one in the façade, is a second false door, moulded like the former, but with a niche in the centre; and directly below this again is the real door leading into the sepulchral chambers, which, neither in grandeur of dimensions, nor elegance of details, answer to the external appearance of the tombs. They are quadrilateral, of various sizes, and rudely hollowed in the rock, having a flat or slightly-vaulted ceiling and ledges of rock against the wall for the support of sarcophagi. In some cases the sarcophagi have been sunk in the rock in two rows, side by side, with a narrow passage between them, and seem to have been originally covered over with tiles. In the interstices which separate the monumental façades, there are in many cases flights of steps cut in the rock, and leading to the plain above."

Tombs of a more decorative character exist at Norchia, adorned with pediments filled with sculpture, and Doric friezes, and bas-reliefs on the inner walls of the portico. The interiors, however, are of similar character to those at Castel d'Asso. At Bieda, are tiers of tombs hewn in terraces one above the other, and connected by flights of steps cut in the rock. Here also another peculiarity is presented, the tombs standing out from the rock completely isolated, and of similar form to dwelling-houses, having roofs sloping down on either side with overhanging eaves at the gable. The internal arrangement likewise bears a very great resemblance to that of dwelling-houses.

The tombs near Cervetri, opened in 1836, were originally covered with a large conical mound, and contain two apartments, an inner and outer one, separated by a partition, the latter being somewhat the largest, and the length of the two together measuring about 60 feet. On each side of the first chamber is a small cell cut out of the rock, the chamber itself being lined with masonry, and roofed over with a kind of Gothic vault, which springs at about three feet from the ground. Of this vault we have spoken above.

A curious range of sepulchres has been discovered at Chiusi, which, from the winding passages which lead from one tomb to another, presents the idea of a labyrinth, and caused it at one time to be considered a portion of the tomb of Porsenna, a description of which is given by Varro.

The following account is taken from the publication before referred to:—"The tombs to which we allude, are excavated in the conical crest of a broad hill, surrounded by a fosse about three feet wide, and lined on the inner side with large blocks of travertine, which thus form a wall measuring about 855 feet, this being the circumference of the base of the enclosed tumulus. The chief sepulchres open from the encircling wall; the largest, a circular chamber facing the south, and supported in the centre by a huge pillar hewn in the rock, is connected with the fosse by a passage of about 50 feet in length. Towards the south-east is a group of smaller chambers; close upon the fosse, and facing the south-west, is another, connected with the former by a passage about 45 feet long; while other smaller ones again, are situated all around, facing all the points of the compass.

"Above this tier is another, containing likewise several groups of chambers of different size and shape; and below the level of the fosse is a third tier, the chambers of which are, however, in a very ruinous state. Opening from the circular chamber facing the south, is a narrow passage, which winds by many a circuitous route towards the western group of chambers, and then turning again to the south, branches out into many side-passages. These passages were at first thought to form a regularly planned labyrinth, but their lowness being such as barely to allow a man to creep through on all-fours, the irregularity of their level, and the circumstance of the passage opening into the western group of chambers, breaking through one of the stone benches with which the walls of the chamber are lined, and on which the dead reclined, have subsequently led to the abandonment of this opinion, and of the idea of this being the site of the far-famed tomb of Porsenna."

We must not omit to mention that colour was used in these tombs as a means of decoration. At Tarquinii, they are all painted, but there is one, the Grotta Querciola, which in the design and execution of the pictures, surpasses all the others.

The walls are entirely covered with paintings illustrative of the social manners of the Etrurians, the colours of which, though now somewhat dim, must have been originally splendid. In the Grotta del Triclinio, hard by, the colours have retained their brilliancy, and the effect is described as perfectly dazzling by those who have beheld them in a bright light.

The Etrurians do not seem to have been a people of any great native taste, and are not to be compared with the Greeks in this respect; they preferred utility to beauty, and convenience to decoration. Some assert that all that is really beautiful in their monuments, emanates solely from Greece; but this we cannot suppose; they were destitute indeed of the creative imagination of the Greeks, and probably borrowed very largely from them, but at the same time we cannot suppose them to have been entirely devoid of originality.

For further information on this subject, we would refer to Michali and Inghirami, as also to the recent work of Mr. Dennis on the Cities and Cemeteries of Etruria. *See* Roman Architecture.

EUANTHI COLOURS, in painting, a term used by the Greeks, to express what the Romans called the *floridi colores*, or such as had remarkable brightness: the duller and coarser colours, the Romans called *austeri colores*, and the Greeks *bathyci*. Of the first sort were cinnabar, lapis arminus, chrysocolla, minium, indigo, purpurissa, according to the Romans; but the Greeks, as we find by Dioscorides, made cinnabar one of the austere colours.

EVOLVENT (from the Latin *evolo*, to unfold) in geometry, the curve resulting from the evolution of a curve, in contradistinction to the evolute, which is the curve supposed to be opened or evolved.

EVOLUTE, or Evoluta, in the higher geometry, a curve first proposed by Huygens, and much studied by the later mathematicians: suppose a string, or flexible line, be unwound, so that the part unwound may be kept straight and in the plane of the curve, the extremity will describe a new curve, of which the first turn is the evolute.

The radius of the evolute, is the part of the thread contained between any point where it is tangent to the evolute, and the corresponding point, where it terminates in the new curve.

Every curve may therefore be considered as the evolution of another.

EURYTHMY, (from the Greek εὔρυθμος, *harmony*,) a certain majesty or elegance in the composition of the different parts of a building.

The word is Greek, and signifies literally a consonance or fine agreement; or, as we call it, *harmony*, of all the parts: it is compounded of ευ, *well*, and ρυθμος, *rythmus*, *cadence*, or agreement of numbers, sounds, or the like.

EUSTYLE, (from the Greek, ευ, *bene*, *well*, and ϛυλος, *column*) a disposition of columns in which the intervals are exactly two diameters and a quarter. This intercolumniation was most approved of by the ancients, as being a medium between the pycnostyle and areostyle.

Vitruvius, lib. iii. chap. 2. observes, that the eustyle is the most approved of all the kinds of intercolumniation, and that it surpasses all the rest in conveniency, beauty, and strength.

EXAGON, *See* Hexagon.

EXCAVATING MACHINES, for digging and removing earth in extensive excavations, have occupied the attention of many ingenious men, and various machines for the purpose have been proposed and tried with different degrees of success. The great difficulty seems to consist in adapting any peculiar arrangement of mechanism which shall be capable of digging into the various sorts of earth. Were it only to operate upon a uniform mass, the task would be of comparatively easy accomplishment.

Amongst others who have devoted much time and capital in the attempt to overcome these difficulties, Mr. G. V. Palmer applied himself to the construction of machines of this kind. In 1830 he took out a patent "for a machine to cut and excavate the earth." This invention is designed, by the application of steam-power, to loosen, dig up, and remove into a cart, earth from a canal or other cavity, and to move itself forwards as the excavation proceeds. In principle, its leading arrangement resembles the dredging-machines employed in clearing the beds of rivers and harbours; but it has several appurtenances, such as *picks*, for loosening the earth; *cutters*, for separating it; and *scrapers*, for filling it into scoops or elevators; the latter convey it into the cart by which it is carried away. The machine is mounted upon four wheels, and gradually moves forward upon a temporary railway, as the excavation proceeds. The moving power is applied to the axis of a fly-wheel, and to the same axis is fixed a drum or pulley, around which passes an endless pitched chain, giving motion to another drum or pulley, which revolves in bearings fixed to the upper ends of two long cheeks or supports. Around this second drum passes another endless chain, by which a third drum or pulley, of a quadrangular figure, is set in motion, and which turns on an axis in the lower ends of the long cheeks; to this last-mentioned chain are fastened a series of earth-scoops, which are successively brought into operation in taking up the earth. So far, the machine resembles the common ballast-engine; we have now to describe how the several actions of picking, digging, and projecting the earth are effected. A third endless chain is actuated by the drum on the main axis, and gives motion to a spur-wheel; this spur-wheel drives another toothed wheel attached to the fore-wheels of the carriage, and thus the carriage gradually advances. By an ingenious system of levers, connected to a crank on the main axis, a row of pick-axes, a row of cutters, and a row of scraping-shovels, are alternately brought into action. When the pickers have descended and loosened a portion of earth, the cutters follow, and separate it from the mass, and this separated portion is immediately afterwards drawn forwards by the scraping-shovels into the scoops, which, by the action of the machine, are brought into the required position on one of the sides of the revolving quadrangular drum; and filled scoops thence proceeding to the top of the machine by the revolution of the attached endless chain, discharge their contents into a cart or waggon to be conveyed away. The same gentleman patented another engine for this purpose in 1832. This consisted of an excavated cart and plough united, to be worked by horses or other power. The cart-wheels are made considerably wider than those in common use, and the interior portion of the ring of each wheel is made into a series of earth-boxes; these earth-boxes are made to open inwards, and also towards the centres of the wheels. Underneath the cart, immediately adjoining each wheel, is placed a plough, for raising and turning the earth into the boxes, as the cart is moved forwards; the wheels at the same time turning round, bring up the earth, and deliver it into the body of the cart. When a sufficient load has been thus deposited in the cart, the ploughs are raised from the ground by means of a lever, and then the cart can be drawn in every respect as a common cart, to the place intended for the deposition of the excavated earth, where it is to be unloaded by withdrawing a pair of bolts, which allow the bottom of the cart to fold downwards sufficiently to permit the earth to escape. There are many circumstances where the application of excavating machines of this kind might be employed to advantage, but though the use of them in the extensive excavations of railway works has been many times attempted, they have not been found to answer so well in practice as to bring them into general employment.

EXCAVATION, (from the Latin *ex*, out, and *cavus*, hollow) the act of hollowing or digging a cavity, particularly in the ground.

The excavation for the foundation of a building, by the Italians called *cavatione*, is settled by Palladio at a sixth part of the height of the building, unless there be cellars under ground, in which case he would have it somewhat more.

But this proportion is vague, and contrary to experience and reason. Good firm gravel, clay, or rock, forms as good a foundation at a foot or 18 inches from the surface, as at any greater depth; while swampy or boggy land is not good at any depth. *See* Digging and Foundation.

EXCHANGE, a building where merchants resort to transact business. The principal commercial cities of Europe and America have edifices appropriated for this purpose, and the Bourses of Paris, Amsterdam, Antwerp, and other continental cities, and the Exchanges of London, Liverpool, New York, &c., are distinguished for their beauty and convenience. In London there are three buildings of this kind; the Corn Exchange—the Coal Exchange—and the Exchange of London, *par excellence*, the Royal Exchange. The two first are appropriated to the particular branches of commerce indicated by their names, and are more especially resorted to by persons therein engaged; the Royal Exchange is the general place of assembling, at a certain hour of the day, of the merchants and traders of London. Here meet together men from all parts of the world, and here are settled transactions of commerce of a magnitude inconceivable by those unacquainted with the subject. There are few merchants in the city but make it a rule to attend the Exchange daily, or, as it is termed in commercial phraseology, "to go on 'Change." We propose to give a brief description of each of these places of mercantile rendezvous.

The Corn Exchange is situated in Mark Lane, and consists, in fact, of two buildings adjoining each other, and known respectively as the Old and New Corn Exchange. Business, however, is carried on in both, and together they are considered as the "Corn Exchange."

The new building, as we have before observed, immediately adjoins the older one, which still continues to be made use of, and which may therefore with propriety be briefly described here, if only for the purpose of affording some kind of comparison between the two. "The lower part of the structure is an open colonnade, whose pillars are of the modern Doric kind, but the entablature has a plain frieze, and its architrave is singularly narrow for the order, or indeed for any order whatever. There are eight columns, with an iron palisading between them; displaying, however, a very peculiar arrangement, four of them being placed in pairs, but in such a manner, that, beginning to reckon from the south end, we find them placed thus: first, a pair of columns at that angle, then three single columns, then another pair, and at the north angle another single column, forming altogether five inter-columns, corresponding with which are as many windows in each of the two stories forming the upper part of the building over the colonnade; which are quite plain, with the exception of the centre one on the first floor, which, in addition to other dressings, has a pediment."

There is no wall behind these columns, and the space within is open to the street, forming a court rather than a hall, the centre space of which is not covered by a roof. With this difference, it resembles the similar part of the plan in the new building, having, as that has, three intercolumns at each end, and five on each side; and it further resembles it in the great depth of the ambulatory around it. The building, though making little pretension to architectural character, except what it derives from its columns and their arrangement, has, in its general effect, a degree of picturesqueness both unusual and pleasing, especially as there is a second range of columns between those in front and the area of the Exchange itself.

The New Corn Exchange was erected in 1828, from the designs of Mr. G. Smith, the architect of St. Paul's School, and exhibits a very tasteful and appropriate application of the *Grecian* Doric.

In point of design, this facade merits investigation, because, whatever else may be alleged against it, no one can object to it, that it is either a direct copy, or an assemblage of copies, that is, of parts entirely borrowed from other buildings, without other novelty than what they derive from their combination with each other.

The colonnade forming the centre, (which being an hexastyle in antis, gives the same number of intercolumns as an octostyle,) does not constitute a loggia, or even a mere corridor; for, as may be seen by the plan, the space between the columns and the wall is occupied, except where the entrances occur, by a sunk area screened by the stylobate. This area being barely equal to one diameter, the colonnade is much shallower than usual, and therefore likely to be censured, on that account, by those who consider a certain depth of space behind the columns to be an indispensable requisite for their proper effect, and invariably demanded in all situations and under all circumstances.

In the present instance, the very moderate distance at which the wall is placed behind the columns, occasions greater breadth of surface, as the light falls upon that as well as on the columns themselves; which would not be the case were the wall so far back that the columns would relieve themselves entirely against the shadow of the parts beyond them. At the same time, the columns receive a greater portion of reflected light, and thus contrast more distinctly with the shadows which they cast on the wall itself, and which produce an agreeable variety and equipoise of light and shade, according to the sun's elevation, when it shines on this (the west) side of the building. But that to which, more than anything else, this façade is indebted for its classical air and architectural beauty, is the entire absence of windows within the colonnade. Not only do such apertures—unless introduced very sparingly indeed—destroy repose, by frittering what requires to be preserved nearly an unbroken surface, but they show themselves in a situation where their serviceableness is greatly lessened. Besides which, the colonnade or portico itself seems misplaced, being overlooked by the rooms behind it.

To return to the immediate object of our description: we may observe, that the wall is not entirely plain, it having slightly projecting antæ or pilasters corresponding with the columns, and the faces of those in the centre serve partly as a ground upon which the jambs of the large door are raised. This door is a feature not only important for its size, but tasteful in design—bold and simple, yet at the same time carefully finished.

In the frieze, wreaths composed of ears of corn are substituted for triglyphs; and even had they not elegance of form as well as novelty to recommend them, they would still have a propriety and significance which we rarely meet with in those similarly-shaped decorations of laurel transferred to modern buildings, from the entablature of the monument of Thrasyllus.

The cornice here given to the order is rendered less cold and scanty than usual by the addition of a cymatium above the corona, ornamented with lions' heads, that slightly break its upper line. Much of the peculiar character arises from the unusually lofty blocking-course, surmounted in the centre by a podium bearing the following inscription:—'Corn Exchange, erected 1828, according to act of parliament, 7th George IV. Chap. 33.' This podium is, in turn, surmounted by a piece of sculpture representing the royal arms, grouped with implements symbolical of agriculture. Thus the upper part of the front acquires considerable variety of outline, and somewhat of a pyramidal form, together with distinctly marked individuality of character. Instead of being at all at variance with the style adopted, the part we are now considering is not only consistent with, but seems to give additional expression to all the rest; at the same time that it takes away from it that air of direct imitation which it is so difficult to avoid without endangering, if not destroying, the classical physiognomy intended to be preserved.

Whether, in his treatment of the wings, the architect has successfully overcome this last-mentioned difficulty, is what we have now to inquire. As far as regards the order itself, that is kept up with sufficient strictness, and the mode in which the antæ are applied, deserves commendation. Had these been merely coupled, after the usual fashion, the effect would have been rather formal and monotonous; besides which, it might not improperly have been objected, that such duplication was at variance with the arrangement of the columns. But by compounding, instead of pairing them, and placing the broader anta at the outer angle, while the other is made to project slightly upon it, both a due expression of strength and solidity is kept up, a certain degree of play and variety is obtained, although there appears to be nothing at all new in the idea itself, except that here the two united faces are of unequal breadth—an irregularity converted into a merit by its obvious propriety.

"The windows, which entirely occupy the space between the antæ, may be considered as assuming the character of small loggiæ, whose intercolumns are filled in with sashes. In style, therefore, they harmonize with the general design far better, perhaps, than anything else that could have been devised for the same purpose; the chief objection to be made in regard to them is, that somewhat less plainness—not to call it severity of style—would not have been amiss, and would have prevented the small antæ of the windows from appearing a repetition of the larger ones on a diminished scale.

"The upper story of the wings, to which we now come, display more invention and decided novelty than any other part of the building; and although exhibiting somewhat of unusual forms and combinations, the style here preserves its characteristic energy, boldness, and breadth. Although, too, the parts themselves are simple, they acquire much picturesque complexity from the lofty position in which the windows are placed, being thrown further back, owing to which the pedestals detach themselves with considerable projection. In addition to the variety thus produced, we have that arising from the attic itself, if it may so be termed, being both loftier than the pedestals, and narrower than the compartment of the front below; from both which circumstances result great contrast and diversity of outline.

"The interior calls for very little description or remark, the walls being perfectly plain, and their being no other decoration of any kind than the columns, which are of very slender proportions, and have deep capitals, composed of ears of wheat. Above the centre space within the columns, is a lantern with vertical lights; and those on each side have seven skylight compartments in their ceilings. The north wing contains a tavern and coffee-room, and the opening in the south wall of the other wing communicates with the old Corn Exchange."—*Public Buildings of London.*

The Coal Exchange is a new building erected in Thames-street, near the Custom House, and completed so lately as the month of November, 1849.

The importance of the vast trade in that precious mineral to which Great Britain owes so much of her prosperity, may well demand that the merchants and others trading in coal, should have their own Exchange. The enormous extent of this trade can hardly be conceived, or its value in a pecuniary sense estimated.

"In respect to its natural supply of coal," says McCulloch, "Britain, among the nations, is most singularly favoured; much of the surface of the country conceals under it continuous and thick beds of that valuable mineral, vastly more precious to us than would have been mines of the precious metals, like those of Peru and Mexico; for coal, since applied to the steam-engine, is really hoarded power, applicable to almost every purpose which human labour directed by ingenuity can accomplish. It is the possession of her coal-mines which has rendered Britain, in relation to the whole world, what a city is to the rural district which surrounds it—the producer and dispenser of the rich products of art and industry. Calling her coal-mines the coal-cellars of the great city, there is in them a supply which, at the present rate of expenditure, will last for 2,000 years at least; and therefore a provision which, as coming improvements in the arts of life will naturally effect economy of fuel, or substitution of other means to effect similar purposes, may be regarded as inexhaustible."

The former Coal Exchange being quite unfit for the purposes required, and the inconvenience felt by the merchants frequenting it much complained of, an enlarged site was purchased by the corporation of London, for the erection of a new Exchange. This site afforded a frontage next Lower Thames-street of 113 feet, and a similar frontage next St. Mary-at-Hill. The building is erected from the designs of Mr. Bunning, the architect to the corporation, and is so arranged as to give an increased width to the two thoroughfares above-named. It presents two distinct elevations, connected by a tower, placed within the re-entering angle formed by the two fronts.

The façades of the building are of very simple, yet bold and effective design; and, with the exception of the cornice, but few projections are introduced. The fronts in Thames-street and St. Mary-at-Hill, are respectively about 112 feet in width, by 61 feet in height. The unequal form of the plot of ground on which the Exchange stands, is skilfully masked at the corner by breaking the mass of building, and introducing the circular tower before mentioned. This tower is 109 feet high to the top of the gilded ball, and 22 feet in diameter at the lowest part, and is divided into three stories. The lowest story, containing the entrance vestibule, is of the Roman-Doric style of architecture; and presents a striking peculiarity in the arrangement, to which we must advert. The wall of the tower not only contains the vestibule by which entrance to the hall or rotunda is attained, but serves also as a centre to flights of steps, which lead, on either hand, to a landing on the first story of the building. From this landing, a spiral staircase is carried up in the tower to the other stories. The first story is of the Ionic order, carrying an entablature, and is lighted by windows. The top story, 15 feet in diameter, is ornamented by pilasters, with windows between; the roof rising to a cone, and being crowned with a gilded ball. The front of the whole is faced with Portland stone. Entering the rotunda, the attention of the visitor is immediately arrested by its beautiful effect, and extremely novel arrangement. It forms a circle of some 60 feet in diameter, and is crowned with a dome, or, in fact, double dome, as a lesser cupola rises from the eye of the great dome to the height of 74 feet from the floor. The dome rests on eight light piers, the space between each pier being divided by stanchions into three compartments. There are three galleries, and from these galleries, entrance is obtained to the numerous offices in the building. The galleries are peculiarly constructed, and entirely composed of iron, embellished with symbols of the coal trade. Iron, indeed, has been most extensively made use of; the stanchions, brackets, ribs, and eye of the dome, are all of iron, and above 300 tons have been used in the building in the several parts. Each rib, of which there are 32, is 42 feet 6 inches long, is cast in one length, and weighs on the average two tons. The arrangement of pateræ in the stanchions, brackets, and soffits of galleries, is original and good. The ornament chiefly used is a cable, twisted about in various patterns, and the balustrade to the galleries is of loops of cable, broken at intervals by the introduction of the City arms. This rope-ornament has perhaps been used in too great profusion, for it is displayed on the stanchions, gallery-railings, soffits, and every place where it could possibly be introduced. The frame-work to the offices is of wood, and panelled with rough plate-glass. By this means, they receive light from the great dome of the hall. The dome itself is glazed with large pieces of ground plate-glass of great thickness, the glass of the small upper dome having an amber tint. The chief public offices surrounding the Rotunda are those appropriated to the offices of the corporation, whose business it is to collect the coal dues; the factors' board-room, the weighers' society, and the merchants' and factors', among whom Sir James Duke, lord-mayor of London at the time of the opening of the Coal Exchange, holds a very prominent position.

The floor of the Rotunda is composed of inlaid woods, disposed in form of a mariner's compass, within a border of Greek fret, and in its appearance is beautiful in the extreme. In its construction are employed upwards of 4,000 pieces of wood of various kinds, comprising black ebony, black oak, common and red English oak, wainscot, white holly, mahogany, American elm, red and white walnut, and mulberry. The whole of these materials have been prepared by Messrs. Davison and Symington's patent process of seasoning woods, to which we have alluded under the word Desiccation.

The same desiccating process has been applied to the woodwork throughout the building. The black oak introduced is part of an old tree which was discovered imbedded in the river Tyne, where it had unquestionably lain between four and five centuries. The mulberry wood, of which the blade of the dagger in the shield of the City-arms is composed, is made of a piece of a tree planted by Peter the Great, when he worked as a shipwright in Deptford dockyard.

The coloured decorations of the Exchange are peculiarly characteristic, and the entrance vestibule, in particular, is extremely rich and picturesque in its embellishments. Terminal figures, vases with fruit, arabesque foliage, &c.; all of the richest and most glowing colours, fill up the vault of the ceiling, through an aperture in which is seen that of the lantern, adorned with a figure of Plenty scattering riches, and surrounded by *figurini*. Over the entrance-doorway, within a sunk panel, are painted the City-arms. Within the Rotunda the polychromatic decorations immediately arrest the eye. The range of panels at the base of the dome, and the piers which carry the dome, are all fully and harmoniously decorated. Commencing with the piers in the lowest story:— It will be seen that the Raffaelesque decorations are very rich in character. In each pier a scroll supports and encircles four compartments; the lowest are semi-circular panels, within which are painted symbolic figures of the principal coal-bearing rivers in England: the Thames, the Mersey, the Severn, the Trent, the Humber, the Aire, the Tyne, &c. Small oblong panels, with marine subjects, are a little above the symbolic figures just described; and above these again, within borders of flowers of every kind, are figures symbolical of Wisdom, Fortitude, Vigilance, Temperance, Perseverance, Watchfulness, Justice, and Faith. These figures are the most prominent objects in the decorations of the piers in the lower story, and in circles above them are painted groups of shells; whilst at the top, in semi-circles corresponding with those at the base of the piers, snakes, lizards, and other reptiles, are introduced. In the first story, the leading feature in the arabesques is a series of views of coal-mines, including the air-shaft at Wallsend, Percy Pit Main Colliery, Wallsend Colliery, Regent's Pit Colliery, &c. Groups of fruit and flowers are in small circles just above the views, and in oblong panels beneath the latter the series of nautical "bits" is continued. At the base, in each pilaster, are representations of different specimens of Sigillaria—a fossil found in coal formations. In the second story, the largest panels contain figures of miners engaged in different parts of their labours, but these figures we think are not so well executed as other portions of the decorations. Nautical subjects, clusters of fruit and flowers, are introduced among the arabesques. The third story contains, within oval panels, miners at work, picking the coal, &c.: flowers and small landscapes add to the richness and variety of the decorations on this floor; and both in this and the lower, *calamites*, (fossils from the coal formations,) are depicted amongst the arabesques. The twenty-four panels at the springing of the dome, of which we have before spoken, have oval compartments painted in them, surrounded by a gracefully flowing border of extremely rich and varied design, being light ornaments on a dark ground. The spaces within the oval borders are coloured of a turquoise blue tint, on which is painted a series of representations of different fossil plants met with in the coal formations. This portion of the decoration is extremely striking and appropriate; and, we need scarcely say, the representation of the plants are strictly correct. These were painted in encaustic by Mr. Sang, from the drawings of Mr. Melhado, (a pupil of the architect,) taken from specimens in the British Museum. A staircase leads to the hypocaust, which was discovered in excavating for the foundation, a remnant of the time when the Romans ruled here. A visit to this will amply repay the lovers of antiquity, and its minute agreement with the details of such constructions given by Vitruvius, should be noticed.

The artificers' work generally were performed by Mr. Trego; the iron-work by Messrs. Dewer; and the woodwork was seasoned by Messrs. Davison and Symington's patent desiccating process. The floor of the merchants' area was laid down by the first-named of these gentlemen, Mr. Davison.

The cost of this Exchange was about £40,000.

The Royal Exchange, in general, has been fortunate in finding historians, still the current descriptions are, for the most part, imperfect and incorrect, and utterly without the sanction of official authority.

Like everything in the City, the existence of the Royal Exchange is owing to individual enterprise. This is the spirit and essence of commercial prosperity. The merchant is generally the architect of his own fortune; his pursuits necessarily bring him into contact with his fellow-men; and thus, while the principle of association obtains with him, and expresses itself in the guild and the corporation, in his own person he maintains a special individuality. To him who would indulge personalities, and portray characteristics, a visit to the City would afford many examples—some strange and odd enough, but all striking and strongly marked. In other pursuits of life there is more or less of a professional costume, which sinks the man in the official; but the merchant pleases himself, or acts upon early associations, in his dress and conduct. His success mostly depends, indeed, upon the personal. Gresham, the founder of the Royal Exchange, is an illustrious example of the truth of these remarks, and another instance of the great works that may be accomplished by the zeal, activity, and perseverance of an individual.

To Sir Richard Gresham, however, father of the Sir Thomas Gresham, whose name has become a "household word" to the citizens of London, the merchants of this great metropolis are indebted for the first serious attempt to found an Exchange. Before this time, the merchants met together in the open air in Lombard-street, exposed to the many inconveniences of such a place of assembling. In the reign of Queen Elizabeth, Sir Thomas Gresham, who determined to carry into effect what his father had been unable to do, proposed to the corporation, in 1564, "That if the City would give him a piece of ground in a commodious spot, he would erect an Exchange at his own expense, with large and covered walks, wherein the merchants and traders might daily assemble, and transact business at all seasons, without interruption from the weather, or impediments of any kind." This offer was accepted, and the new building, when completed, was visited by the Queen, who "caused the same to be proclaimed by sound of trumpet, the *Royall Exchange*, and so to be called from thenceforth, and not otherwise." Sir Thomas Gresham, who died in November, 1579, bequeathed the whole of this edifice, and its various appurtenances, after the death of his wife, "jointly for ever to the corporation of London and the Company of Mercers," upon trust for various purposes.

The fabric erected by Gresham was almost entirely destroyed by the great fire of London in 1666. Measures for the erection of a new building were, however, promptly taken, and in October 1667, King Charles II. laid the base of the column on the west side of the north entrance of the second Exchange; and, on the 31st of the same month, the first stone of the eastern column was laid by his brother, the Duke of York.

The popular notion has always been that Sir Christopher Wren was the architect of this Exchange; this is not the fact, the architect was Edward Jerman, one of the surveyors to the City in 1666. As this is a matter on which much difference of opinion has existed, we think the insertion of the following evidence from a letter in "The Builder," will definitively settle the question. The writer states, that the extracts we have given below, were taken from the records of the City, and of the Mercers' Company, and from them are obtained the following facts, which leave no doubt whatever that Jerman, and not Wren, was the architect of the late Royal Exchange.

"That on the 19th———1666, the commissioners appointed to the work, summoned to their assistance, Mr. Mills and Mr. Jerman, the City surveyors. Again at a joint committee, held on the 25th April, 1667, the following minute is recorded:—

"The committee, concluding it very necessary at this meeting, to make choyce of a surveyor for directing and overseeing the building of the Royal Exchange, and assisting them in carrying on that designe to the best advantage, as to substantiallnesse, ornament, and frugality; and forasmuch as Mr. Mills, the City surveyor, hath declared that hee cannot perform that worke alone, and the committee being very sensible of the greate burden of businesse lying upon him for the City all this time; and considering that Mr. Jerman is the most able knowne artist (besides him) that the City now hath: therefore the committee unanimously made choice of Mr. Jerman, to assist the committee in the agreeing for, ordering, and directing, of that worke; and, having declared the same unto him, hee, after much reluctancy and unwillingness (objecting, it might bee thought an intrenchment upon Mr. Mills his right,) at length accepted, being assured first by the Lord Mayor and the committee, that itt was no intrenchment, that this wholle committee, at all times, would acquit him from any scandall in that behalfe; then the committee ordered the clerke to acquaint Mr. Jerman with all the proceedinges of this committee about the said building."

After this appointment Mr. Mills's name does not occur again, and the works evidently proceeded with great rapidity, for they were finished within three years and a half from the period of Jerman's appointment.

On the 9th December occurs the following entry. "The committee considering that Mr. Jerman, who was chosen surveyor for rebuilding the Exchange in April last, hath not yet received any gratification for drawing drafts and directing the building; they therefore ordered that £50 shall be payed him upon account until further consideration of his merits."

These extracts, I think you will agree with me, prove that Edward German (or Ierman as sometimes spelt) was the sole architect. In these records Sir Christopher Wren is spoken of, under date of the 7th Jan., 1670, as "Dr. Wren, Surveyor-general of His Majesty's workes."

The building erected by Jerman, was publicly opened for business on the 28th of September, 1669, the expense of its construction having amounted to £80,000, which was defrayed in equal moieties by the City and the Mercers' Company.

This structure also was doomed to fall by the same element which had proved fatal to its predecessor, for on the night of the 10th of January, 1838, it was discovered to be on fire, and in the course of the night, though not entirely destroyed, was so much damaged, that for all purposes of usefulness the destruction may be said to have been complete.

The architecture of the building thus destroyed has been variously estimated; by some decried, by others praised; but probably it merited the extravagant praises of the one party as little as it deserved the severe criticism of the other.

The four orders of the quadrangle were richly decorated, with the basements, arches of the walks, the cornices over them, the niches, statues, pillars, circular windows, entablature, pediments, and balustrade, all in correct proportion and arrangement. Its principal front was towards Cornhill; and on each side there were Corinthian demi-columns, supporting a compass pediment; within each of which were niches containing statues of Charles I. and II. in Roman habits, by Bushnell. Within the quadrangle there were twenty-four niches in the intercolumns, with statues of English kings and queens, most of the kings before Charles II. being sculptured by Cibber. The centre of the area had for some time a statue of Charles II. by Grinlin Gibbons, which was subsequently displaced for one by Spileer, habited in the Roman style. In an obscure position under the piazza, the statue of Gresham, too, had its niche; and nigh to it, that of one, whose modesty would have been better content had his merit received no such acknowledgment—Sir John Bernard; to whom, in his lifetime, the memorial was erected as a mark of civic respect, but who could never bring himself to visit the walks afterwards.

The destruction of this building having deprived the merchants of London, for the second time, of their great place of resort, they were obliged temporarily to assemble in the space attached to the Excise Office, in Old Broad Street. This was, of course, attended with much inconvenience to those accustomed to attend 'Change, and it became therefore a matter of pressing importance to remove that inconvenience by the erection of a new building, fitted in every respect for its purpose, and worthy the merchant-princes of the first metropolis in the world.

In preparing to re-erect the Royal Exchange, many interests had to be considered—those of the Underwriters of Lloyd's, the Royal Exchange Assurance Company, and the shopkeepers who had occupied the ground-floor. An act of parliament was also necessary; this was applied for, and obtained. By this act, which received the Royal assent on the 10th of August, 1838, the Joint Gresham Committee were empowered to purchase and remove all the buildings to the eastward, extending nearly to Finch Lane, and to raise a sum of £150,000 upon the credit of the London Bridge Trust.

After considerable delay, the Gresham Committee issued their advertisements for designs for the new building, but in doing so, unfortunately did not avoid the errors into which so many similarly-constituted public bodies have fallen, under similar circumstances. There is little doubt but that the Committee intended a fair and honest competition, but with *not singular* bad management, they so contrived matters, as to bring down on themselves a storm of indignation from all sides, and to disgust not only the competitors, but the public in general.

The system pursued of late years in the management of architectural competitions, has been attended with manifest evils, and fraught with gross and palpable injustice to the profession. Hastily and inconsiderately commenced, under the control of persons unfitted to sit in judgment on the various designs referred to their decision, they have in too many instances been attended by results, as injurious to the best interests of art, as unfair and unjust to its professors.

In making these remarks it is not intended to attack the principles upon which competitions are based; properly conducted, their tendency is unquestionably, not only to call out the talent and genius of the experienced artist, but to rouse a spirit of emulation in the young professor, as an assistance in encouraging rising merit, which without such a stimulus might possibly remain undeveloped, or, without such a means of exercise, unknown and unappreciated.

There may be many advantages attending architectural competitions, but there is so total a want of security, under the operation of the present defective system, so general an impression existing, whether justly or not, that fairness and impartiality in the decisions cannot always be relied upon, that the great body of the profession hold themselves aloof from entering an arena where fair play is, to say the least, doubtful. The competition for the Royal Exchange, it is to be lamented, afforded another proof, if proof were wanting, of the truth of those observations.

It is not our purpose to enter on a discussion of the merits of a controversy which filled many pages of the periodicals more especially devoted to recording matters connected with architecture and building, but we think we cannot pass to a description of the New Exchange without slightly noticing the manner in which the design for it was selected, or its architect appointed.

The following are extracts from the—

"*Resolutions of the Gresham Committee, as to Instructions to the Architects.*

"1. That architects be invited to offer designs for the rebuilding of the Royal Exchange, in general competition, and that premiums be offered for three designs adjudged by the Committee to be the best.

"3. That the new building be of the Grecian, Roman, or Italian style of architecture, having each front of stone of a hard and durable quality.

"6. That a specification be required to accompany each design, giving a general description of the building, and such other information as cannot be clearly shown on the drawings, stating also what stone, or other material, are proposed for use in the different parts of the building, and specifying particularly the estimated expense of carrying the designs into execution in the most substantial and complete manner in every respect for occupation, the expense not to exceed £150,000.

"10. That for the design for which the Committee shall award the first premium, the sum of £300 shall be given; that for the second design the sum of £200; and for the third the sum of £100. The successful competitor, to whom the first premium is awarded shall not be considered as having necessarily a claim to be entrusted with the execution of the work; but if not so employed, and his designs are carried into execution, a further sum of £500 shall be paid to him—the Committee retaining possession of all the drawings for which the premiums have been given.

"11. That if reasonable doubts should arise in the minds of the Committee as to the practicability of carrying into execution the successful design for the amount of the estimated expense of the building, the Committee shall be at liberty to call upon the party to give sufficient and satisfactory proof of the accuracy of the calculations, and to withhold the premium, and reject the designs unless such proof be furnished."

After issuing these Instructions, the Committee appointed three architects—Sir Robert Smirke, Mr. Gwilt, and Mr. Hardwick, to examine and advise on the designs which might be sent in. Above fifty competitors appeared, and the above gentlemen, after due examination, made a report to the Committee, from which we extract the following passages.

"In the first class, those that we think may be executed for £150,000, we beg to report as follows:—

First	No. 36
Second	„ 43
Third	„ 37
Fourth	„ 33
Fifth	„ 57

"In the second class, or that in which we consider the cost would vastly exceed the sum of £150,000, equal impracticabilities of execution with those of the first class are to be found; and, notwithstanding the very great talent they exhibit, there are circumstances of inconvenience and unsuitableness which would bring them, as we conceive, into the predicament of being unadvisable for adoption. We wish it, therefore, to be understood, that we report on them respectively as the works of very clever artists, who have produced pieces of competition in which, besides the circumstances above-mentioned, stability arising from solid bearings for upper apartments, and other essential matters, have been sacrificed to grand architectural features.

"The designs in the second class, in our estimation of their order of merit, are as follows:—

First	No. 50
Second	„ 46
Third	„ 27

"We again venture to state to the Committee the difficulties which have attended the making of the report herewith submitted, and which, but for the unanimous decision at which we have arrived, we confess, might have left doubts in our minds, if our view had not been confined by the Committee to the expenditure of a given sum."

On receiving this report, the Joint Committee met at Mercers' Hall on Friday, the 18th October, to consider the report, and again inspect the designs, and came to the following resolutions :—

"Resolved,—That the premiums be awarded to the architects who have produced the plans numbered as under—

No. 36 the first premium . . . £300
„ 43 the second „ . . . £200
„ 37 the third „ . . . £100

being those reported by the architects as the three best designs.

"And it was resolved, that Sir R. Smirke, and I. Gwilt, and P. Hardwick, Esqrs., having stated in their report upon the respective merits of the plans selected by them, that they cannot recommend any one to be carried into execution, this Committee doth request them to take the 1st, 2nd, and 3rd plans, as selected by them, into consideration, and prepare a plan and specification for a new Royal Exchange, such as in their judgment should be carried into execution, having reference, at the same time, to the printed instructions issued by this Committee to the architects."

The following were the architects to whom the premiums were adjudged.

No. 36, £300, to Mr. William Grellier, district surveyor, 20, Wormwood-street.

No. 43, £200, to M. Alexis De Chateauneuff, of Hamburgh ; and Mr. Arthur Mee, of Carlton Chambers.

No. 37, £100, to Mr. Sydney Smirke, of Carlton Chambers.

The architects of the remaining designs of the first class.

No. 33, Messrs. Wyatt and Brandon.
„ 46, Mr. Pennethorne.

The architects of the second-class designs, which were considered too expensive.

No. 50, Mr. T. L. Donaldson.
„ 46, Mr. Richardson.
„ 27, Mr. David Mocaotta.

The next step taken by the Committee was to appoint Mr. George Smith, the City-surveyor, and Mr. Tite, to inquire into the eligibility of some one of the designs selected by the umpires for the premiums. Mr. Tite, however, refused to act, and the onus devolved on Mr. Smith alone. This gentleman submitted a report to the Committee, in which he advised the rejection of the whole of the designs; and the Committee acting on this advice, without ceremony threw the supposed successful candidates overboard, and boldly selected six other architects, whom they requested to send in designs for the contemplated building. The gentlemen so honoured by the Committee were Sir R. Smirke, Mr. Barry, Mr. Gwilt, Mr. Hardwick, Mr. Cockerell, and Mr. Tite, the whole of whom, excepting the two last, declined accepting the invitation, being doubtless influenced to such course by the bad faith observed to all parties by the Committee. What also added to the public dissatisfaction, was that rivalry or competition between Mr. Cockerell and Mr. Tite was considered out of the question, from their previous connection. Thus the whole matter evidently settled down in Mr. Tite being selected finally to prepare the design for the new Royal Exchange.

That design we shall now proceed to describe, as given by Mr. Tite, himself, in his explanation to the Committee :—

Extent and Site.

The total length of the building is 293 feet 6 inches, from the columns of the portico on the west, to the pilasters at the east end ; the width of the portico is 89 feet 6 inches ; the extreme width at the east end, at the broadest part, is 175 feet, and the width through the centre, from north to south, is 144 feet.

The building is placed in the centre between the south front of the Bank, and a mean line of the irregularities presented by the houses on the south side of Cornhill ; the east and west fronts are at right angles to the centre line, and, of course, the angle formed by the intersection of the north and south fronts, with the east and west fronts, is the same ; by this means the building, though not rectangular, is regular in the plan.

Arrangement.

Gresham College occupies the north-west angle of the building on the principal story, and is entered from the north.

The Royal Exchange Assurance occupies the south-west angle, and the space over the west end of the colonnade, on the one-pair floor, and is entered from the south side of the loggia, under the portico.

The London Assurance occupies the greater part of the south front on the principal story and is entered from the south.

Lloyd's fills up the remainder of the east and north fronts of the principal story, and is entered in three places, viz., from the east and the north-east corner, and from the north.

There is a small additional staircase and entrance to the principal lecture-room of the Gresham College (which I propose to use for the exit from the lectures only) and this opens into the loggia under the portico.

The commercial room proposed to be attached to Lloyd's, and which, in a letter from Mr. Barnes, of the 26th February, I am requested so to manage as that it might be appropriated for offices, if not eventually required for the above purpose, has been accordingly placed by me on the principal story on the north side. If not required by Lloyd's, I should propose to convert this room into a double range of offices, one lighted from the street, and the other lighted from the area of the Exchange, each office having a room over in a third floor; the access to these rooms would be by a distinct staircase and entrance on the north, for which a distinct shop must be taken. The mean width of this commercial room is 39 feet, and its length 96 feet; allowing, therefore, for an 8 feet passage in the middle, it would provide for 12 sets of offices, each 16 feet by 15 feet.

The shops and offices are very material features of any design for this building, for, under the 62nd section of the act for providing a site for the Royal Exchange, the Gresham Committee are bound to compensate any party holding a lease in any part of the old Royal Exchange, unless the owner or lessee is reinstated. As regards the offices this would probably only be the value of the difference between the reserved rent and the actual rent, and not a matter of much importance ; but unless the valuable trades and occupations round the Exchange are reinstated, the question would become a very important one, because it would involve the good-wills of the parties. The mere question of reinstatement, however, is not the only one ; for it is clear the revenue to be obtained from the shops, after the expiration of the present leases, must form a very important item in any income to be derived from the building. In order to meet these requirements, and still, I hope, in no way to injure the design, I have placed the shops or offices on a level with the street, round the north, south, and east sides; and, inasmuch as I found that in the old Royal Exchange there were shops in three of the entrances, and as I could very conveniently arrange a few in the east entrance of my design, I have placed six there. Let the claims, however, arise as they may, with this plan now under discussion, there could be no difficulty in meeting them all, for the area of all the shops and offices of all descriptions, in the ground-floor of the Old Exchange, amounted to 8,106 feet only, whereas, in this plan, the shops and offices provided, exclusive of the part appropriated to Lloyd's, to the Gresham College, the London Assurance, and the Royal Exchange Assurance, exceeds this quantity by 1,087 feet, the total being 9,217 feet. The increased value of all this, and the exact nature of the accommodation, will, however, be further explained under other heads of this descriptive particular.

Accommodation.

Gresham College.—In considering this department of the building, I was placed in considerable difficulty, not only from the total absence of instructions, but because I found, as well amongst the committee as in society, very considerable differences of opinion on the subject.

After much reflection, I have, however, arranged what I hope will be considered a complete establishment for most purposes, and it is as follows:—On the north side of the Exchange, about 45 feet from the west end, is an entrance with a small hall and staircase. In this hall a porter would be placed, who would prevent the admission of improper persons.

The entrance-doorway is large, and over it is placed a shield containing the arms of Sir Thomas Gresham. This entrance and hall are also quite distinct, and, like all the other parts or distinct portions of the design, it is separated by party-walls. On the first landing of the staircase is a porter's room, which would also serve for umbrellas, coats, or cloaks.

On the one-pair, or principal floor, is a lecture-room or theatre, of a horse-shoe form, the dimensions being 46 feet, 6 inches, by 36 feet. To this is added a library or lesser lecture-room, 25 feet by 24 feet; a lecturer's or librarian's room, 19 feet by 15 feet 6 inches; apparatus-rooms, 16 feet 3 inches, by 11 feet: with a water-closet and washing-room; and two rooms over the librarian's, and apparatus-rooms for some resident servant.

The theatre would seat 250 persons on the floor, and 200 more might be conveniently seated in the gallery. It is probable, however, that for many lectures or continuous courses, this might be too much, but for some it might be too little. I have, therefore, placed the library at the back of the theatre, by which, in the latter case, the accommodation might be increased, or in the former it might be sufficient in itself for such purposes. The result, therefore, is this, that for an auditory of 40 or 50 persons, the library would be sufficient; beyond that number, and up to 450 persons, the theatre would be the proper place; if a larger number were expected, the partition dividing the library from the theatre might be removed, (as is shown in the plan) by sliding it into the wall, when, by removing the lecture-table a little further back, 50 persons more might be accommodated. Beyond this extent of 500 persons, it is probably undesirable to carry it further.

If, however, I have erred altogether, and have provided too much, it is easy to diminish it; or if it is determined to abandon this site for this purpose, the space so complete and isolated would readily let by itself, or might be combined with the unappropriated offices in the north-west angle immediately under the theatre. It remains to be added, that I have also provided ample vault-room in the basement of this establishment, and a second staircase connected with the theatre, and only intended to be used on a crowded occasion, for the dismissal of so large an audience as 400 or 500 persons, and for a private approach or retreat for the lecturer.

Royal Exchange Assurance.—This establishment in the old building occupied apartments in the mezzanine, and on the one-pair floor. The net area being 5,235 feet, exclusive of passages, staircases, water-closets, kitchen, and rooms in the roof. I have had many meetings with the governor on the subject, and at length I received, so late as the 4th instant, a list of the rooms, of which I have attached a copy to this description.

The total area in this is 6,284 feet, but omitting the store-rooms and kitchen for the sake of comparison, the net quantity is 5,894 feet. My plan gives this so nearly, and the dimensions of the rooms also correspond so generally with the requirements, that I need not occupy the time of the Committee with any further description; but, in addition, I have added what appears to me obviously necessary, viz., strong rooms and cellars in the basement.

As the heights of the floors of this part of the building differ in some respects from the general section, I beg to add them here, and they are as follows, viz.: The ground-floor is 2 feet 6 inches above the level of the floor of the Exchange, and 6 feet above the street; under this is a lower ground story, the height being 10 feet with vaults under.

The ground-floor will be 13 feet, high, the mezzanine 10 feet, the one-pair floor is 18 feet, except where there are rooms over, when this will be 13 feet.

London Assurance.—I attach a copy of the instructions received from this company to my letter of the 6th March, addressed to Mr. Barnes. The total quantity of space required is 5,553 feet, exclusive of waiting-rooms, water-closets, &c.; as some of the rooms seemed extravagant in size, I have arranged them somewhat less, and the company express themselves satisfied with my dimensions, the total being 4,834 feet.

Lloyd's.—With regard to this very important establishment, I beg a reference to my letter to Mr. Barnes, of the 6th instant, to which I attach a copy of the new instructions forwarded by their architect. The total quantity of space occupied in the old Exchange by this company, exclusive of staircases, was 7,914 feet. The space now required is 13,781 feet, exclusive of passages, staircases, water-closets, urinals, &c.; but this includes the commercial room, which is 4,050 feet. The dimensions of the several apartments in my plan are very nearly consistent with their requirements, and the total result the same.

The arrangement of the rooms is best understood by a reference to the plan of the one-pair floor, and I believe it to be quite in accordance with the wishes of the Committee.

Shops.—I propose that each shop shall have a cellar below, and, with very few exceptions, a mezzanine over. The average height of the shops will be 14 feet, the basement-floor 12 feet, and the mezzanine 10 feet. Each shop will be secured by party-walls, and roofed with iron beams and arches under the one-pair floor. The water-closets will be in the basements, there will be a separate flue in each shop, and room for the fire-places; and I propose that each shop and room shall be warmed by an open, or Arnott's stove, of the same pattern.

The staircase will be circular, and of cast-iron. Staircases of this kind, though not much known here, have been extensively used in Paris, and are admirably adapted for such purposes. I have paid every attention to the mode of lighting the deeper shops, and I hope I have succeeded in obviating all reasonable apprehension on that subject. The shops without mezzanines, are one in the south front, one in the north front, and four in the eastern entrance to the Exchange. In the area, in the latter case, they are left out, to allow of light being obtained over the shops to the back parts of the other premises.

Exchange.—The Exchange is entered from four arched openings in the centre of each side; the form is a parallelogram, and the inner area exactly a double square. This form has many advantages, both in point of convenience and elegance over the old form, and is also better adapted to the shape of the ground.

As to the level of the floor of the Exchange, I have heard many opinions; but it appears to me to be of the greatest importance, that it should be as nearly level with the street as possible. From the natural fall of the ground, however, which is quite gradual, but amounts to 3 feet 6 inches in the length of the building from east to west, it is impossible to avoid a few steps at the north, south, and west entrances. This is an advantage at the west end, as it gives height and character to the façade or portico; the exact effect and extent of this fall of the ground is shown in my north and south elevations. In the shops the steps are avoided, because they can follow the natural inclination of the ground.

Basement.—Much of the basement (or vaults,) is occupied by the establishments over the respective divisions, and I have added some to the lesser shops, but there is still a large space which may be let off, as the basement of the old building was. I have lighted the basement by area gratings in the pavement of the Exchange, exactly as formerly.

The public vaults are approached by two staircases, which are placed in the eastern entrance. The central area is proposed to be left without a basement; it would be difficult to keep it dry, and I do not know any use to which it could be applied which would pay for the cost.

Style of Architecture.

This is naturally one of the most important considerations in the design, and one in which I have most to regret the limited time I have had to consider this most extensive and difficult composition. It appears to me, that a building for essentially commercial purposes should present the character of grandeur, simplicity, and usefulness. In this way, the universally acknowledged good effect of the Bourse at Paris has been obtained. In that building the lines are simple and unbroken, and the large arched windows surrounding the walls behind the columns have all the character of shops or offices. The west front of the Exchange of London, as in that of Paris, must be the principal feature, the other sides being bounded by buildings.

Another difficulty arises from the shape of the ground; because any tower placed to agree with the lines of the south front must disagree with the lines of the east and west fronts, which are in different planes; and such an object, when seen from a distance, or from the area of the Exchange, would produce an effect that would be discordant and unarchitectural, because it would bring into distinct notice a fact which it should be the business of the architect to conceal. For a long time I contended with this difficulty, because I was anxious to place the tower or towers in the south front, but it was impossible to get over the irregularity; it would, indeed, have been easy to have concealed this defect in the drawings, or have kept it out of notice, but the result, when built, would only have ended, in my judgment, in disappointment and failure. For these reasons, and with these views, I have composed my design as it is now exhibited. I have placed a portico at the west end, and the tower at the east. The south and north fronts exhibit unbroken lines of entablature, with a repetition of arches of the same character for the shops, offices, and entrances. We are deficient in England, of specimens of architecture of this unbroken kind: were I to adduce instances, I should quote the National Gallery, as affording an illustration of the bad effect of broken and detached masses, and the Reform Club, of the excellent effect of continuous and unbroken ones.

The portico would be very superior in dimensions to any in this country, and not very inferior to any in the world. The width, from outside to outside of the 8 columns, is 90 feet, and the height, from the ground to the apex of the pediment, is 74 feet 6 inches. The portico of St. Martin's Church is 64 feet wide and 58 feet high; that at the Post-Office 76 feet wide and 67 feet high; and from these dimensions a fair comparison may be made of the relative size of the two porticos.

The height of the order used in this edifice is 50 feet, and the height of the tower, to the top of the vane, is 170 feet. From the point of view prescribed by the instructions, the tower is not seen. Had I been at liberty to have removed the station further to the westward, as to Mansion-House-street, or the Poultry, the tower would have been seen over the portico, and the effect of the composition thereby greatly improved. The sections and view show the exact character of the interior of the Exchange, the lower story is a colonnade of the Doric order, the columns are 34 inches in diameter; the upper order is Ionic.

Specification of the nature of the work.—The examination of the foundations, which I ventured to suggest, has proved that the nature of the sub-soil is of the best kind for supporting a large building. At an average of fifteen feet from the surface, a very compact gravel is found. For the sake of perfect uniformity, I should excavate sufficiently for a few feet below this; and by a uniform bed of concrete, of the thickness of six feet over the whole surface, a most certain and safe foundation would be made. The gravel is full of water, and therefore the drainage must be carefully considered.

Your conditions require a general specification, but, without going into full technicalities, I am at a loss to furnish a specification of any value. I intend everything to be executed in the best manner. All external work to be faced with Portland stone; all the horizontal divisions that require it, for the purpose of security from fire, to be constructed with iron beams and brick arches; and the ceiling and floor over the colonnade constructed in the same manner. The timber used to be all Baltic timber, English oak, or African teak. Everything to be sufficiently and completely finished in all respects.

Sculpture.—I have not introduced much sculpture into this design, because the estimate would not allow of it; and I have, therefore, aimed at a style which did not require it to any extent. The sculpture introduced as essential to the architecture, embraces the five panels in the attic of the south front, and the two figures at the west end. The panels in the south front are intended to represent Britannia, supported by the principal cities of the empire receiving the representatives and productions of the four quarters of the world; the two seated figures in the west front, are emblematical of Peace and Abundance. There are several shields of arms, which though not falling exactly under the head of sculpture, I think it desirable to mention, and they are as follows:—the escutcheons on the key-stones of the three great arches of the west front, are the arms of Queen Elizabeth, Charles the II., and Queen Victoria. These arms are repeated in the panels of the attic at the east end. In the north and south fronts, on the keystones of the centre arches, the arms are those of the City, the Mercers' Company, and Sir Thomas Gresham.

Estimate.

I estimate the cost of this edifice, as thus described, including the sculpture, at the sum of £143,800.

Income.

I have estimated with great care the income to be derived from the various shops, offices, and public establishments, proposed in the several floors of the building, by comparing dimensions and other circumstances, with the previous lettings, and by the actual value derived from my own experience; and I am of opinion that the total net annual value, if let on lease, would amount to the sum of £8,718 per annum. In addition to this, if the space allotted to Lloyd's commercial room on the north side, and that to the London Assurance on the south side, were arranged as offices, each set having two rooms, one over the other, as suggested in an early part of this statement, though the estimate would be increased £3,000, I have no doubt this annual income might be raised to the extent of £800 per annum, making a total income of £9,500 per annum.

In the drawings themselves, I have carefully laboured to follow out the instructions under which I undertook this competition. The views are strictly confined to the points of view prescribed: in the colouring of the views themselves, and in the drawings of the adjoining buildings, I have laboured to be accurate, and to give as nearly as I could, the actual effect of this edifice, if it were constructed. I cannot but feel that a more elaborate style of architecture would have been productive of more picturesque effects, and it would have been easy to have produced them; but I have ventured to come to the conclusion, that nothing but plain grandeur and elegant simplicity is consistent, either with the means at the disposal of the committee, the purposes and uses of this building, or its situation in the very heart of the City of London.

We have given at length Mr. Tite's own description of the building, as affording the most perfect and complete explanation of every particular connected with it, and also as showing the many requirements he had to meet, and the various interests he had to provide for. It is due to him to say, that he has certainly succeeded in satisfying all parties, in the convenience of his arrangements for individual benefit, while he has added to the public buildings of London an edifice in every respect worthy the first community in the world. On one part of the design much discussion took place at the time, viz., whether the area of the new Exchange should or should not be an open court, as in the old building. In the instructions issued to the competing architects by the Gresham Committee, this was insisted on, and, as we are informed, in compliance with the general opinion of the merchants and bankers of London. With submission, however, we are strongly inclined to believe that the merchants and the Gresham Committee might have left this matter, with benefit, to the discretion of the architects offering designs, with whom it would have remained to demonstrate the advantage or defects of either mode of construction, whether open or covered.

It is worthy of remark that the Bourse at Paris, and at St Petersburg, the Exchanges of Dublin and Glasgow, and almost all modern structures erected for a similar purpose, are, we believe, roofed in; one advantage of which is, that the whole of the area is available, let the weather be as unfavourable as it may, consequently, the same superficial extent can accommodate a far greater number of persons than where it is only partially sheltered, and where a considerable portion must frequently be altogether useless, as far as actual serviceableness is concerned. The present arrangement therefore is to be approved of only where what is thus sacrificed, with regard to mere convenience and utility, is amply atoned for by what is gained as to architectural character and effect.

We do not deny that a *cortile*, whether surrounded by columns or by arches, and whether partially or entirely so, is favourable to scenic effect and display, and, farther, admits of very great variety as to plan and design. This is sufficiently testified by examples in Italian buildings, where cortiles frequently constitute the most striking and beautiful parts, generally picturesque and piquant, though not always unexceptionable in design. But then it does not exactly follow, that because a cortile is beautiful as such, it is eligible for a purpose requiring more than a sheltered corridor around the open part; for, although that kind of shelter is sufficient for a place of *passage* to and fro, it certainly does not seem to be sufficient for one intended for the assemblage of a concourse of persons, not on particular occasions, when, in case of the weather proving unfavourable, the company may be protected from it by awnings provided for the emergency, but daily, throughout all seasons of the year. When a place of the kind already exists, it may conveniently and properly enough be applied just as it is to the purpose of an Exchange; its inconvenience may, then, be put up with as unavoidable. But there is no qualifying circumstance, to reconcile us to a defect studiously adopted, voluntarily and with premeditation, to the exclusion not only of positive convenience, but likewise of originality of design. Either our climate is most unjustly reproached, not only by foreigners, but by ourselves, or it ought at once to have banished all idea of rebuilding the Royal Exchange upon the plan of the former one, as regards that very principal part of it where the merchants will daily assemble, and to which all the rest is to be considered as merely supplementary.

Be it any improvement or not, all our lately built markets are floored with flagstone pavements, and covered in from the weather, shaded from the burning sun in summer, as well as sheltered from rain and snow in winter; nor do we believe that either the occupiers of them, or their customers, at all regret the change which has taken place. Nevertheless, with instances of that kind before their eyes, not in the Metropolis alone, but at Liverpool, Newcastle, and other places, the merchants of London have decided that they are to meet for business as heretofore, within an area only partially and imperfectly protected from the weather. Even beneath the colonnades, they must be more or less exposed to wind and rain, and be inconvenienced by the throng of persons; whereas, by converting the central space into the part more particularly appropriated to the transaction of business, the sides, which might still be separated from it by colonnades, would be left free for persons passing in or out, without interruption to those engaged in business.

There may possibly be contrary reasons for not adopting a mode of building securing the advantages here pointed out by us; but they have not been brought forward by others, nor can we divine what they can be. Hardly can it be objected, that any plan of the kind would destroy all peculiarity of character, by converting the Exchange itself into merely a spacious hall, lighted from above, which, however it might be decorated, would, in its general effect, resemble any other public apartment of the same dimensions; because, although it would no longer be a cortile—an open space enclosed by façades of external architecture—it might be kept altogether different from anything we are accustomed to, in interior architecture, and appropriately rendered *sui generis.*

It will appear a very singular pendent to the above observations, that we should have to insert the following petition to the Gresham Committee, from the very parties to oblige whom this "uncovered" area was insisted on.

"The undersigned Merchants of the City of London are of opinion, that, in the construction of the new Royal Exchange, sufficient attention has not been paid to the comfort of those who attend the same, and beg most respectfully to submit to the Gresham Committee the following alterations, which are necessary before they can assemble there without danger to their health and personal comfort. The alterations suggested are:—1. That the area be covered in. 2. That some remedy be provided to remove the cold damp from the pavement. 3. That a remedy be also provided to protect them from the currents of air."

The above petition has been signed by Messrs. Barings, Rothschilds, Heath, Morris Prevost, Doxat and Co., Lemme and Co., and some hundreds of the first firms in the city. After much discussion in Committee, the clerk was directed to communicate to the memorialists:—

"That in the month of September, in the year 1838, before the Gresham Committee took any steps whatever as to the erection of a new building, they applied by circular to most of the leading merchants and brokers, requesting their opinion as to whether the new Exchange should be a covered hall, or partially open, as in the original Exchange of Mr. T. Gresham, and in the one recently destroyed; that besides, the Committee took every opportunity, by personal inquiry, of ascertaining the wishes of their fellow-citizens on the subject; that the result of the circular, and of these inquiries, was, that a large majority wished the Exchange to be partially open, as heretofore, alleging the great noise in the Bourse at Paris, and the necessity for ventilation of the most free kind, as their reasons for the decision; that in consequence of this determination, they directed a part of the merchants' area to be left uncovered as before, but that, for greater shelter, they further directed that the covered space should be increased from one-half, (the proportion of the space covered in the late building,) to two-thirds; and that the architect of the present edifice had strictly followed out these instructions; and, for these reasons, the Committee could not comply with the wishes of the merchants; that, with regard to currents of air, the committee had directed such inner doors to be put up, at the north and south entrances, as might check the draughts, at the same time providing that such doors should not interfere with the extensive uses of the area of the Exchange, as a thoroughfare to all the neighbouring streets, the Bank, the Stock Exchange, and other important public and private buildings of the neighbourhood."

We have given the above, as *apropos* to the question of a roofed or unroofed area, though this is hardly the proper place for a petition delivered some months after the Exchange had been opened for business. Such a petition, however, proves clearly the justice of the observations we, in common with the great body of the profession, have urged to the central space of the building having been left uncovered.

To return from this apparent digression.—After much consideration as to whether the material employed should be magnesian limestone, similar to that used for the Houses of Parliament, it was determined that the whole of the exterior of the building, with the exception of the socle or stylobate (which was to be of granite) should be Portland stone of the best quality. This point having been decided, the Gresham Committee at length found themselves in a position to enter on the contracts for the new structure. About fourteen of the principal builders were applied to, and sent in tenders; and those of Messrs. Webb for the first contract, (the excavation and concrete foundation); and of Mr. J. Jackson for the second (the super-structure),—were accepted. The first was for £8,000—the last for £115,000.

In excavating the merchants' area, (originally intended to have been left solid,) for the purpose of extending the basement beneath that part of the plan: a number of antiquities were discovered, beneath what was the west wall of the former building; in particular, the remains of some Roman structure were found, which proved, on examination, to have been built on a very large pit or pond, irregular in shape, but about 50 feet in length from north to south, 34 in breadth, and 13 in depth. This pit was filled with hardened mud, in which were immense quantities of bones of sheep, of bones and horns of stags, also numerous fragments of the red Roman pottery, usually called Samian ware, pieces of glass, and glass vessels, broken lamps, &c., and several copper coins, two of the emperor Vespasian, the remainder of Domitian—all of which antiquities were, by the terms of the contract, reserved for the Gresham Committee. On Monday the 17th January, 1842, the first stone was laid by His Royal Highness Prince Albert, with much state and ceremony, a full description of which appeared in the newspapers of the day; and the works then proceeded with such rapidity, that in three years from that date the new Royal Exchange was completed—a very brief space of time for such a work, especially considering that it consists entirely of stone.

On Monday the 28th of October, 1844, the Exchange was opened by Queen Victoria in person. The "pomp and circumstance" of such a ceremonial are not for a work like the present, they have been duly chronicled by those publications which record so faithfully and so minutely events like these: but the following observations, which appeared in one of the newspapers at the time, seem so pertinent to the subject, that we think their insertion here not inappropriate. "The present ceremonial," says the writer, "will, in many things, resemble that which was presided over by the 'Virgin Queen:' for state and its observances partake of the traditional, and are transmitted down with comparatively slight changes. But in all else how different! What an empire! and what a metropolis! How vast the increase in all that constitutes the strength of nations, in the England of Victoria, since it was the England of Elizabeth! The empire is one of many tongues and nations; the population of its chief city is counted, not by thousands, but by hundreds of thousands; and as for the commerce of the realm and city of Gresham's royal mistress, it was, as compared with that of the England and London of to-day, but as the rivulet to the ocean; its development has been as vast as that which could bring 'Dodona's forest from an acorn cup.' Between the day on which a Queen of England passed through the Temple-Gate to open the first Royal Exchange—and the hour which will see another Queen of the same fair land pass along the same road on the same august errand—great has been the destiny of England among the nations of the world! At this point the mind naturally goes forward to the future, and asks itself the question, what will be the state of this 'crowning city,' of the traffickers of the earth, when three centuries shall have passed over the now white walls, the fair chambers, and sculptured portico, of the new Exchange? What will be the condition of the empire, when the generation that gazes on the pageantry of to-day, shall—with many succeeding ones—be mingled with the dust? They are solemn questions; and, happily for us, can find no answer from human intelligence. The misery of Adam, when the angel, in Milton's immortal epic, revealed to him the doom of the future race of man, is but a type of what would be felt by all, if the coming time were not, with infinite wisdom and mercy, hidden from our ken. The past we know; the present we can govern; for the future we can only hope, making our actions such as to render a cheerful hope justifiable. Let the spirit of commerce, then, when it takes up its new abode, work with the energy and activity that have always marked it. Above all, let it preserve that integrity and commercial honour which have been so long the pride of the English merchant, and then will it have done the best to secure a still further development of the wealth, extent, power, and numbers of that realm over which Elizabeth watched, and which Victoria now rules; queens, who, differing in much, yet resemble each other in the extent to which they have commanded the loyalty and affection of the people; and in this also—that the commercial activity of their respective ages received the countenance of both. In its reference to our history, the opening of the New Royal Exchange by Queen Victoria, is one of the most interesting events of modern times."

We must not conclude our description of this magnificent building, without reference to the sculpture with which the new Royal Exchange has been adorned. That by Mr. Richard Westmacott, in the tympanum of the pediment at the west front, deserves the earliest and highest mention, both from its position and its merit. Allegorical in subject, it nevertheless avoids the objections to which such compositions are generally liable. It consists of seventeen figures, carved in compact limestone, and, with two exceptions, modelled as entire and detached figures. The centre figure, which is ten feet high, represents Commerce; with her mural crown, her cornucopia, bee-hive, and other accessories. Her left hand holds the charter of the Exchange, her right rests on part of a ship; two dolphins and a shell forming her pedestal. The groups on either side consist, on the right, of three British merchants in their civic robes—as lord-mayor, alderman, and common-councilman; two Asiatics, a Hindoo, and a Mahommedan, in appropriate costume; a Greek bearing a jar; an Armenian scholar, and a Turkish merchant; and, on the left, of two British merchants examining some woven fabric shown to them by a Persian; a Chinese; a sailor of the Levant; a negro; a British sailor cording a bale of cotton, &c.; a super-cargo, or factory agent. The opposite angles are filled with anchors, jars, packages, and other nautical and commercial emblems. The arches of the upper story are decorated with the arms of various nations, according to the order determined at the congress of Vienna—the arms of England occupying the centre of the eastern side. The sheltered walk for the merchants also has the ceiling and sides panelled, painted, and emblazoned with the arms of countries and monarchs; namely, Edward the Confessor, Edward III., Elizabeth, and Charles II. In the south-east angle there is a statue of Queen Elizabeth, and in the south-west a statue of Charles II.

It only remains now to speak of the statues of Queen Victoria inside the building, and of the Duke of Wellington without. The latter is a bronze equestrian figure, by Chantrey, and was composed of the metal of the guns taken in battle, contributed by the government, and valued at £1,500. The cost of the statue itself was £900. It was completed on the anniversary of Waterloo, the 18th June, 1844, when the inauguration took place, at which the King of Saxony, who was in England at the time, attended. The marble statue of the Queen, by Lough, in the centre of the merchants' area, was not placed on its pedestal until the 27th of October, 1845. An interesting fact is recorded by historians respecting the statue of Gresham. During the raging of the great fire of 1666: "When the fire was entered," writes the old chronicler, "how quickly did it run round the galleries, filling them with flames; than descending the stairs, compasseth the walks, giving forth flaming volleys, and filling the court with sheets of fire. By-and-by the kings fell all down on their faces, and the greater part of the stone building after them, *the founder's statue alone remaining*."

It is a remarkable fact, that this statue was again saved in the fire of 1838.

The gates of the Exchange are exceedingly handsome. They are made of wrought-iron, the decorations being cast-iron. In the centre of the gates, on either side, are the arms of the City of London, and of the Mercers' Company, with the cipher of Sir Thomas Gresham, (T. G.,) very ingeniously introduced. In the ornamental heads of the gates, the rose, thistle, and shamrock appear entwined.

After the publication of the first portion of this article, the following paragraphs appeared in *The Times;* and we think we cannot better conclude our account of the Exchanges of London, than by recording so high and so well-deserved a compliment, to the designer of the Coal Exchange:—"A piece of plate, weighing 222 ounces of silver, was presented to the City architect, for services which are sufficiently indicated by the inscription: 'Presented to I. B. Bunning, Esq., by the coal-factors and merchants of the City of London, as a testimonial of their admiration of his genius and judgment in the erection of the Coal Exchange, and of his urbanity throughout the progress of the structure; which is not more approved of by those for whose use and convenience it was designed, than by the public at large, for its taste and elegance as a work of art. Anno Domini M.D.CCCL.' The plate was presented by Mr. Harris, as the organ of the coal-factors, with an appropriate speech. In addition to this pleasing compliment to Mr. Bunning, the coal-factors and merchants have signed a declaration, for presentation to the Corporation of the City, of their satisfaction of all the accommodations provided for them by means of the New Coal Exchange, which they attribute to a union of talent on the part of the architect, which has enabled him to produce an edifice which, whilst it embodies all the requirements of the coal-factors and merchants as men of business, is, at the same time, in design, taste, and judgment, the admiration of the numerous strangers who daily visit it, as one of the chief objects of interest and of Art in the City of London."

EXEDRÆ, (from the Greek εξεδραι, *a parlour*) among the ancients, places wherein the philosophers, sophists, and rhetors, held their conferences and disputes. They are supposed to have been recesses in the walls, or little chapels, answering to what we call *chapters* in the cloisters of monks, or collegiate churches.

Also applied to an apse or recess in a building, or to a projecting porch, in short, to any addition to a building. In the early Christian church, the term is applied to all the buildings within the consecrated enclosure which were detached from the church. Such were the baptisteries, vestries, diaconica, schools, libraries, and such like.

EXENTRIC, or Eccentric, (from the Latin *eccentricus*) in geometry, a term applied to two circles or spheres, in which, though in some measure the one is contained within the other, yet the two have not the same centre, and consequently their surfaces are not parallel. The word is opposed to *concentric* where they are parallel, and have the same centre.

EXOSTRA, in the ancient theatre, a place where such parts of the play were recited as were supposed to be acted privately in the house.

EXPANSION, (from the Latin, *expando*) that degree of increment, which a body is susceptible of extending, in one or more of its dimensions by heat. Bodies of every kind, as far as we are acquainted with them, are expanded in bulk by heat, and are contracted by cold; and to this law there are but few exceptions, which will be noticed in due time. The expansions, or the increments of bulk, are not exactly proportional to the increments of heat in the same body; nor are different bodies expanded alike by the like elevation of temperature. Thus, if a quantity of water be increased one inch in bulk by the communication of ten degrees of heat, the communication of twice or thrice as much more heat will not cause it to expand two or three inches more. Also, if a rod of gold, and another similar rod of glass, be heated to the same degree, their increments of bulk, arising thereby, will not be equal, the gold expanding more than the glass.

Of the three principal states of natural bodies, viz., solids, liquids, and elastic fluids, the solids are expanded least; the liquids are expanded more than the solids; but the elastic fluids are expanded a vast deal more than the liquids. The knowledge of the precise quantities of these expansions of bodies is of great use in philosophy, in mechanics, and in other scientific subjects; hence no pains have been spared by philosophers to investigate and ascertain them; various instruments have been contrived for that purpose; innumerable experiments have been instituted; and a great many useful results have been obtained. Of these results we shall now endeavour to give a regular and distinct account.

The instruments which have been contrived for the purpose of measuring the expansions of solids arising from an elevation of temperature, are called *pyrometers*. The objects which must be had in view in the construction of pyrometers, are to form a steady frame, wherein solids of a certain length may be applied either successively, or several of them at the same time; some contrivance by which those metallic bodies may be heated to any required degree; and a mechanism capable of measuring the increase of bulk which is caused by the heat; and this may be accomplished by means of multiplying wheels, by levers, by screws, by a microscopical micrometer, or otherwise.

Some of the first determinations of the expansion of bodies, that may be considered as being sufficiently accurate, were made by Mr. Ellicot, with a pyrometer of his contrivance. Mr. Ellicot determined the proportional expansions of seven metallic bodies by the same elevation of temperature. They are as follow:—

Gold.	Silver.	Brass.	Copper.	Iron.	Steel.	Lead.
73.	103.	95.	89.	60.	56.	149.

Mr. Smeaton contrived a much better pyrometer, and with it he determined the expansions of several solids. M. De Luc also contrived a pyrometer of a peculiar construction; but Mr. Ramsden's pyrometer is superior to any other contrivance of the kind.

The following table shows, in parts of an inch, how much one foot's length of different substances is expanded by 180° of heat, Fahrenheit's scale, between the freezing and the boiling points of water. To the first seven substances (which were examined in Mr. Ramsden's most accurate pyrometer) there are added the expansions for a single degree of heat. The others were determined by Mr. Smeaton with his pyrometer.

	Fahrenheit's Scale. By 1°	Fahrenheit's Scale. By 180°
Standard brass scale, supposed to be Hamburg brass	0.0001237	0.0222646
English plate brass in form of a rod	0.0001262	0.0227136
English plate brass in form of a trough	0.0001263	0.0227386
Steel rod	0.0000763	0.0137368
Cast-iron prism	0.0000740	0.0133126
Glass tube	0.0000517	0.0093138
Solid glass rod	0.0000539	0.0096944
White glass barometer tube		0.0100
Martial regulus of antimony		0.0130
Blistered steel		0.0138
Hard steel		0.0147
Iron		0.0151
Bismuth		0.0167
Copper hammered		0.0204
Copper eight parts, with tin one part		0.0218
Cast brass		0.0223
Brass sixteen parts, with tin one part		0.0229
Brass wire		0.0232
Speculum metal		0.0232
Spelter solder, viz., of brass two parts, and of zinc one		0.0247
Fine pewter		0.0274
Grain tin		0.0298
Soft solder, viz., lead two parts, tin one		0.0301
Zinc eight parts, with tin one, a little hammered		0.0323
Lead		0.0344
Zinc or spelter		0.0353
Zinc hammered half an inch per foot		0.0373

Iron, instead of being condensed into a smaller bulk, expands in its transition from a fluid into a solid state; so that a quantity of iron occupies more room in the solid form than it does in a fused state.

Dr. Wollaston, in order to form some estimate of the comparative rate of expansion of platina and palladium, says, "I riveted together two thin plates of platina and palladium, and observing that the compound plate, when heated, became concave on the side of the platina; I ascertained that the expansion of palladium is in some degree the greater of the two. By a similar mode of comparison I found that palladium expands considerably less than steel by heat." *Phil. Trans. for* 1805.

It must be remarked, with respect to the expansion of glass, that sometimes glass tubes are extended more than solid glass rods; their dilatation, however, is not constant; for tubes of different diameters, or of different sorts of glass, are expanded differently by the application of like degrees of heat.

Wood is not much expanded longitudinally, that is, in the direction of its fibres, by heat; and this is particularly the case with deal and other straight-grained wood. Probably, upon the whole, the longitudinal expansion of wood is less than that of glass. It has been observed, (especially by Dr. Rittenhouse, *Trans. of the American Phil. Society*,) that very dry and seasoned wood, if not exposed to a very high or to a very low temperature, will expand in length pretty regularly; otherwise its expansion by heat, and its contraction by cold, are very irregular; for they seem to depend partly upon the heat, and partly upon the moisture, which the wood acquires in certain circumstances, and is deprived of in others. It is hardly necessary to mention, that the solids of the preceding table contract their dimensions by cooling, as much as they are expanded by heating; thus, for instance, if a yard's length of any particular metallic body, by being heated 100 degrees above the actual temperature of the atmosphere, be lengthened one-fiftieth part of an inch; afterwards, when cooled down to the temperature of the atmosphere, it will be found to have lost exactly that fiftieth part of an inch which it had acquired by heating.

From the experiments hitherto made on the expansions of solids by heat, no correspondence has been observed between the expansions and the quantities of caloric they are capable of absorbing. The fusibility of metals seems to coincide with the dilatations; platina, the least fusible of the metals, dilates the least; lead dilates most; and the most fusible glass is also the most dilatable. We may therefore conclude with M. Berthollet, that bodies are so much the more expansible, the less caloric they require, to change their constitution from solid to liquid, and from liquid to gases or vapours.

There is a substance which expands when heated, but does not contract when cooled; and of this singular property Mr. Wedgwood availed himself for the construction of his ingenious thermometer for measuring the highest degrees of heat; viz., those degrees which exceed the scale of the mercurial thermometer. The substance alluded to is the argillaceous earth or clay, and it appears that the above-mentioned property belongs, more or less, to argillaceous bodies of every kind. This property may at first sight appear to be an unaccountable exception from the general law: the difficulty, however, will vanish, if it be considered that bodies of the argillaceous genus contain a considerable quantity of water, and that the contraction of these bodies, when exposed to the action of a strong fire, is in a great measure due to the escape of the water, and hence they do not contract by subsequent cooling.

EXPERIENCE, knowledge derived from trials, long use, practice, or a series of observations. Experience consists in the ideas suggested by what we have seen, read, or done: we reflect on these things, and the judgment forms for itself a rule or standard, which standard is experience.

Authors make three kinds of experience: the first is the simple uses of the external senses, whereby we perceive the phenomena of natural things, without any direct attention thereto, or making any application thereof.

The second is, when we premeditatedly and designedly make trials of various things, or observe those done by others, attending closely to all effects and circumstances.

The third is that preceded by an apprehension of an event, and determines whether the apprehension were true or false; the two latter kinds, especially the third, are of great service in philosophy.

EXPERIMENT, (from the Latin *experimentum*,) a trial, an act, or operation designed to discover some unknown truth, principle, or effect, or to establish it when discovered. In philosophy, it means the result of certain applications, dispositions, or combinations, of natural bodies, made with some particular view. The history of physical science from the commencement of the present century, strikingly demonstrates how powerful an instrument experiment is in the discovery of facts. Experiments are said to be mechanical, or chemical, or electrical, or magnetical, &c., according to the subject to which they more immediately belong. The object of making experiments is to ascertain either certain causes or certain phenomena; and for the proper attainment of these objects, care must be had to institute experiments that admit of no equivocal result, and so as to answer the purpose in the quickest and most direct way. The main object, however, of the inquiry can seldom be determined by a single decisive experiment; hence, in most cases, it becomes necessary to divide the question into parts, and to ascertain each part separately by one or more appropriate experiments. When the experiment is so prescribed, as to decide the question without any possible doubt or equivocation, it has in that case frequently been called *experimentum crucis*; a *crucial experiment*, meaning a capital or decisive experiment; such as supersedes the necessity of instituting more experiments for the same purpose. The origin of the expression *experimentum crucis* has by some been derived from its being a kind of torture, whereby the nature of the question is, as it were, extorted by force. It has been also attributed, by others, though with less apparent probability, to the guide or instruction which it affords, like that of a direction-post, which is shaped somewhat like a cross.

It is not practicable to give any instructions for the right performance of experiments in general; for not only every subject, but every particular question belonging to any subject, must be determined by a particular mode of investigation. The experimenter can only be instructed by practice. The nature of the subject, a strict attention to every apparent circumstance, an accurate statement of particulars, and an unprejudiced mode of reasoning, will easily suggest a proper train of experiments which the subject in question may admit of. It deserves to be remarked, that though in the investigation of any subject, the philosopher proposes a certain order of investigation, (and it is always proper to propose to oneself some such plan or train of experiments;) yet it is but seldom that the proposed plan can, or deserves to be, strictly executed; for the result of the first or second experiment frequently points out a new tract, or a more promising road; in consequence of which, new and different trials must be instituted; it is in the ready adoption of such plans as may be best suited to the last indications, that the genius of the philosopher is rendered conspicuous.

Such mode may suffice for the determination of any doubtful point; but when a discovery has been made, and is to be explained to other persons, then it is of use to show the same result by different experiments; for it is not only a satisfaction to have several concurring proofs of the same proposition; but it is also rendered intelligible to a greater number of readers or hearers; it being seldom the case, that the same experiment conveys an equal degree of conviction and satisfaction to the mind of everybody.

EXPERIMENTAL PHILOSOPHY. Philosophy, from the Greek *philosophia* (φιλοσοφια,) literally signifies "love of wisdom or knowledge," and a philosopher, (φιλοσοφος,) is a lover of wisdom. Pythagoras is said to have been the first person who called himself philosopher, from which appellation the word philosophy was derived, meaning the love of general knowledge. The terms philosophy, philosophical, philosopher, are often used in our language apparently with no great precision, though it is not difficult to deduce from the use of these terms the general meaning or notion which is attached to them. We speak of the philosophy of the human mind, as being, of all philosophies, that to which the name philosophy is particularly appropriated; and so also, by using qualifying terms, we speak of natural philosophy, experimental philosophy, &c.

If this knowledge or philosophy relate to the manners, the duties, or the conduct of human beings, considered in a rational and social light, it is called *moral* philosophy; if to the phenomena of natural bodies—*natural* philosophy. Experimental philosophy, as will be shown hereafter, may be defined as the philosophy of *proof*, in contradistinction to the philosophy of opinion, to the manners, the duties, and the conduct of human beings, considered in a rational and social light, or to the phenomena of natural bodies, so it has been called either *moral philosophy* or *natural philosophy*.

The philosophers of the primitive ages, among the Greeks, Romans, &c., in explanation of the phenomena of nature, such as the motions of the celestial bodies, the rain, snow, frost, thunder and lightning, the rainbow, the combustion of fuel, the production of animals and vegetables, and so forth, generally offered the inadequate suggestions of their imaginations, which, though mostly unintelligible, and frequently in the greatest degree absurd, were nevertheless received with deference by their scholars, and were propagated with fidelity and diligence from one generation to another. Their acquiescence rested merely on the authority of the teacher. That these explanations were generally inadequate and absurd, is easily evinced by observing, that different contemporary philosophers entertained and taught opinions diametrically opposite to each other, though they related to the very same question; and that subsequent philosophers have, by actual observations, and unerring demonstrations, shown their fallacy. It may amuse an inquisitive mind to observe, that whilst the exertions of the early mathematicians, whose productions have obtained the admiration of subsequent generations, were strictly rational and correct, the investigations of their contemporary philosophers were conducted in a manner altogether slovenly and superficial. This method of philosophizing prevailed for a very long period, and several centuries elapsed, during which the knowledge of nature made no progress deserving of notice, excepting a few rare and accidental discoveries.

The 15th century, which was productive of the greatest events and the most consequential discoveries that history can record, seems to have given a new turn to the subject of natural philosophy. The old tenets began to be doubted, and the energies of the human mind began to manifest their unfettered powers. In the next century, the incoherent dogmas of the preceding ages were freely combated; the authority of names and sects was disregarded, and, in lieu of opinions, the explanation of natural phenomena was referred to the evidence of actual experiments. Then was introduced the appellation of *experimental philosophy*, by which is meant, the knowledge of natural powers and natural effects acquired by means of experiments or trials. The least reflection readily showed the superiority of this new method of philosophizing; but, independent of any other consideration, its establishment is principally due to the success with which it was attended, and which exceeded even the most sanguine expectations of its first promoters. No sooner was it adopted, than discoveries of importance were made, old-established errors were detected, and the subject of philosophy assumed an entirely new aspect.

It is undoubtedly true, that in this mode of investigation the experiments must be preceded by hypothesis, or supposition; for a man cannot begin to make experiments without the previous formation of a certain plan; but then the plan, the supposition, or the hypothesis, goes no farther than to propose something, the confirmation or refutation of which is referred to the result of experiments, assisted by mathematical calculation. In the 13th century, the necessary preliminaries for the improvement of natural knowledge began to be made; viz., collections of what then prevailed under the denomination of scientific knowledge, natural knowledge, secrets of nature, and the like; and the farrago of truths, errors, inconsistencies, doubts, and perplexities, which these works contain, is strange indeed. Among the few who effectually began to work in the experimental mode of investigation, during that century, Friar Bacon held the most distinguished place. His desire of information was great; his views extensive; his mind clear and capacious; and he is said to have spent about £2,000 (a sum very considerable at that time) in the performance of his numerous philosophical experiments. Baptista Porta also distinguished himself for similar pursuits in Italy. This inquisitive person lived at Naples, and about the year 1560 formed a society of scientific persons, who met in his own house. The great Galileo, who was born in Italy, in the year 1564, became famous as a philosopher and a mathematician, towards the latter end of that century and the beginning of the next. His genius, superior to the prejudices of the times, investigated and established several leading propositions in natural philosophy; and his success, his example, and his precepts disseminated a universal ardour for the true mode of investigating the powers and the effects of natural bodies. His successor, Torricelli, was not unworthy of a most distinguished rank amongst the philosophers of the age; and the Torricellian tube, or the barometer, is a magnificent monument of his experimental inquiries.

In England, as we have already mentioned, Friar Bacon was the first promoter of true knowledge; but a great part of the work of philosophical reformation was accomplished by another inquiring genius of the same name. Francis Bacon, lord-chancellor of England, gave a fresh and vigorous impulse to the progress of experimental inquiry. He recorded a vast number of facts, proposed and executed a great many experiments, and nothing that related to nature seemed to be below his notice.

These early reformers of philosophy, besides other obvious difficulties, were obliged to struggle against, and the success of their labours was much impeded by, the erroneous notions which then prevailed, and which had been long rooted in the minds even of the most able persons then living. Galileo was oppressed by the ignorance and prejudices of the clergy. Crichton, who flourished about the latter end of the 16th century, wrote an able book expressly against the vain philosophy of Aristotle, which had long been read in the schools. The two Bacons, and other able writers, frequently allude to, and strenuously endeavour to remove, the absurd and fanciful notions of their contemporaries. In short, the demolition of the old defective fabric, proved nearly as laborious as the erection of the new structure.

The reform which had been begun by the above-mentioned, and other worthy persons, was soon after completed by the extraordinary genius of Newton. This truly great man, like a luminary of the first magnitude, illustrated whatever came within the limits of his notice, and his notice was employed in the greatest and most admired works of the creation. His method was to institute experiments, to examine the phenomena with accuracy, and to ground upon them the strictest mathematical reasoning. The conviction which such a rational method conveyed, and the numerous discoveries with which it was attended, completely exploded the old tenets, and established the only true method of investigating nature.

The progress of experimental philosophy might have been interrupted by the death of a single individual; for it does but seldom occur that genius, health, opulence, and other opportunities, concur in the qualification of an experimental philosopher; but the danger was in great measure averted by the institution of philosophical societies. These societies, by bringing together learned men, and concentrating, as it were, their efforts against the ignorance and prejudice of the age; by uniting the efforts of several ingenious labourers, by furnishing in great measure the means of investigation, by encouraging improvements, and by recording and propagating the results, at length succeeded in establishing the progress of knowledge in a regular and permanent channel.

The first society of the kind which we find recorded, is that which we have already mentioned at the house of Baptista Porta, in Naples, towards the latter end of the

16th century. It was called "Academia Secretorum Naturæ." Next to this, and before the end of the same century, the academy, called the Lyncei, was founded at Rome, and was rendered famous throughout the world, principally by the renown of one of its members, the great Galileo. The Academy del Cimento, and several other associations of scientific persons, were established in the succeeding, viz., the 17th century. Amongst those associations the first rank must be assigned to the Royal Society of London. This most learned and distinguished society had its origin soon after the middle of the 17th century. A few men of learning began to meet at stated times at Wadham college, Oxford; and among those persons were the following conspicuous characters: viz., Dr. Ward, Mr. Robert Boyle, Dr. Wilkins, Sir William Petty, Mr. Matthew Wren, Dr. Wallis, Dr. Goddard, Dr. Willis, Dr. Bathurst, Dr. Christopher Wren, and Mr. Rooke. From Oxford this association transferred its meetings in the year 1658, to Gresham college, in London. There they increased their number; and soon after the restoration of Charles II., the society received a royal charter, which established it in the form that has been continued ever since.

The objects of the universe, or the natural bodies which affect our senses, become known and useful to us by their properties, some of which affect one of our senses, whilst others affect some other sense. Thus we perceive luminous bodies through our eyes, sound through our ears, heat or cold by the touch or feel, &c. Some of these properties are called general, like gravity and extension, because they belong to all bodies; and others, like transparency and fluidity, are called particular, because they belong to certain bodies only. The better we become acquainted with the properties of natural bodies, the more extended the sphere of our powers and of our advantages becomes; and it is for the discovery of these properties, either in simple or in compound bodies, that experimental inquiries are instituted.

In the acquirement of knowledge, the human being has no other assistance besides that of his senses, and of his reasoning faculty. By the first he observes and acquires ideas of self-evident propositions, or properties of natural bodies; such as the human mind cannot dissent from without manifest violence to its perceptions; by the second he is led from one of these evident simple propositions, to another strictly depending upon the first, then to a third strictly depending upon the second, and so on, to the acquisition of some idea more complex, and less apparent at the first annunciation. The constant observation of philosophers, with Sir Isaac Newton at their head, and the dictates of plain reasoning, have furnished certain axioms and certain rules of philosophizing, the propriety of which is too evident to be objected to.

The axioms of philosophy, or the axioms which have been deduced from common and constant experience, are so evident, and so generally known, that it will be sufficient to mention a few of them only.

1. Nothing has no property ;. hence

2. No substance, or nothing, can be produced from nothing.

3. Matter cannot be annihilated, or reduced to nothing.

The propriety of the last axiom may perhaps not be readily admitted by certain persons; observing that a great many things appear to be utterly destroyed by the action of fire; also that water may be caused to disappear by means of evaporation; and so forth. But it must be observed, that in these cases the substances are not annihilated; they are only dispersed, or removed from one place to another, and by being divided into particles very minute, they elude our senses, and escape our immediate notice. Thus, when a piece of wood is placed upon the fire, the greatest part of it disappears, and a few ashes only remain, the weight and bulk of which do not amount to the hundredth-part of the weight and bulk of the original piece of wood. In this case the piece of wood is divided into its constituent principles, which the action of the fire drives different ways. The fluid part, for instance, becomes steam, the light coaly part either adheres to the chimney, or is dispersed through the air, &c., so that if, after the combustion, the scattered materials were collected, (which may in a great measure be accomplished,) the sum of their weights would equal the weight of the original piece of wood.

4. Every effect has, or is produced by, an adequate cause, and is proportionate to it.

It may, in general, be observed, with respect to these axioms, that we only mean to assert what has been constantly shown, and confirmed by experience, and is not contradicted, either by reasoning, or by any known experiment. But we do not mean to assert that they are as evident as the axioms of geometry; nor do we in the least presume to prescribe limits to the agency of the Almighty Creator of every thing, whose power and whose ends are too far removed from the reach of our finite understandings.

Having thus stated the principal axioms of philosophy, it is in the next place necessary to mention the rules of philosophizing, which have been formed, after mature consideration, for the purpose of preventing errors as much as possible, and of leading the student of nature, along the shortest and safest path, to the attainment of true and useful knowledge. These rules may be reduced to four, viz.

1. We are to admit no more causes of natural things, than such as are both true, and sufficient to explain the appearances.

2. Therefore, to the same natural effects we must, as far as possible, assign the same causes.

3. Such qualities of bodies as are not capable of increase, or of decrease, and which are found to belong to all bodies within the reach of our experience, are to be esteemed the universal qualities of all bodies whatsoever.

4. In experimental philosophy we are to look upon propositions collected by general induction from phenomena, as accurately, or very nearly true, notwithstanding any contrary hypothesis that may be imagined, till such time as other phenomena occur, by which they may either be corrected, or may be shown to be liable to exceptions.

With respect to the degree of evidence which ought to be expected in natural philosophy, it is proper to remark, that physical matters are not, in general, capable of such absolute certainty as the branches of mathematics. The propositions of the latter science are clearly deduced from a set of axioms so very simple and evident, as to convey perfect conviction to the mind; nor can any of them be denied without a manifest absurdity. But in natural philosophy we can only say, that because certain particular effects have been constantly produced under certain circumstances, therefore they will most probably continue to be produced as long as the same circumstances exist; and likewise that they do, in all probability, depend upon those circumstances. And this is what we mean by *laws of nature*, viz., certain effects which are, or have been uniformly, produced by certain causes, as far as our observations reach.

We may, indeed, assume various physical principles, and by reasoning upon them, we may strictly demonstrate the deduction of certain consequences. But as the demonstration goes no farther than to prove, that such consequences must necessarily follow the principles which have been assumed; the consequences themselves can have no greater degree of certainty than the principles are possessed of; so that they are true, or false, or probable, according as the principles upon which they depend are true, or false, or probable.

The foundations of experimental philosophy, as we have already observed, are the properties of natural bodies, viz., of all these bodies, either solid or fluid, which in any way affect any of our senses; and since our senses are affected by the properties of these bodies, viz., by their extension, colour, hardness, transparency, &c., we cannot know any more of these bodies than what is manifested to us by such properties only as we are able to perceive. Were we furnished with other senses, doubtless we might discover other properties which would make us more intimately acquainted with the nature of such bodies.

Human art has not been able to discover more senses than those which everybody knows; but it has, in great measure, improved some of those which we possess, and this alone is sufficient to point out the limited nature of our perceptions. Thus, for instance, the discovery of the microscope and the telescope have shown us wonders, of which our forefathers were utterly ignorant; and the number and variety of these wonders have increased, in proportion as the above-mentioned instruments have been improved. The improvements of these instruments have been suggested by the discoveries that have been made respecting the refrangibility of light, and the properties of transparent bodies, and these have been made in consequence of the innumerable experiments that have been instituted by various intelligent persons. Thus it appears, that by means of trials and observations, new facts are ascertained, which, besides their being immediately useful to the human species, furnish, at the same time, the means of making farther discoveries; and the treasures of the natural world are far, indeed, from a state of exhaustion. Hence the improvements and the discoveries of experimental philosophy proceed in a kind of increasing geometrical progression; unless they are impeded by some extraordinary occurrence.

In contemplating the intimate nature of natural bodies, when our mind goes beyond the bounds of our senses, (and our senses, even with the assistance of instruments and reasoning, are only capable of perceiving a few properties of those bodies;) we wander in the boundless field of probability and conjecture. Two principal hypotheses have been entertained with respect to the primitive component particles of bodies. One is, that the particles of each peculiar species of bodies are different from the particles of another species of bodies. Thus the primitive particles of gold are supposed to be different from the particles of calcareous earth, different from the particles of water, &c. The other hypothesis is, that there is one kind of primitive, or original particles of matter, and that from the different arrangement of those ultimate particles, the various bodies arise. Experience shows, that certain bodies, which at first sight appear to be absolutely different from each other, are, upon farther examination, exactly of the same nature. On the other hand, a vast number of bodies are so distinct from each other, that no art has been able to form one of them from the particles of the other; thus gold cannot be converted into a diamond, iron cannot be converted into lead, &c. The former of these observations seems to favour the second hypothesis; the latter seems to favour the first hypothesis; but it is not in our power to determine the real state of the matter.

With respect to the number of bodies, which, by our not being able to change one of them into the other, are called elementary, or primitive and distinct; it may be remarked, that new bodies are frequently discovered in proportion as new instruments, and the improvements of science in general, furnish us with the means of discriminating them from others. We are thus naturally led to conclude, that in all probability there exists a vast number of other bodies, of which we at present have not the least suspicion. Some of these may perhaps be discovered hereafter, others may remain utterly unknown to the human species for ever.

The properties of natural bodies, which are the objects of research to the experimental philosopher, are either general, or particular. The general properties, which belong to all kinds of bodies, are, as far as we know, not more than six; viz., extension, divisibility, impenetrability, mobility, vis inertiæ, or passiveness, and gravitation. We have said that these are the general properties as far as we know, because matter in general may possess other properties with which we are yet unacquainted. And the same observation may be made with respect to the universality of these properties: for they are said to be general, because nobody was ever found which wanted any one of them. But mankind are not acquainted with all the bodies of the universe, and many which are known to exist, cannot be subjected to experiments.

The peculiar properties, viz., those which belong to certain bodies only, and not to others, are density, rarity, hardness, softness, fluidity, rigidity, flexibility, elasticity, opacity, transparency, the properties of light, the properties of heat, the properties of electricity, the properties of magnetism, and three other kinds of attraction, (independent of gravitation, of electricity and of magnetism,) viz., the attraction of aggregation, which the homogeneous parts of matter have towards each other, or by which they adhere together; and such is the power by which two small drops of mercury, when placed contiguous to each other, rush, as it were, into each other, and form a single drop; the attraction of cohesion, or that power by which the heterogeneous particles of bodies adhere to each other without any change of their natural properties, such as the adhesion of water to glass, of oil to iron, &c.; and the attraction of composition, or of affinity, which is the tendency that the parts of heterogeneous bodies have towards each other, by which they combine, and form a body, differing more or less from any of its components.

It is to be remarked, that of all these properties we know their existence only, and some of the laws under which they act; but we are otherwise utterly ignorant of their nature and dependence.

The investigation of some of the above-mentioned properties, whether general or particular, has been carried much farther than the investigation of other properties. The results of these investigations have likewise been various, both in point of extent and of application. Some of them are so very extensive and so useful, as to form the foundations of very important branches of science, or of art, under peculiar appellations. Thus, upon the mobility, and the vis inertiæ of bodies, the doctrine of motion, or dynamics, is grounded, which comprehends mechanics, hydrostatics, or the mechanical properties of fluids, pneumatics, &c. Transparency and the properties of light form the important foundation of optics. The attraction of affinity is the foundation of chemistry, as well as of various arts; and so forth.

The phenomena of the universe, are the appearances which take place in consequence of the above-mentioned properties of natural bodies, together (respecting some of them at least) with some original impulse. The phenomena which take place amongst the luminous celestial bodies, properly so called, such as the stars, the planets, &c., are examined by a particular science, called astronomy; the meteors, or the phenomena which take place within the limits of the terrestrial atmosphere, such as shooting stars, northern lights, halos, rain, fogs, hail, winds, &c., form the subject of meteorology.

EXPLOSION, in natural philosophy, a sudden and violent expansion of an aërial or other elastic fluid, by which it instantly throws off any obstacle that may be in the way. It differs from expansion, properly so called, in this, that the latter is a gradual and continued power, whereas the former is always sudden, and of only momentary duration.

Explosion, in military engineering. It is a matter of great moment, so to load, and indeed to construct a mine, that it may explode with the greatest precision, and with the maximum effect. Numerous theories have been given upon this subject, but it would be out of place to notice the whole of what appertains thereto in a work like this.

In commencing operations, it is necessary in the first instance to ascertain, so nearly as may be practicable, what depth, and what weight of soil is to be removed by an explosion. This being done, the mine is formed, by constructing a gallery leading to the chamber in which the powder is to be placed. This must be deposited in a very strong chest, let into a recess, and firmly secured in every part. Now, it being the nature of rarefied air to escape by that part which may be the weakest, it is evident, that if a mine is made under a rampart, so as to be within six feet of the surface, while all the sides are thicker by far than that measurement, the explosion will be directed towards that part which is thinnest, and which, from that circumstance, is called "the line of least resistance."

But, in order to direct the explosion to that part, it will be necessary to consider whether the soil be everywhere alike; for if the superincumbent portion should be part of a large stratified rock, while the sides are of a loose, inadhesive substance, the latter, though measuring more in diameter will give the line of least resistance, which, in such case, would follow the intenacity, and create a false explosion. For it must be recollected that explosions may be lateral as well as vertical.

It was formerly supposed, that the diameter of the *entonnoir*, or explosion, was equal to double the line of least resistance; but we find that six times that line may be exploded, by allowing a load of 300 lbs. of gunpowder, duly concentrated, and fired in the middle of the mass, for every foot of the line of least resistance. We are not to infer from this, that 300 lbs. will be requisite to lift one foot of soil; far from it; for as a cubic foot of excavation will contain only 75 lbs. of powder, the above quantity (300 lbs.) would require a space of exactly four cubic feet; the proportion would therefore be preposterous. But when we calculate upon large masses of soil, such as those prodigious cones thrown out from entonnoirs of great extent, we then find, that, to produce the completest explosion, an immense quantity of powder must be supplied.

It is self-evident, that the power of the powder, according to the above scale, is only computed to that extent which may be necessary towards the ordinary purposes of military devastation; for if we were to contribute, *ad infinitum*, 300lbs. of gunpowder for every foot in the line of least resistance, we should be accumulating power only in arithmetical proportion, while the resistance would be increasing in a geometrical ratio: of course the power must be in a regular state of comparative diminution, in proportion as the line of least resistance is increased; and this must, after a while, occasion the powder to be inert; or, if there should be any explosion, it could only follow the track of the train. Its ignition, to be sure, might be felt partially, like that of a slight earthquake, but no superficial effects would be observable.

It has been already stated, that the powder must be lodged in bulk; and that it should be ignited at the centre. This may, perhaps, appear superfluous; but all military men know, that much powder is blown out of the muzzles of pieces without ever being ignited; and we have a most remarkable fact in modern times, one indeed, which shows, that, unless in bulk, powder is not always sure to be fired *in toto*. The incident alluded to is as follows:—

In the month of March, in the year 1809, a barge was proceeding along the new cut, from Paddington, laden with casks of spirits and barrels of gunpowder. One of the crew, it is supposed, allured by the former, bored a hole for the purpose of drawing off a little wherewith to tipple. Unhappily the action of the gimblet set fire to the contents of that barrel, which the dishonest navigator had mistaken for one of spirits. The barrel exploded, and drove eleven other barrels, filled with gunpowder also, to the distance of near a hundred and fifty yards. It is curious, that although the whole of the powder-barrels were together, indeed, in contact, only that in question exploded.

Vauban gives us the following scale for exploding soils of various descriptions. He calculates, or perhaps found from experience, that for a cubic fathom (six feet) of soil, measuring in all 216 solid feet, the following proportions of gunpowder were needful.

	lb.
1. Light earth, mixed with sand	11
2. Common earth	12
3. Strong sand	15
4. Clay, or fat earth	16
5. Old, and good masonry	18
6. Rock	20

In following this calculation, we are to consider the entonnoir to be in diameter equal to only double the line of least resistance; and not according to a maximum explosion.

A new substance, gun-cotton, which is cotton wool steeped in nitric or nitro-sulphuric acid, and dried, by which it becomes explosive, has been lately introduced as a substitute for gunpowder in blasting. It is not yet sufficiently understood to have come into extensive use.

EXPONENT, in algebra, is a number placed over any power or involved quantity, to show to what height the root is raised; thus 2 is the exponent of x^2 and 4 is the exponent of x^4 or $x\,x\,x\,x$.

EXPONENTIAL CURVES, those curves which partake both of the nature of algebraic and transcendental ones. They are algebraical in their nature, because they consist of a finite number of terms, though these terms themselves are indeterminate, and they are in some measure transcendental, because they cannot be algebraically constructed.

EXPOSURE, the act of exposing or laying open to view; as we say a building, a garden, or a wall, had a northern or a southern *exposure*, and we speak of its exposure or exposition to a free current of air, or to the access of light.

EXTEND, to stretch in any direction, to continue in length as a line, to spread in breadth.

EXTENSION, in philosophy, one of the general and essential properties of matter; the extension of a body being the quantity of space which the body occupies, the extremities of which limit or circumscribe the matter of that body. It is otherwise called the *magnitude*, or *size*, or *bulk* of a body.

A quantity of matter may be very small, or so as to elude the perception of our senses, such as a particle of air, a particle of water, &c.: yet some extension it must have, and it is by the comparison of this extension, that one body is said to be larger than, equal to, or smaller than, another body. The measurement of a body consists in the comparison of the extension of that body with some determinate extension, which is assumed as a standard, such as an inch, a foot, a yard, a mile; hence it is said, that a body is a foot long, or three inches long, &c.

The extension of a body is measured three different ways; or a body is said to have length, breadth, and thickness. Thus an ordinary sheet of writing paper is about 16 inches long, about 14 inches broad, and nearly one hundredth part of an inch thick. Either of these dimensions might be called the length, or the breadth, or the thickness; but, by general custom, the greatest extension is called the length, the next is called the breadth, and the shortest is called the thickness. The outside of a body, its boundary, or that which lies contiguous to other bodies that are next to it, is called the *surface* of that body, and this surface has two dimensions only, viz., length and breadth; but it has no thickness, for if it had, it would not be the outside of the body; yet a surface by itself cannot exist. In mathematics, however, surfaces are mentioned, and are reasoned upon, abstractedly from matter. But in these cases the surfaces exist in the imagination only, and even then our ideas have a reference to body, for our senses cannot perceive a surface without a body.

As a surface is the outside or boundary of a body, so a *line* is the boundary of a finite surface. Suppose, for instance, that a surface is divided into two parts, the common boundary of the two parts is called a *line;* this has one extension only, viz., it has length.

The beginning or the end of a line, or the intersection of two lines which cross each other, is called a *point*, and this has no dimensions; or, according to the mathematical definition, a point is that which has no parts or magnitude, its use frequently is to mark a situation only as a point upon a surface by the intersection of two lines, &c. Thus, if you divide a line into two parts, the division or boundary between the two parts is a point.

Our senses are only capable of perceiving bodies which have three dimensions; or rather the surfaces of bodies, which surfaces have two dimensions, but a surface cannot be represented nor perceived without a body, and of course neither a line nor a point can be perceived without a body. In the study of geometry, and in a variety of other branches, surfaces, lines, and points are represented upon paper, or upon something else; but in those cases, the paper, or that something else, is the body whose surface we perceive, and the surface of a particular figure is circumscribed, not by real lines, but by a narrow slip of surface, which is sufficient to direct our reasoning with respect to the geometrical properties of lines and surfaces. Thus also, when points are represented by themselves, the marks are not real points, but very small portions of the surface of a body.

There is a case in which extension is often said to be perceived without the existence of a body, and this is the extension between two bodies. But, upon consideration, it will easily be comprehended, that we may perceive the two bodies, and that they are separate from each other; but we cannot perceive anything positive between them. So that in this case the word extension is used in a figurative manner, as if some other body existed between the two bodies.

The particular extension, whether under the name of inch, foot, yard, metre, league, &c., with which other extensions are compared, or by which they are measured, is established only by the common consent or agreement of persons of a certain nation, or profession, and used as standard measure by them only. Hence, the measures of different nations, though sometimes they have the same name, differ considerably from each other. Great endeavours have been made by divers ingenious persons, at different times, for the purpose of determining an unalterable universal standard of measures; those endeavours, and the results with which they have been attended, will be found described under the article STANDARD *of Measures.*

Extension is usually described as consisting in the situation of parts beyond parts; but to this definition some authors object, maintaining, that we can conceive absolute extension without any relation to parts.

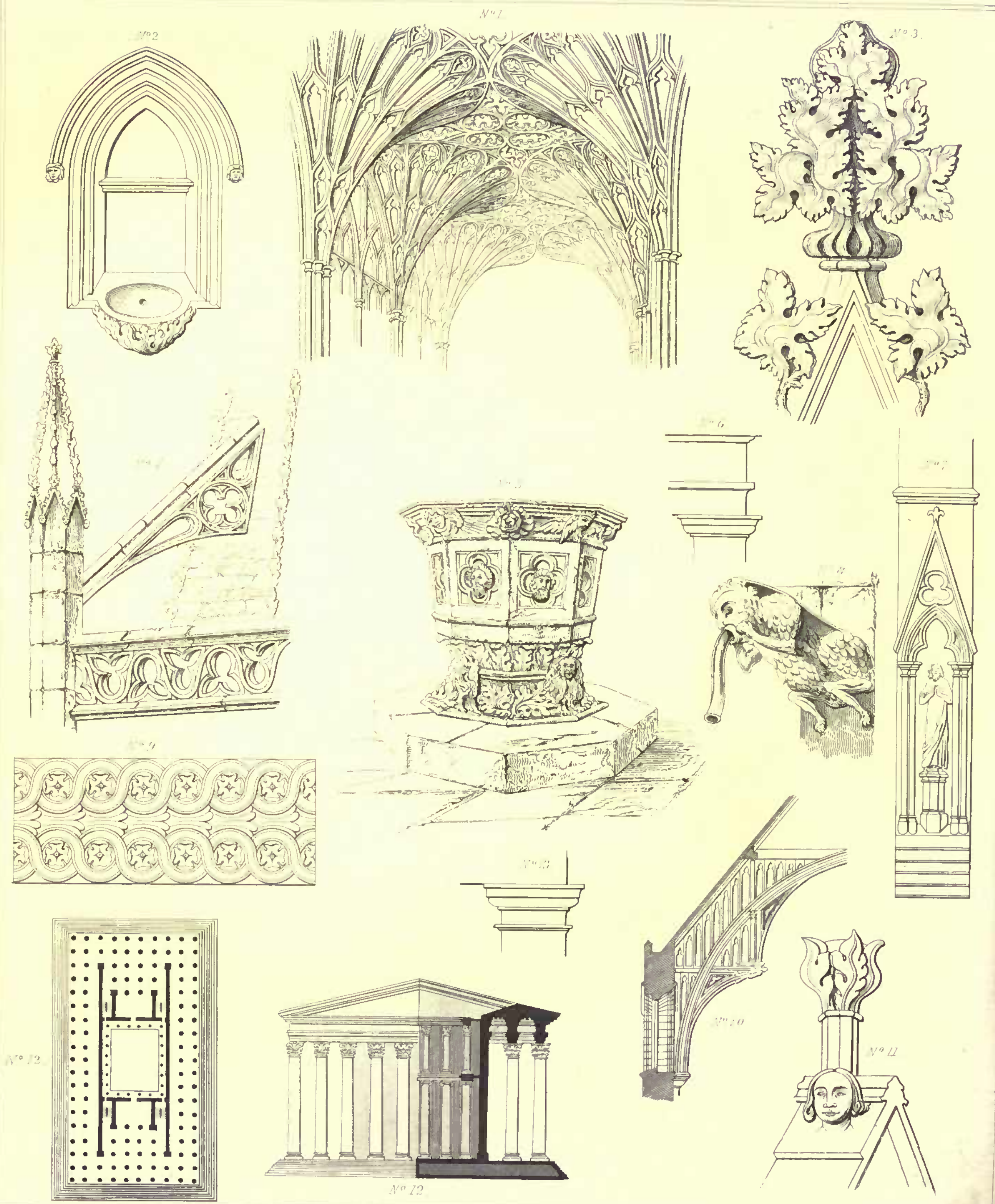
If a man consider the distance between two bodies abstractedly, and without any regard to bodies which may fill that interval, it is called space; and when he considers the distance between the extremes of a solid body, it is called extension.

Extension is frequently confounded with quantity and magnitude; and, for what we can perceive, without much harm, the thing signified by them all appearing to be the same; unless we admit a distinction made by some authors, that the extension of a body is something more absolute, and its quantity and magnitude more respective, or implying a nearer relation to much and little. The infinite divisibility of extension has been a famous question in all ages. It is not easy to reconcile the doctrine of mathematicians on this head with the tenets of some philosophers. Those who hold that all extension and magnitude are compounded of certain *minima sensibilia;* and that a line, for instance, cannot increase or decrease, but by certain invisible increments or decrements only, must, consistently with themselves, affirm, that all lines are commensurable to each other. But this is contrary to the tenth book of Euclid, who demonstrates that the diagonal of a square is incommensurable to its side. And further, if all lines were composed of certain indivisible elements, it is plain one of those elements must be the common measure of the diagonal and the side.

Bishop Berkeley observes, that the infinite divisibility of finite extension, though it is not expressly laid down, either as an axiom or theorem in the elements of geometry, is yet throughout the same everywhere supposed, and thought to have so inseparable and essential a connection with the principles and demonstrations in geometry, that mathematicians never admit it into doubt, or make the least question of it. And as this notion is the source from whence do spring all those amusing geometrical paradoxes, which have such a direct repugnancy to the plain common sense of mankind; so it is the principal occasion of all that nice and extreme subtilty which renders the study of mathematics so difficult and tedious. Hence, says he, if we can make it appear, that no finite extension contains innumerable parts, or is infinitely divisible, it follows, that we shall at once clear the science of geometry from a great number of difficulties and contradictions which have ever been esteemed a reproach to human reason, and withal, make the attainment thereof a business of much less time and pains than it hitherto hath been.

Every particular finite extension, which may possibly be the object of our thought, is an idea existing only in the mind, and consequently each part thereof must be perceived. If therefore, says this author, I cannot perceive innumerable parts in any finite extension that I consider, it is certain they are not contained in it; but it is evident, that I cannot distinguish innumerable parts in any particular line, surface, or solid, which I either perceive by sense, or figure to myself in my mind; wherefore, I conclude they are not contained

DETAILS, PLATE 6.



Gilbert Archt. del. — R. Thew Sc.

Nº. 1. Fan tracery Vaulting. Nº 4. Flying Buttress. Nº 8. Gargoyle. Nº 11. Hip knot.

in it. Nothing can be plainer to me than that the extensions I have in view are no other than my own ideas; and it is no less plain, that I cannot resolve any one of my ideas into an infinite number of other ideas; that is, that they are not infinitely divisible. If by an infinite extension be meant something distinct from a finite idea, I declare I do not know what that is, and so cannot affirm or deny anything of it. But if the terms extension, parts, and the like, are taken in any sense conceivable; that is, for ideas; then to say a finite quantity or extension consists of parts infinite in number, is so manifest a contradiction, that every one at first sight acknowledges it to be so.

On the other hand, it is observed by an eminent mathematician, that geometricians are under no necessity of supposing that a finite quantity of extension consists of parts infinite in number, or that there are any more parts in a given magnitude than they can conceive or express: it is sufficient that it may be conceived to be divided into a number of parts equal to any given or proposed number; and this is all that is supposed in strict geometry concerning the divisibility of magnitude. It is true, that the number of parts into which a given magnitude may be conceived to be divided, is not to be fixed or limited because no given number is so great, but a greater than it may be conceived and assigned: but there is not therefore any necessity for supposing that number infinite; and if some may have drawn very abstruse consequences from such suppositions they are not to be imputed to geometry. Geometricians are under no necessity of supposing a given magnitude to be divided into an infinite number of parts, or to be made up of infinitesimals; nevertheless they cannot so well avoid supposing it to be divided into a greater number of parts than may be distinguished in it by sense in any particular determinate circumstance. But they find no difficulty in conceiving this; and such a supposition does not appear to be repugnant to the common sense of mankind, but, on the contrary, to be most agreeable to it, and to be illustrated by common observation. It would seem very unaccountable not to allow them to conceive a given line, of an inch in length for example, viewed at the distance of 10 feet, to be divided into more parts than are discerned in it at that distance: since by bringing it nearer, a greater number of parts is actually perceived in it. Nor is it easy to limit the number of parts that may be perceived in it when it is brought near to the eye, and is seen through a little hole in a thin plate; or, when by any other contrivance it is rendered distinct at small distances from the eye. If we conceive a given line, that is the object of sight, to be divided into more parts than we perceive in it, it would seem that no good reason can be assigned why we may not conceive tangible magnitude to be divided into more parts than are perceived in it by the touch; or a line of any kind to be divided into any given number of parts, whether so many parts be actually distinguished by sense or not. In applying the reasonings and demonstrations of geometricians on this subject, it ought to be remembered, that a surface is not considered by them as a body of the least sensible magnitude, but as the termination or boundary of a body; a line is not considered as a surface of the least sensible breadth, but as the termination or limit of a surface; nor is a point considered as the least sensible line, or a moment as the least perceptible time; but a point as a termination of a line, and a moment as a termination of a limit of time. In this sense they conceive clearly what a surface, line, point, and a moment of time, is; and the postulata of Euclid being allowed and applied in this sense, the proofs by which it is shown, that a given magnitude may be conceived to be divided into any given number of parts, appear satisfactory; and if we avoid supposing the parts of a given magnitude to be infinitely small, or to be infinite in number, this seems to be all that the most scrupulous can require.

Dr. Reid, in his "Inquiry into the Human Mind, on the Principles of Common Sense," considers that it is absurd to deduce from sensation the first origin of our notions of external existence, of space, motion, and extension, and all the primary qualities of bodies; they have, he says, no resemblance to any sensation, or to any operation of our minds, and therefore they cannot be ideas either of sensation or reflection; nor can he conceive how extension, or any image of extension, can be in an unextended and indivisible subject like the human mind.

EXTERNAL, or Exterior, (from the Latin *externus*, outward,) a term of relation, applied to whatever is on the surface or outside of a body, and opposed to *internal* or *interior*.

External or Exterior Angles. *See* Angles.

EXTRADOS, (from the Latin, *extrà*, outer, and *dorsus*, the back,) the external surface of a vault. The surface on the upper side of the voussoirs of an arch. *See* Arch, Bridge.

EXTREME, (from the Latin *extremus*, utmost,) whatever finishes or terminates on one side of a thing. The extremes of a line are points.

EYE, (from the Saxon,) a circular window in a pediment, attic, the reins of a vault, or the like.

Eye, *Bullock's*, (in French, *œil de bœuf*) a little skylight in the covering or roof, intended to illuminate a granary, &c. It is also applied to the little lanterns in a dome, as at St. Peter's at Rome, which has forty-eight, in three rows.

Eye of a Dome, the aperture at the summit, as that of the Pantheon at Rome, or of St. Paul's, London.

Eye of a Volute, the circle at the centre, from the circumference of which the spiral line commences. *See* Spiral and Volute.

Eye, in perspective, the point where the organ of vision is fixed, in order to view the object.

Eye-Brow, the same as Fillet, which see.

F.

FABER, a workman, the Romans gave this name to artisans or mechanics who worked in hard materials.

FABRIC, (from the Latin, *fabrica*, French *fabrique*, originally the workshop of a mechanic, *a smith's shop or forge*) the structure or construction of anything, particularly a building.

In Italy, the word is applied to any considerable building; in France, it rather signifies the manner of building.

FAÇADE, or Face, (from the Latin *facies*, the front) the face or front view of an edifice; that portion of the surface of a building which presents itself to the eye. Façade was used originally to denote the principal front of a building; and the term Facciata, used by the Italians, is, for the most part, applied to such fronts as have a principal entrance. The word is now generally made use of when speaking of architectural buildings, as the façade of the Louvre, or the façade of St. Peter's, &c.

FACE, or FACIA (from the Latin) a vertical member in the combination of mouldings, having a very small projection, but considerable breadth; such as the bands of an architrave. *See* FASCIA.

FACE MOULD, in the preparation of the hand-rail of a stair, a mould for drawing the proper figure on both sides of the plank; so that when cut by a saw held at a certain inclination, the two surfaces of the rail-piece will be every where perpendicular to the plan, when laid in their intended position.

FACE OF A STONE, the surface intended for the front of the work. The face is easily known when the stone is scalped, as being opposite to the back, which is rough as it comes from the quarry. The surface of the splitting grain ought always to be perpendicular to the face.

FACET, or FACETTE, a flat projection between the flutings of columns.

FACIA. *See* FASCIA.

FACING, in engineering, a small thickness of common earth, soil, or stuff of a canal, laid in front of the side lining or puddle on the sloping sides. It is of use to hold up the puddle while working and chopping, in the act of puddling, and afterwards to guard the puddle from being penetrated by the hitchers and poles used by the barge-men.

FACING, a thin covering of a better material, to improve the appearance, or add to the strength of anything. Thus the thin covering of polished stone, or the stratum of plaster, or cement on a brick or rough stone wall is called a facing.

FACING, FAÇADE, or REVETEMENT, in fortification, the portion of masonry, or rather building, given to ramparts, with a view to prevent the soil of which they are composed from crumbling or giving way. When the wall is of masonry, it should be 5 feet thick at the top, with tresses, called *counterforts*, at about 15 feet apart, to strengthen the facing. In order to prevent escalade, the facing is generally made full 27 feet high, from the bottom of the ditch to the cordon. When the facing is carried up as high as the soles of the embrasures, it is called a *whole revetement;* but when confined to the ditch only, it is called a *half revetement.* These must depend upon the nature of the soil, the facility of obtaining materials, the time that can be allowed, the importance of the post, &c. When difficulties occur, as also in temporary works, the facings are made with turf, in which case they are said to be *gazoned.* For field-works, and particularly in the conducting of sieges, fascines or faggots, made of various materials, are very generally employed, and answer the intention.

FACINGS, in joinery, all those fixed parts of wood-work which cover the rough work of the interior of walls, and present themselves to the eye in the completion.

FACTABLING. *See* COPING.

FAIR CURVE, in ship-building, a winding line, used in delineating ships, whose shape is varied according to the part of the ship which it is intended to describe.

FAHRENHEIT, the presumed inventor of the thermometer which bears his name. It is quite unknown on what grounds he made choice of the fixed points on his scale, or of the number of graduations between them, but it is supposed that one of the fixed points was that of boiling-water, and that the other, the *zero* of the scale, was that at which the top of the column stood, when the instrument was exposed to an intense cold in Iceland, in 1709. The extent of the scale between this last point, and that of boiling-water, is divided into 212 parts, and the point of freezing water is at the thirty-second division from the zero point.

FALD-STOOL, a portable folding seat of wood or metal, often of elaborate workmanship, and covered with rich hangings of silk or other material. The term is applied to the Litany stool, or low desk, used in churches, from which the Litany is said. Its position is in the middle of the choir, near the steps of the altar.

FALL. *See* MEASURE, and WEIGHTS AND MEASURES.

FALLING MOULDS, the two moulds which are applied to the vertical sides of the rail-piece, one to the convex, the other to the concave side, in order to form the back and under surface of the rail, and finish the squaring.

FALLING SLUICES, in engineering, gates contrived to fall down of themselves, and enlarge the water-way, on the increase of a flood, in a mill-dam, or the pond of a river navigation.

FALSE ROOF, of a house, that part between the upper room and the covering.

FANE. *See* VANE.

FAN-SHAPED WINDOW, a window consisting of rather more than a semi-circle, the circumference of which is cut out in circular notches.

FAN-TRACERY VAULTING, a mode of vaulting very much in use in late Perpendicular buildings. In this vaulting, all the ribs and principal lines diverge equally in every direction from a point at the springing of the vault; every rib preserving the same curvature; the spaces between the ribs are piled up with panelling and rich tracery. The name is applied from the similarity of this kind of roof to an open fan. Beautiful specimens exist at King's College Chapel, Cambridge; St. George's, Windsor; and Henry VII.'s Chapel, Westminster; also in many smaller erections, such as chantries, tombs, &c.

FANUM, among the Romans, a temple consecrated to some deity. The deified mortals, among the heathens, had likewise their *fana:* even the great philosopher, Cicero, erected one to his daughter Tullia.

FANUM JOVIS, a temple of Jupiter, in Asia Minor, near the Thracian Bosphorus and the Syrnæan promontory.

FARM. It is not within our province to enter on the subject of the mangement of a farm; but as the construction of the buildings belonging to one is frequently entrusted to architects and surveyors, especially in a country practice, it is desirable to offer a few observations respecting farm-buildings. The directions of Vitruvius are as follow:—"The magnitude of the buildings must depend wholly on the quantity of land attached to them, and upon its produce. The number of courts and their dimensions must be proportioned to the herds of cattle and quantity of oxen employed. The kitchen should be situated in the warmest part of the court, and the stable for the oxen contiguous to it; the stalls should be made to face the hearth and the east, because when oxen are constantly exposed to light and heat they become smooth-coated. No husbandman, however ignorant, will suffer cattle to face any other quarter of the heavens than the east. The width of the stables ought not to be less than 10, nor more than 15 feet, their length proportioned to the number of yokes, each of which should occupy an extent of 17 feet. The scalding-rooms should adjoin the kitchen, in order that the operation of cleansing the utensils may be performed upon the spot. The courts for sheep, &c., should be so spacious as to allow not less than 4½, nor more than 6 feet, to each animal.

"The granaries should be above ground, and made to front either the north or the north-east, in order that the grain may not be liable to ferment; but, on the contrary, by exposure to a cold atmosphere, may be preserved a long time: all other prospects encourage the propagation of worms and insects destructive to grain. The stables should be built in the warmest part of the villa, most distant from the hearth; because when horses are stalled near fire they become rough-coated. It is likewise expedient to have stalls for oxen at a distance from the kitchen, in the open air; these should be placed so as to front the east, because if they are led there to be fed in winter, when the sky is unclouded, they will improve in appearance. The barns, the hay-yards, the corn-chambers, and the mills, ought to be without the walls, so that the farm may be less liable to accidents by fire." An excellent work on farm-buildings has been written by Mr. G. A. Dean, of Stratford.

FASCIA, FACIO, or FACE (from the Latin, *facia*) a vertical member, of considerable height, but with a small projection, used in architraves and pedestals. In the Grecian Doric, the architrave under the band consists only of a single face; as does also the Ionic on the temple of the Illysus, in Attica. The Ionic on the temple of Erechtheus, at Athens, has three fasciæ; as have several celebrated examples of the latter order. Vitruvius allows only a single face to the Tuscan and Doric orders: that is, he makes it all plain, without any divisions or cantoning into parts or fasciæ.

In brick buildings, the jutting out of the bricks beyond the windows in the several stories, except the highest, are called *fascias* or *fasciæ*. These are sometimes plain, and sometimes moulded; but the moulding is only a sima reversa, or an ogee, with two plain courses of brick over it, then an astragal, and lastly, a boultine.

FASCINE, (from *fascis*, a bundle,) in fortification, a number of small sticks of wood, bound at both ends and in the middle, used in raising batteries, in filling ditches, in strengthening ramparts, and making parapets. Smeaton and other engineers have used wattled wood or hedge-work for groins, &c., to retain the pebbles or beach, and break the waves on the shore.

FASTIGIUM, (Latin, *a top* or *ridge*) the upper or crowning member of a building. The term is also applied to PEDIMENT; which see.

FATHOM (from the Saxon) a long measure of six feet, taken from the extent of both arms, when stretched in a right line. It is used in measuring the depth of water, quarries, wells, and pits. It is also always used in nautical matters, as in heaving the lead, &c.

FAUX, a narrow passage used as a means of communication between the atrium and peristylium, the two principal divisions of a Roman house.

FAVISSA (Latin) a hole, pit, or vault under ground, to keep something of great value.

FEATHER-EDGED BOARDS, those of a trapezoidal section; that is, thicker on one edge than on the other: they are used in the facing of wooden walls, and sometimes for the covering of an inclined roof, by lapping the thick edge of the upper board upon the thin edge of the lower one: boards of this description are also employed in fence walls, but are then most frequently placed vertically.

FEATHER-EDGED COPING. *See* COPING.

FEATHERING, an ornament in use in Early English, and the later periods of Gothic architecture, consisting of an arrangement of small arcs in juxtaposition, and forming, at their intersection, projecting points or cusps. Sometimes we find a second and even a third series of these ornaments, one within the other. *See* FOLIATION.

FEEDER, in engineering, a cut or channel, sometimes called a *carriage* or *catch-drain*, by which a stream or supply of water is brought into a canal: sometimes the stream of water itself thus supplied, is called a *feeder*.

FEEDING-HOUSE, or SHED, a building in a farm, for the purpose of fattening neat cattle. It should have a dry warm situation, capable of free ventilation, and be well supplied with proper conveniences for the reception of food and water.

FELLING, of timber, the cutting of trees close by the root, for the purpose of building: the proper season for this purpose, is about the end of April.

FELT-GRAIN: when a piece of timber is cloven or split towards the centre of the tree, or transversely to the annular rings or plates, that position of splitting is called the *felt-grain;* and the transverse position, or rather that which is in the direction of the annular plates, is called the *quarter-grain.*

FELTING, the splitting of timber by the *felt-grain.*

FEMUR, the plane space intervening between the channels in the triglyphs of the Doric order.

FENCE, (from the Latin *defendo*, to defend) any sort of construction for the purpose of enclosing land; as a bank of earth, a ditch, hedge, wall, railing, paling, &c.

FENCE, the guard of a plane, which obliges it to work to a certain horizontal breadth from the arris: all moulding planes, except hollows, rounds, and snipes' bills, have fixed fences, as well as fixed stops; but in fillisters and plows the fences are moveable.

FENESTELLA, a niche on the south side of the altar in churches, in which the piscina and sometimes credence table also is placed. These niches are of various forms and degrees of ornamentation; some of them are very richly finished. In some instances a double niche is found, one for the piscina and the other for the credence table. *See* PISCINA, CREDENCE TABLE, CHANCEL, &c.

FENESTRATION, the arrangement of windows in a building. The term is also used in contradistinction to *columniation*, when speaking of the design and composition of a building generally; the former term being used in reference to an edifice in which windows form the principal feature, the latter to that in which the columnar arrangement is adopted. Buildings in which both windows and columns are employed, are termed *columnar-fenestrated.*

FERETORY, (Latin *fero*, to carry,) a bier, coffin, shrine, or tomb. The term is more properly applied to portable shrines.

FESTOON, a representation in sculpture of bands of flowers, drapery, foliage, &c., looped up or suspended at regular intervals. This decoration was used by the ancients in friezes, &c.

FETCHING THE PUMP, the act of pouring water into the upper part of a pump, to expel the air contained between the lower box, or piston, and the bottom of the pump.

FIGURE (from the Latin *figura*, likeness) in a general sense, the terminating extremes, or surface of a body.

No body can exist without figure, otherwise it would be infinite, and consequently all space would be solid matter.

FIGURE, in geometry, any plane surface comprehended within a certain line or lines.

Figures are either rectilinear, curvilinear, or mixed, according as the perimeter consists of right lines, or curved lines, or both.

The superficial parts of a figure are called its *sides*, or *faces*, and the lowest side its *base;* if the figure be a triangle, the angle opposite the base is called the *vertex*, and the height of the figure is the distance of the vertex from the base.

FIGURE, in architecture and sculpture, representations of things made of solid matter, as statues, &c., thus we say, figures of brass, of marble, of stucco, of plaster, &c.

Figures, in architecture, are said to be *detached* when they stand singly, in opposition to those compositions called *groups.*

Figure, in conics, the rectangle under the latus rectum and transversum, in the hyperbola and ellipsis.

Figure, in fortification, the interior polygon, which is either regular or irregular. It is called a regular figure, when the sides and angles are all equal.

Figures are either Circumscribed or Inscribed, Equal, Equilateral, Similar, Regular, or Irregular. *See* these words.

Figure of the Diameter, a name given to the rectangle under a diameter and its perimeter, in the ellipsis and hyperbola.

FILLET, (from the French *filet*, a band) a small member, consisting of two planes at right angles, used to separate two larger mouldings, to strengthen their edges, or to form a cap or crowning to a moulding, or sometimes to terminate a member, or series of members.

The fillet is one of the smallest members used in cornices, architraves, bases, pedestals, &c.

It is called by the French, *reglet*, *bande*, and *bandelette;* by the Italians, *lista* or *listella.*

Fillet, in carpentry or joinery, any small timber scantling, equal to, or less than, battens: they are used for supporting the ends of boards, by nailing them to joists or quarters, &c., as in sound-boarding, and in supporting the ends of shelves.

Fillet Gutter. *See* Guttering.

FILLING - IN PIECES, in carpentry, short timbers, less than the full-length, fitted against the hips of roofs, groins, braces of partitions, &c., which interrupt the whole length.

FINE-SET, when the iron of a plane has a very small projection below the sole, so as to take a very thin broad shaving, it is said to be *fine-set.*

FINE STUFF, in plastering. *See* Plastering.

FINIAL, (from the Latin, *finio*, to finish,) in the pointed style of architecture, a termination to a building, or principal part, in the form of a flower or knop of foliage; used in high-pointed pediments, canopies, pinnacles, &c. It is usually in the form of a lily, trefoil, acorn, pomegranate, endive, &c., or consists of four or more of the leaves which compose the crockets tied up in one bunch.

FINISHING, a term frequently applied to the termination of a building, as also to the interior, in the plaster-work, in giving the last coat; and very frequently to the joiner's work, as in the architraves, bases, surbases, &c.

Finishing, in plastering. *See* Plastering.

FIR, (from the Welsh *fyrr*,) a species of timber much used in building. The native fur of this country is called *Scottish fir*, which is chiefly employed in out-houses, offices, &c. It is much inferior to the Baltic timber, which is used wherever durability is required. *See* Timber.

Fir, *Wrought*, that which is planed upon the sides and edges.

Fir, *Wrought and framed*, such as is both planed and framed.

Fir, *Wrought*, *framed*, *and rebated*, is what its name imports.

Fir, *Wrought*, *framed*, *rebated*, *and beaded*, is what its name imports.

Fir-Boards, the same as deal-boards. *See* Deal.

Fir-framed, is generally understood of rough timber framed, without undergoing the operation of the plane.

Fir-in-bond, a name given to all timber built in a wall, as bond-timbers, lintels, wall-plates, and templets.

Fir-Poles, small trunks of fir-trees from ten to sixteen feet in length, used in rustic buildings and out-houses.

Fir-no-labour, rough timber employed in walling, without framing or planing.

FIRE-BRICKS, are made from a natural compound of silica and alumina, which, when free from lime and other fluxes, is infusible under the greatest heat to which it can be subjected. Fire-bricks are brought to London from Stourbridge and from Wales; they are also made near Windsor: *See* Brick, and Windsor Bricks.

Fire-Engine, a term formerly applied to the steam-engine, but now confined to those machines which extinguish fires by throwing water from a jet upon the burning materials.

Fire-Escape, a machine for escaping from windows when houses are on fire.

Fire-Place, that space in an apartment where the fuel is consumed in communication with a flue through which the proceeds of combustion are carried away. In modern houses the fire-place is usually taken out of the space within the apartment, and flanked by projecting walls, upon which is carried up a flue, also projecting within the apartment, but in ancient houses the fire-place and flue were often taken out of the thickness of the wall, or projected outwards on the exterior of the building.

The most ancient fire-places in England, now existing, are those at Rochester and Conisborough Castles, which date of the twelfth century. The former is deeply recessed, with a semi-circular back, while the back of the former is flat, and not recessed at the level of the floor, but slopes backward as it rises; the hearth consequently projects into the room, but is covered by a hood which projects from the wall to collect the smoke. We have not many specimens of Early English work, but in the later styles they are more frequent. In Early English and Decorated buildings fire-places are not often very deeply recessed, and sometimes not at all, but they are frequently covered with projecting hoods. In the Perpendicular style they are generally entirely recessed, and in that case are without the hood; some specimens of this period are of a very ornamental description.

Fire-proof Houses, such as are built without the use of any combustible matter: for this purpose, vaulted or cast-iron floors and roofs should be employed in every apartment. Vaulting is well adapted to the lower story of a building, but if used in the upper stories, the walling must be carried up very thick, in order to resist the thrust of the arches; and this extra substance not only darkens the apartments, but occasions an enormous expense. The builder is therefore obliged to have recourse to other modes of construction for common purposes. The most convenient substitute is cast-iron joists, vaulted between with brick, or covered with cast-iron boards flanged and keyed together.

Mr. Bartholomew strongly recommends that roofs should be so constructed as to lessen as much as possible the possibility of fire. "It should be," he observes, "the architect's study, in all roofs, to have as little as possible that will either burn or rot; if the roof-trusses were made of cast-iron, as Mr. Gwilt has made those to his restoration of the choir of St. Saviour's Church, Southwark; and if slight horizontal rafters, reaching from truss to truss, supported tiles of the ornamental description above referred to, (tiles made of burnt earth, moulded in the form of leaves, &c.,) all combustible materials might be banished from our invaluable cathedrals."—We quite agree with Mr. Bartholomew in principle, but, in such cases, would beg to recommend a vaulted stone roof in preference to one of iron.

The late Sir John Soane constructed nearly all the apartments of the Bank of England fire-proof, and without any carpentry whatever; in his arches and domes, making use largely of hollow pots or cones of coarse earthenware; these, while strong enough not to crush, by their lightness relieve the walls in a great measure, both from the lateral thrust, and the perpendicular pressure, caused by the use of heavier materials.

A method of rendering the floors of houses fire-proof, has been adopted with success in many parts of France. After the joists are laid they are boarded over with rough boards, and these covered with a coating of plaster of about eight inches in thickness, above which are laid tiles of an ornamental description, or sometimes a floor of parquetry. In some instances, the boards on which the plaster is laid, are omitted altogether, and the plaster inserted between the joists. The staircases likewise are made of brick-nogging, and covered with tiles.

It is a cause of wonder and regret, that these or similar means for rendering buildings fire-proof, are not adopted in London, where so great a loss is annually sustained by neglect on this head: the immediate outlay would not be very much greater than at present, and in the end the practice would assuredly prove the more economical. Our timber partitions, roofs, and staircases would seem to be made for the purpose of burning; and when once a portion of a building takes fire, there is little chance of saving the remainder; whereas if the chambers, or at least the floors, were isolated by fire-proof partitions, a fire could readily be confined to that part of the building where it commenced.

But perhaps of all parts of a house, that which requires the greatest care in this respect is the staircase; it is no easy matter to calculate how great a loss of human life has been occasioned by recklessness on this point. The staircase forms a shaft to carry up the flames, and is one of the first things to be destroyed, thus cutting off the means of escape from persons above the ground-floor: if nothing else be attended to, surely our staircases should be rendered fire-proof.

Iron has of late years been much used for the purpose of rendering buildings more safe from the effects of fire, but we are inclined to think the success of this application doubtful. This material is generally used as a substitute for summers, girders, or bond-timber, in which instances wood is almost as secure as iron; for in the former cases, the timbers are of too great scantling thoroughly to ignite, and in the latter they are well protected, and will be seldom found more than charred on the exposed surfaces. Besides this, iron has its disadvantages, for it is liable to expand and contract under the influence of heat and cold, and is known by this means to destroy the brickwork.

FIRE-STONE, is used in joinery, for rubbing away the ridges made by the cutting-edge of the plane.

FIRMER,
FORMER, } *See* Tools.
FURMER,

FISH-POND, a reservoir of water, for breeding, feeding, and preserving fish.

FISTUCA, (Latin) in antiquity, an instrument of wood, used in driving piles. It had two handles, and being raised by pullies fixed to the head of large beams, was let fall directly on the piles; sometimes it was wrought by hand only.

FIXED AXIS, in geometry, the axis about which a plane revolves in the formation of a solid.

Fixed Points, in carpentry, the points at the angles of a piece of framing, or where any two pieces of timber meet each other in a truss. If a third piece join the meeting of the two, it may be pushed or drawn in the direction of its length, without giving any cross strain.

Fixed points are of the utmost use in shortening the bearings of the exterior timbers of the frame; neither is there any other method by which this can be so effectually done. When two sides of a frame are similar, any points in the length of the pieces may be supported by as many beams, extending between the opposite points: though this will keep the frame in *equilibrio*, it will not prevent it from being shaken by heavy winds, or lateral pressure.

FLAGS, thin stones used in paving, from one and a half to three inches thick, and of various lengths and breadths, according to the nature of the quarry.

FLAKE WHITE, in painting, lead corroded by the pressing of grapes, or a ceruse prepared by the acid of grapes. It is brought to England from Italy, and far surpasses, in the purity of its whiteness, and the certainty of its standing, all the ceruses of white-lead made with us in common. It is used in oil and varnish painting, for all purposes where a very clean white is required. Flake white should be procured in lumps, as brought over, and levigated by those that use it; as that which the colourmen sell ready prepared, is levigated and mixed up with starch, and often with white-lead, or even worse sophistications.

FLAMBOYANT, a name applied to a style of Gothic architecture prevalent in France in the 15th century, from the circumstance of the principal lines of the tracery converging together in the shape of flames. This undulating distribution of lines is the characteristic of the style, if it may be so termed. The tracery is frequently of a very elaborate character, and the ornamentation intricate and redundant, while at the same time the mouldings are meagre. These consist usually of large hollows separated with small and insignificant members of different contour, which gives the whole an appearance of poverty, ill contrasting with the richness of the tracery. The centre moulding in the mullions of windows, and similar positions, projects often to an unusual extent, so as to give it the appearance of weakness. Pillars, piers, jambs, and such like, are often devoid of capitals, the mouldings of arches which abut against them, dying into them without any finishing ornament. The more ornamented parts, such as foliage, &c., are very rich, and delicately carved, but are frittered away by the minuteness of their parts, thus losing all boldness and even distinctness of outline.

FLANK, (from the French, *flanc*,) that part of a return body which adjoins the front; as flank-walls. In town-houses, the flank-walls become party walls.

FLANK WALLS, in engineering, the same as the wing or return walls of a lock or bridge.

FLAPS, folds or leaves attached to the shutters of a window, which are not sufficiently wide of themselves to cover the sash-frames, or to exclude the light.

FLASHES, in engineering, a kind of sluices erected upon navigable rivers, to raise the water upon any shoals therein, while the vessels or craft are passing.

FLASHINGS, in plumbery, pieces of lead inserted in a wall for covering other pieces laid down for gutters, &c.

FLAT CROWN. *See* Corona.

FLATTING, in house-painting, a mode of painting in oil, without any gloss on the painted surface when finished. The paint is prepared with a mixture of oil of turpentine, which secures the colour; and when used in the finishing, leaves the paint quite dead, without gloss. This is of great importance to those who are desirous to have their rooms continue white. Flatting is only used for inside work, and rarely for any but principal rooms. Nut oil is sometimes used for the purpose, but not often, on account of its high price.

As useful a flatting as any, is such as is ground in poppy oil. It is pleasant in working, and leaves a beautiful white for some years; but it is rather expensive.

FLEMISH BOND, that method of laying bricks in which headers and stretchers appear alternately in the length of each course. The appearance of this work is generally preferred to that of English bond, for the external facings of walls, but the method of laying is much more complicated, and requires the insertion of a number of small pieces in carrying up the work, to fill up the interstices between the bricks. *See* BRICKLAYING.

FLEMISH BRICKS, in bricklaying, strong bricks, of a yellowish colour, used in paving; their dimensions are about $6\frac{1}{2}$ inches long, $2\frac{1}{2}$ broad, and $1\frac{1}{2}$ thick; 72 set upon their widest sides, or 100 on edge, will pave a yard square, allowing a quarter of an inch for the joints.

FLEXURE, or FLEXION, (from the Latin) the opposition of curvature at a given point, where a straight line becomes a tangent, having the curve on both sides of it, one portion of the curve being concave, and that on the other side of the point of contact, convex.

FLIGHT, in staircasing, a series of steps, whose treads are parallel, and terminate against a straight wall.

FLIGHT, *Leading*, } *See* STAIRCASING.
FLIGHT, *Returning*, }

FLIGHT, is also used in London for a whole stair, between two adjoining floors.

FLOAT, in plastering. *See* PLASTERING.

FLOAT-BOARDS, the boards fixed to undershot water-wheels, to receive the impulse of the stream.

FLOAT-STONE, among bricklayers. *See* BRICKLAYERS.

FLOATED LATH AND PLASTER, set fair for paper. *See* PLASTERING.

FLOATED, RENDERED, and SET, in plastering. *See* PLASTERING.

FLOATING, in plastering. *See* PLASTERING.

FLOATING BRIDGE. *See* BRIDGE.

FLOATING RULES, in plastering. *See* PLASTERING.

FLOATING SCREEDS, in plastering. *See* PLASTERING.

FLOOD-GATE, a gate or sluice, that may be opened or shut at pleasure, to give passage to, or retain the water of a river liable to be swollen by floods. Flood-gates are necessary in many situations; as, upon rivers where the water is retained for the service of mills, canals, navigations, docks, &c.

FLOOR, (from the Saxon) the lowest horizontal side of an apartment, for walking, or for performing different operations upon.

Floors were formerly covered with rushes, carpets being seldom used for such purposes, even at the close of Elizabeth's reign. In much earlier times, however, tapestry-cloths were occasionally used to rest the feet upon. Most of the old dramatists have frequent allusions in their works to the practice of strewing rushes in the principal apartments.

Floors are of various kinds, according to the materials of which they are constructed. Those made of brick and stone, are called *pavements;* those of earth are called *earthen floors;* those of plaster, *lime floors;* and those of timber are called *timber floors.*

FLOOR, in carpentry, includes not only the boarding for walking upon, but all the timber-work for its support. Boarded floors should never be laid till the building is properly covered in, nor indeed till the windows are glazed, and the plaster dry. Previous to the lying of such floors, the boards ought to be rough-planed, and set out to season, a twelvemonth at least, before they are used; that the natural sap may be thoroughly expelled, and the shrinking prevented, which so frequently takes place when unseasoned timber is used. The best timber for flooring is yellow deal, well-seasoned. The quality of this material is such, that when laid, it will be easily kept of a good colour; whereas white timber is liable to become black in a very short time.

Narrow boards are called *battens;* these should never exceed seven inches in width, nor be less than an inch in thickness.

Floors are nailed either at both edges, or at one edge; the longitudinal joints, or those in the direction of the fibres, are either square, ploughed and tongued, or rebated and lapped upon each other. Ploughed and tongued, and rebated joints may be used where the apartment is required to be air-tight, and where the stuff is thought not sufficiently seasoned. The heading-joints are either square or ploughed and tongued. In square longitudinal jointed floors, it is necessary to nail the boards on both edges: but where the boards are dowelled, ploughed and tongued, or rebated, one edge only may be nailed, as the grooving and tonguing, or lapping, is sufficient to keep the other edge down.

Battens used in flooring are of three kinds, and are denominated *best, second best,* and *common.* The best battens are those that are free from knots, shakes, sap, and cross-grained fibres; the second best are those free from shakes and sap, but in which small knots are suffered to pass. The common kind are such as remain after taking away the best and second best.

The best floors are dowelled and nailed only at the outer edge, through which the nails are made to pass obliquely into the joists, without piercing the upper surface of the boards, so that when laid no nails appear: the heading joints of such floors are most commonly grooved and tongued. Some workmen dowel the battens over the joists, but it makes firmer work to fix the dowels over the inter-joists. The gauge should be run from the under surface of the boards, which should be straightened on purpose.

In the most common kind of flooring, the boards are folded together in the following manner: supposing one board already laid, and fastened, a fourth, fifth, sixth, or other board, is also laid and fastened, so as to admit of two, three, four, five, or more boards, between the two, but which can only be inserted by force, as the capacity of the opening must be something less than the aggregate breadths of the boards, in order that the joints may be close when they are all brought down to their places; for this purpose a board may be thrown across the several boards to be laid, which may be forced down by two or more men jumping upon it: this done, all the intermediate boards are to be nailed down, and the operation is to be repeated till the whole is complete. This manner of flooring is called a *folded floor.*

In folded floors, less than four boards are seldom laid together. No attention is paid to the heading joints, and sometimes three or four joints meet in one continued line, equal in length to the aggregate of the breadths of the boards.

In dowelled floors, the distances to which the dowels are set, are from six to eight inches, generally one over each joist, and one over each inter-joist; and, as has been already observed, the heading-joints of this kind of floor are generally ploughed and tongued; and no heading-joint of two boards ought to be so disposed as to meet the heading-joint of any other two boards, and thereby form a straight line equal to the breadth of the two boards.

In common floors, the boards are always gauged from the upper side, then rebated from the lower side to the gauge lines, and the intermediate part adzed down, in order to bring them to a uniform thickness. In doing this, great care should be taken not to make them too thin, which is frequently the case, and then they must be raised with chips, which present a very unstable resistance to a pressure upon the floor.

Flooring is measured by throwing the contents into square feet, and dividing them by 100, which is called a *square of flooring;* the number of hundreds contained in the superficial contents in feet are squares, and the remainder feet.

The method of measuring floors, is by squares of ten feet on each side; the dimensions being multiplied together, cut off two figures from the right of the product, and those towards the left give the number of squares, and the two on the right are feet.

Example.—Suppose the length of a floor 28 feet, and the breadth 24.

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 28
 24
———
112
56
———
6,72
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The product gives six squares, seventy-two feet.

When a naked floor is squared, and the contents found, nothing is deducted for the chimney, because the extra thickness of the trimmers will make up for that deficiency.

Floor, in carpentry, the timbers which support the boarding, called also *naked flooring. See* Carcase Flooring, and Naked Flooring.

Floor also denotes any portion of a building upon the same level: as basement-floor, ground floor, one-pair floor, two-pair floor, &c., but when there is no sunk story, the ground floor becomes the basement; the expressions one-pair floor, two-pair floor, &c., imply the floor above the first flight of stairs above ground, the floor above the second flight of stairs above ground, &c.

The principal floor of every building is that which contains the principal rooms. In the country they are generally on the ground floor; but in town, on the one-pair-of-stairs floor.

Floor Joists, or Flooring Joists, such joists as support the boarding in a single floor; but where the floor consists of binding and bridging-joists, the bridgings are never called floor-joists.

Floors of Earth, or Earthen Floors, are commonly made of loam, and sometimes, especially to malt on, of lime, brook-sand, and gun-dust, or anvil-dust from the forge; the whole being well wrought and blended together with blood. The siftings of limestone have also been found exceedingly useful when formed into floors.

Earthen floors for plain country habitations may be made as follows: take two-thirds lime and one of coal-ashes, well sifted, with a small quantity of loam clay: mix the whole together, and temper it well with water, making it up into a heap: let it lie a week or ten days, and then temper it again. After this, heap it up for three or four days, and repeat the tempering very high, till it becomes smooth, yielding, tough, and gluey. The ground being levelled, lay the floor with this material about two and a half or three inches thick, smoothing it with a trowel; the hotter the season, the better; and when it is thoroughly dried, it will make a good floor for houses, especially malt-houses. But should it be required to make the floor look better, take lime made of rag-stones well tempered with whites of eggs, and cover the floor about half an inch thick with it, before the under flooring is quite dry. If this be well done, and thoroughly dried, it will appear, when rubbed with a little oil, as transparent as metal or glass. In elegant houses, floors of this nature are made of stucco, or plaster-of-paris, beaten and sifted, and mixed with other ingredients. Well-wrought coarse plaster makes excellent safe upper floors for cottages, out-houses, &c., when spread upon good strong laths or reeds.

Very dry and comfortable floors may be formed by covering the area of the rooms with a level stratum of concrete, consisting of dry screened gravel or pounded stone, mixed with a small quantity of ground stone lime, or Portland cement, and laid about six inches in thickness; over this, and before it sets, should be sifted a few ashes, or some fine gravel; which, if worked in and well finished, gives a hard and even surface. This description of floor is similar to those used in Devonshire, which are proverbial for comfort and durability. The ordinary red paving tiles, 12 inches square, make very good, dry, and comfortable floors, and they are easily kept clean. Claridge's asphalte of Seyssel, has also been used for the floors of basement stories, and answers very well, especially in damp situations. For stables, railway-stations, and places of a similar description, perhaps there is nothing better than wood. The wood-pavement of the Metropolitan Wood Pavement Company, has been used with great success for such purposes—in the dock-yards by government; and by the railway companies, for their stations, &c.

FLOORING-CRAMP, a machine invented by Mr. Andrew Smith, for laying down floors. This machine is used with great facility, and enables a person accustomed to it, to get through his work with rapidity and ease; making very tight and close joints in his floors, with much less trouble than by the ordinary method.

Flooring-Machine, a machine for preparing complete flooring boards with great dispatch, and in the most perfect manner: the several operations of sawing, planing, grooving, and tongueing, being all carried on at the same time, by a series of saws, planes, and revolving chisels.

FLOOR-TIMBERS, the timbers on which a floor is laid.

FLORID STYLE, in pointed architecture, that beautiful style which was practised in England during the reigns of Henry VII. and Henry VIII. Its general external character consists of large arched windows, with very obtuse angles at the summit, and with numerous ramifications, consisting of light cuspidated mullions, filled with a variety of polyfoils. The buttresses, instead of having always rectangular horizontal sections, frequently have those of polygons, as in Henry VII.'s chapel, and are crowned with cupolas. The walls are loaded with niches, pinnacles, and crockets, terminating in open mullion-work, forming a parapet, or kind of balustrade, finished with finials or spiracles. The walls are decorated interiorly with panelling, moulded string-courses, niches, canopies, and other kinds of tracery, vaulted over with fan-groins. *See* Gothic Architecture.

FLUE, a passage for smoke in a chimney, leading from the fireplace to the top of the shaft, or into another passage. *See* Chimney.

The same term is also applied to passages in walls made for the purpose of conducting heat from one part of a building to another.

Flues in hot-houses and vineries, frequently make numerous turns on the floor, and then ascend to the wall with several horizontal turnings.

In the construction of a stack of chimneys, particular care should be taken that the drawings show distinctly the turnings of the flues; this will prevent mistakes, and save the apartments from being incommoded with smoke.

FLUSH, a term among workmen, signifying a continuity of surface in two bodies joined together. Thus in joinery, the style, rails, and munnions are generally made flush; that is, the wood of one piece on one side of the joint does not recede from that on the other.

Flush, in masonry or bricklaying, signifies the aptitude of two brittle bodies to splinter at the joints, when the stones or bricks come in contact when joined together in a wall.

Flush and Bead. *See* Bead and Flush.

FLUTES, or Flutings, prismatic cavities depressed within the surface of a piece of architecture at regular distances, generally of a circular or elliptic section, meeting each other in an arris; or meeting the surface in an arris, and leaving a portion of the surface between every two cavities of an equal breadth; or diminishing in a regular progression; according as the surface is plane or curved, or applied to a prismatic or tapering body.

When a portion of the surface is left between every two flutes, that portion is called a *fillet*. When the flutes are parallel, or diminish according to any law, the fillets are also parallel, or diminish in the same degree.

The proportion of each fillet to a flute is from a third to a fifth of the breadth of the flute. That species of fluting, in which the flutes meet each other without the intervention of fillets, is generally applied to the Doric order; and that with fillets, to the shafts of the Ionic and Corinthian orders. The flutes most frequently terminate in a spherical or spheroidal form, particularly in those which have fillets. In the Ionic order of the temple of Minerva Polias at Athens, the upper ends of the fillets of the shafts of the columns terminate with astragals, projecting from the surface of the fillet: the astragals may begin at a small distance from the top of the shaft, ascend upwards, and bind round the top of the flute. In the Corinthian order of the monument of Lysicrates, at Athens, the upper ends of the fillets break into leaves in a most beautiful manner. In the Doric examples of the temple of Theseus, and of the temple of Minerva at Athens, and of the portico of Philip king of Macedon, in the island of Delos, the upper ends of the flutes terminate upon the superficies of a cone immediately under the annulets, in a tangent to the bottom of the curve of the echinus of the capital. The same kind of termination takes place in the temple of Apollo at Cora, in Italy: but in this example, the conic termination of the flutes is not under the abacus, but a small distance down the shaft, leaving a small part quite a plain cylinder, and thus forming the hypotrochelean or neck of the capital. In other ancient examples of the Doric order, the flutes terminate upon a plane surface perpendicular to the axis of the columns, or parallel to the horizon, as in the Propylea at Athens. Palladio, and other Italian authors, have terminated the flutes of the shafts of their designs of Doric columns in the segments of spheres tanged by the surfaces of the fluting.

In the temple of Bacchus, at Teos, in Ionia, the lower extremities of the flutes descend into the scape of the column.

The Greeks never applied fluting to any member of the Doric order, except the shaft, and this was their general practice.

Fluting was used by the Romans almost in every plane, and in every cylindrical surface. *See* a very fine specimen in the corona of the cornice of the temple of Jupiter Stator, at Rome.

The number of flutes in the Doric order is twenty, and in the Ionic, Corinthian, and Composite, twenty-four. Flutes are sometimes filled with cables or staves, except in the Doric order. The cables do not reach higher than one-third of the entire column. *See* Column, Cable.

FLUXIONS, in mathematics, the analysis of infinitely small variable quantities, or a method of finding an infinitely small quantity, which being taken an infinite number of times, becomes equal to a quantity given. The doctrine of fluxions, first invented by Newton, is of great use in the investigation of curves, and in the discovery of the quadratures of curvilinear spaces and their rectifications.

FLYERS, a series of steps whose treads are all parallel.

FLYING BRIDGE. *See* Bridge.

FLYING BUTTRESSES, in pointed architecture, arches rising from the exterior walls up to those of the nave of an aisled fabric, on each side of the edifice, for counteracting the lateral pressure of a groined or vaulted roof.

The contrivance of flying buttresses is due to the architects of the middle ages, and shows their skill in the application of mechanics to the science of architecture. *See* Buttress.

FOCUS, (Latin) in geometry, and in the conic sections, a point on the concave side of a curve, to which the rays are reflected from all points of such curve.

Focus, an altar, a hearth or fire-place: the Latin motto, *pro aris et focis*, is said to be derived from this word.

Focus, of an ellipsis, hyperbola or parabola, is particularly defined under the heads of Elliptic Curve, Hyperbolic Curve, and Parabolic Curve.

FODDER, Fudder, or Fother, (Saxon) a certain quantity, proportioned by weight.

The weight of the fodder varies, in different counties, from 19½ cwt. to 24 cwt. Among the plumbers in London, the fodder is 19½ cwt., but at the Custom House 20 cwt. of 112lb.

FOILS, the small arcs in the tracery of Gothic windows, panels, &c., which are said to be trefoiled, quatrefoiled, cinquefoiled, multifoiled, &c., according to the number of arcs which they contain. An arch with foils in its tracery is called a *foiled arch*. *See* Cusp and Foliation.

Foils, Foliations, the spaces between the cusps employed in the ornamentation of Gothic buildings.

FOLDED FLOOR. *See* Floor.

FOLDING DOORS, such as are made in two parts, hung on opposite jambs, and having their vertical edge rebated, so that when shut, the rebates may lap on each other. To conceal the meeting as much as possible, a bead is most frequently run at the joint on each side of the doors.

FOLDING JOINT, a joint made like a rule-joint, or the joint of a hinge.

FOLDS, or Flaps, of shutters, those parts that are hinged to the shutters, and concealed behind when the shutters are in the boxings, so as to cover the breadth of the window when the shutter and flaps are folded out in the breadth of the aperture. Folds are necessary when the walls are so thin as not to admit of shutters of sufficient breadth, when put together, to cover the opening.

FOLIAGE, in architecture, an artificial arrangement of leaves, fruit, &c. *See* Ornaments.

FOLIATION. *See* Foils.

FONT, (from the Latin *fons*) the vessel used in churches to hold the water consecrated for the purposes of baptism.

In the early church, the baptistery formed a separate building, numbered amongst the exhedræ or outbuildings which were detached from the church, but enclosed within the consecrated area. Within the baptistery was the font or reservoir. These separate buildings continued to prevail till the sixth century, when all occasion for adult baptism ceased, and fonts within the church became general. Many baptisteries, however, still exist in various parts of the

Continent, although there seem to be no specimens in England, unless indeed we consider as such the building surrounding the font at Luton church. This structure is octagonal, about twenty-eight feet high, having open arches at the sides, and a stone roof, the font being placed in the centre, thus forming a small oratory capable of holding seven or eight persons. A similar canopy occurs at Trunch, Norfolk, but it is of wood, and hexagonal.

The material in use for fonts, is for the most part of stone lined with lead, but we have some notice of fonts of metal; that at Canterbury is reported to have been of silver, and that taken from Holyrood Chapel and brought to St. Alban's was of brass. There is also a font at Chobham, Surrey, which consists of a leaden basin enclosed within a screen of oak panelling, the date of which is about A.D. 1600. The situation of the font is within the church, near the door, either in the aisle next the porch, against one of the piers between the aisle and nave, or in the nave near the west end.

The most rude fonts are in shape little better than large stones, without any definite external form, but having a space hollowed out at the top in the shape of a bason; such is that in the church of Little Maplestead. Norman fonts are either of a cylindrical or cubical form; but which shape is the earlier, it is not easy to decide. In some instances the cylindrical fonts taper towards the base; and at St. Martin's, Canterbury, the reverse proportion is adopted. Next to these forms came the square stone hollowed out in the centre, supported on a massive cylindrical stem, or on a central stem, and four smaller shafts, one at each corner, specimens of which form exist at Lincoln cathedral and Iffley church, Oxfordshire. In all these instances, the sides of the font are ornamented with rude sculpture in low relief, frequently of groups, and sometimes of single figures contained in shallow niches, as at Stanton Fitzwarren, Wilts. Symbolical representations are frequently introduced, as are also scenes from the Sacred Writings, especially of such events as relate to the subject of baptism. On the font at Castle Frome, Herefordshire, is a representation of the Baptism of Christ, which is a very favourite subject, the same occurring at Bridekirk, in Cumberland, and West Haddon, in Northamptonshire. Another usual subject is the Fall of Man, as at East Meon, Hants.

Early English fonts are in form very similar to those of the preceding style, but they are readily distinguished by their ornamentation, which consists of work peculiar to this style; the details also are of better execution. The octagonal was a new form introduced into this style. Decorated and Perpendicular fonts are for the most part octagonal, and most frequently supported on a central stem; many of them are of most beautiful form and workmanship. Those of the later period are usually covered with panelling, and have the sides filled up with armorial bearings. Hexagonal fonts are sometimes, though not commonly, found; we have instances at Carlisle cathedral, Farringdon, Berkshire; and Bredon, Worcestershire. Five and seven-sided fonts are extremely rare; of the former we have an example at Hollington, Sussex. At Patrington and Saddington, Leicestershire, we find fonts of twelve sides; and at Stainburn, Yorkshire, one of fifteen sides; but these are purely exceptions: the octagonal form is the most common, as it is also the most appropriate. The font is usually raised on one or more steps, the sides or risers of which are often in the later styles decorated with panelling, quatrefoils, &c. Fonts were furnished with covers, which Edmund, archbishop of Conterbury, A.D., 1236, ordered to be locked down. They were probably in the earlier periods merely flat lids of wood, but in later times they were carried up in the form of a spire to a great height, ornamented with pinnacles and buttresses, with crockets, finials, and other ornaments; and not unfrequently the whole of the sides were pierced with the most elaborate panelling.

FONTANA, DOMINIC, a distinguished architect, born in 1543, at a village on the lake of Como. Having acquired the elements of geometry, he went to Rome, where his elder brother John was a student in architecture. Here he applied himself most diligently to the study of the works of antiquity, and at length was employed by Cardinal Montalto, afterwards Pope Sextus V. Montalto had already begun to display the magnificence of his character, by undertaking the construction of the grand chapel of the Manger, in the church of St. Maria Maggiore. The pope, Gregory XIII., jealous of the munificence of his cardinal, took from him the means of his designs, and thus put a stop to the works. Fontana, with a spirit worthy of a great man, went on with the building at his own expense, which so gratified the cardinal, that when he was raised to the pontifical chair, he appointed Fontana to be his architect. The chapel and palace were finished in a splendid style; but this was a small part of the designs projected by Sextus. Besides completing the dome of St. Peter's, he resolved to contribute to its grandeur, by conveying to the front of its piazza the obelisk, of a single piece of Egyptian granite, which had formerly decorated the Circus of Nero.

This design had been contemplated by some of the predecessors of Sextus, but none had actually attempted it. Sextus summoned architects and engineers from all parts, to consult upon the best means of effecting his purpose; Fontana's plan obtained the preference, and he was able to execute what he had advanced in theory. This was regarded as the most splendid exploit of the age; and rewards and honours of the most magnificent kind were bestowed on Fontana and his heirs. He was afterwards employed in raising other obelisks, and in the embellishment of the principal streets of Rome. He built the Vatican library, and had begun to make considerable additions to that place; but they were interrupted by the death of Sextus. One of Fontana's great works was the conducting of water to Rome, the distance of fifteen miles, in an aqueduct supported on arcades. The successor of Sextus, Clement VIII., was prejudiced against the papal architect, and dismissed him; but his reputation caused him to be engaged by the viceroy of Naples as architect to the king. He accordingly removed to Naples, in 1592, where he executed many works of consequence. His last efforts were directed to a new harbour at Naples, but this he did not live to complete. He died at Naples in 1607, in his sixty-fourth year.

FOOT, (Saxon) a measure, either lineal, superficial, or solid. The lineal or long foot is supposed to be the length of the foot of a man, and consists of twelve equal parts called *inches;* an inch being equal to three barleycorns.

Thus the English standard foot (31 Edw. I.) is =12 lineal English inches, = 36 barleycorns, = 16 digits, = 4 palms, = 3 hands, = $5\frac{1}{3}$ nails, = $1\frac{1}{3}$ spans, = 1.5151 Gunter's links, = .938306 feet of France, = .3047 metres of France.

Geometricians divide the foot into 10 digits, and the digit into 10 lines, &c.

The French divide their foot, as we do, into 12 inches; and the inch into 12 lines. *See* MEASURES.

The foot square is the same measure, both in length and breadth, containing 144 square or superficial inches, = 2.295684 square links; and the glazier's foot in Scotland is = 64 square Scottish inches.

The cubic, or solid foot, is the same measure in all the three dimensions, containing 1728 cubic inches English =6.128 ale gallons=3.478309 cubic links=.0283 cubic metres or steres of France.

The foot is of different lengths in different countries. The Paris royal foot exceeds the English by nine lines and a half; the ancient Roman foot of the Capitol consisted of four palms, equal to eleven inches and seven-tenths English; the Rhinland, or Leyden foot, by which the northern nations go, is to the Roman foot as 950 to 1,000. The portions of the principal feet of several nations, compared with the English and French, are here subjoined.

The English foot being divided into one thousand parts, or into twelve lines, the other feet will be as follow:

	Th. Pts.	Ft.	Inch.	Li.
London . . . . . . Foot	1000	0	12	0
Paris foot, the royal, by Greaves	1068	1	0	9.7
Paris foot, by Dr. Bernard	1066	1	0	9.5
Paris foot, by Graham, from the measure of half the toise of the Chatelet, the toise containing six Paris feet	1065.416	1	0	9.8
By Monnier, from the same data	1065.351	1	0	9
From both these it may be fixed at	1065.4	1	0	9.4
Amsterdam . . . . . Foot	942	0	11	3
Antwerp	946	0	11	3.57
Dort	1184	1	2	2
Rhinland, or Leyden	1033	1	0	4
Lorrain	958	0	11	5
Mechlin	919	0	11	0
Middleburg	991	0	11	10
Strasburg	920	0	11	0
Bremen	964	0	11	6
Cologne	954	0	11	5
Frankfort on the Maine	948	0	11	4
Spanish	1001	1	0	0
Toledo	899	0	10	7
Roman	967	0	11	6
Bononia	1204	1	2	5
Mantua	1569	1	0	9
Venice	1162	1	1	11
Dantzic	944	0	11	3
Copenhagen	965	0	11	6
Prague	1026	1	0	3
Riga	1831	1	9	11
Turin	1062	1	0	8
The Greek	1007	1	0	1
Old Roman	970	0	11	7.6
Roman foot, from the monument of Cossutius in Rome, by Greaves	967	0	11	7.2
From the monument of Statilius, by the same	972	0	11	7.9
Of Villalpandus, deduced from the congius of Vespasian	986	0	11	9.9

Mr. Rapier, who industriously collected a variety of authorities relating to the measure of the old Roman foot, determined the mean to be nearly 968 thousandth parts of the London foot. And by an examination of the ancient Roman buildings in Desgodetz's *Edifices Antiques de Rome*, Paris, 1682, he concluded that the Roman foot, before the reign of Titus, exceeded 970 parts in 1000 of the London foot; and in the reigns of Severus and Diocletian fell short of 965.

The Paris foot being supposed to contain 1440 parts, the rest will be as follow:—

Paris . . . . Foot	1440
Rhinland	1391
Roman	1320
London	1350
Swedish	1320
Danish	1403
Venetian	$1540\frac{2}{5}$
Constantinopolitan	3120
Bononian	$1682\frac{2}{5}$
Strasburg	$1282\frac{5}{4}$
Nuremburg	$1346\frac{1}{4}$
Dantzic	$1721\frac{1}{2}$
Halle	1320

In Scotland, this measure of length, though consisting of twelve inches, exceeds the English foot, so that 185 of the former is equal to 186 of the latter. Accordingly the Scottish foot = 12 Scottish inches = 12 $\frac{1}{15}$ English inches, according to some, and $12\frac{12}{185}$ English inches, according to others. The glazier's foot in Scotland = 8 Scottish inches.

For a farther account of the foot, ancient and modern, and its proportions in different countries. *See* MEASURE.

FOOT-BANK, or FOOT-STEP, in fortification. *See* BANQUETTE.

FOOT-BASE, the moulding above the plinth of an apartment.

FOOT-BRIDGE, a narrow bridge for foot-passengers. *See* BRIDGE.

FOOT OF THE EYE DIRECTOR, in perspective, that point in the directing line which is made by a vertical plane passing through the eye and the centre of the picture.

FOOT OF A VERTICAL LINE, in perspective, that point in the intersecting line, which is made by a vertical plane passing through the eye and the centre of the picture.

FOOT-IRONS, in engineering, pieces of iron plate, used by navigators, or canal-diggers, to tie upon that part of the sole of their shoes with which they strike the top of their spade or grafting tool, in digging hard soil.

FOOT-PACE, in hand-railing, a flat space in some stairs, always situated between the starting, or first step, and the landing. *See* STAIRCASING.

FOOT-PACE, the dais or raised floor at the upper end of an ancient hall.

FOOT-STALL, the base or plinth of a pillar.

FOOTING-BEAM, a term used in Cumberland, Westmoreland, Somersetshire, and perhaps in other counties, for the tie-beam of a roof.

FOOTINGS, in bricklaying and masonry, projecting courses of stone, without the naked of each face of a superincumbent wall, used as a base to the wall, in order to prevent it from sinking and rocking by heavy winds.

FOOTING DORMANT, the tie-beam of a roof; the term is used in Westmoreland.

FORCE, (from the Latin, *fortis*, strong) in philosophy, the cause of motion in a body, when it begins to move, or when it changes its direction from the course in which it was previously moving. While a body remains in the same state, whether of rest or of uniform and rectilinear motion, the cause of its so remaining is in the nature of the body, which principle has received the name of *inertia*.

Mechanical force is of two kinds: that of a body at rest, by which it presses on whatever supports it, and that of a body in motion, by which it is impelled towards a certain point. The former is called by the names of *pressure*, *tension*, *force*, *vis mortua*, &c., the latter is known by the appellation of *moving force*, or *vis viva*. To the first of these are referred *centrifugal* and *centripetal* forces because, though they also reside in the *vis viva*, they are homogeneous to weights, pressures, or tensions of any kind. For want of a true knowledge of the nature of force, we are accustomed to consider its measure by velocity, upon the supposition that, under precisely similar circumstances, the velocity is equal to the force; an hypothesis highly probable, though not easily demonstrable. Velocity itself is a compound idea, derived from a certain relation between time employed and space described. Thus, if two bodies be supposed to move uniformly upon two different lines, the distances which they describe upon their respective lines in any given time, may be measured and represented by some standard measure, from which we acquire an idea of their relative velocity or force; and considering velocity as an abstract number, it is said to be equal to the space, divided by the time; and thus we are led to consider velocity, or the space described in a given time, as the measure of force.

Force may also be expressed by other functions of velocity; for it may be proportional to the square or cube of the velocity; and La Place has very ingeniously proved that the difference between the proportionality of force to velocity, if any really exists, must be extremely small; whence he argues it is highly improbable that any does exist. If there were any material variation in this law, the relative motions of bodies on the surface of the earth would be sensibly affected by the motion of the earth; in other words, the effect of a given force would vary considerably, according as its direction coincided with, or was opposed to, that of the earth's motion. The effects of the same apparent forces would likewise vary in different seasons of the year; the velocity of the earth being less by about one-thirtieth in summer than it is in winter. But as no such variation is discernible, we may justly conclude the proportion between force and velocity to be as 1 to 1; that is, there is no difference. To illustrate this, suppose two bodies moving upon one straight line with equal velocities; by impelling one of them with a force which increases its original force, its relative velocity to the other body remains the same as if both had been primitively in a quiescent state. The space described by the body, in consequence of its original force, and of that which has been added to it, becomes equal to the sum of what each of them would have caused it to have been, described in the same time; therefore the force is proportional to the velocity.

This law, and that of *inertia* above alluded to, may be considered as derived from observation and experiment: they are simple and natural, and are sufficient to serve as a basis for the whole science of mechanics.

Early in the last century, a warm controversy arose relative to the measure of force, which was carried on with considerable acrimony, though it now appears that the question was rather about words than facts. Sir Isaac Newton had defined the measure of force to be "the mass of a body mutiplied into its velocity;" which definition was not only convenient for the philosophical investigation in which he was engaged; but was really mathematically just. But in another point of view, in which the effects of force may be said, without any impropriety, to depend on the mass multiplied into the square of the velocity, this product has been called the *vis viva*, and was considered by Bernouilli and Leibnitz as the true and universal measure of force, in opposition to Sir Isaac's definition; though it now appears that they were led into an error by not duly considering all the circumstances of the question at issue. The measure adopted by them, the *vis viva*, however, merits attention, as in all cases of practical machinery it is frequently the most accurate, and always the most useful; at the same time it implies no contradiction to the Newtonian definition. But the force thus measured ought to be distinguished by some appropriate name, *e. g.* the *vis mechanica;* the Newtonian measure being applied to the *vis motrix*, as suggested by Mr. Wollaston in the *Bakerian Lecture* for 1805.

Force, *Direction of*, the straight line which it tends to make a body describe.

Forces, *Composition of.* If two forces be conceived to act on a material point, it is evident that if they both act in the same direction, they will mutually increase each other's effect; but if they act in opposite directions, the point will move only in consequence of their difference, and it would remain at rest if the forces were equal. If the directions of the two forces make an angle with each other, the resulting force will take a mean direction; and it can be demonstrated geometrically, that if, reckoning from the point of intersection of the two directions of the forces, we take on these directions straight lines to represent them, and then form a parallelogram with such lines, its diagonal will represent their resulting force, both as to its direction and magnitude. The resulting force thus determined, which likewise represents the velocity of the moving point, may therefore be substituted as a force equivalent to the two component forces; and reciprocally, for any force whatever, we may substitute any two forces, which according to this rule would compose it. Hence we see that any force whatever may be decomposed into any two forces, parallel to two axes situated in the same plane, and perpendicular to each other. To effect this, it is only necessary to draw from the first extremity of the line representing the force, to other lines parallel to the axis, and to form with such lines a rectangle, whose diagonal will be the force required to be decomposed. The two sides of this rectangle, or parallelogram, will represent the forces into which the given force may be decomposed, parallel to such axis. If the force be inclined to a plane in position, a line in its direction may be taken to represent it, having one of its extremities on the surface of the plane, and the perpendicular falling from the other extremity will be the primitive force decomposed in the direction perpendicular to the plane. The straight line, which in the plane joins the other extremity of the line representing the force with the perpendicular (or the orthographic projection of the line of the plane) will represent the primitive force decomposed, parallel to the plane. This second partial force may itself be decomposed into two others, parallel to two axes in the same plane, perpendicular to each other. Thus we see that every force may be decomposed into three others, parallel to three axes perpendicular to each other; which axes are termed *rectangular co-ordinates.*

Hence we have a very simple mode of obtaining the resulting force of any number of forces supposed to act on a material point. This method was first adopted by Maclaurin, followed by La Grange, in the *Méchanique Analytique*, and also by La Place in the *Méchanique Céleste.* By decomposing each of these forces into three others, parallel to the given axes in position, and perpendicular to each other, we have all the forces parallel to the same axis reduced to one single force, which latter will be equal to the sum of the forces acting in the same direction, minus the sum of those acting in a contrary direction: so that the point will be acted on by three forces perpendicular to each other. From the point of intersection, or origin of the co-ordinates, take three right lines to represent them in each of their directions, and on such lines form a rectangular parallelopipedon, and the diagonal of this solid will represent the quantity and direction of the resulting force of all the forces acting on the point.

The principle of the composition of forces is of the most extensive utility in mechanics, and is in itself sufficient for determining the law of equilibrium in every case. Thus, if we successively compose all the forces, taking them by two's, and then take the result as a new force, we obtain one that is equivalent to all the rest, and which, in case of equilibrium, must equal 0, when the system under consideration has no fixed point; but if the conditions of the problem insist on an immoveable point, the resulting force must necessarily pass through it.

Though it is admitted by all writers on this subject, that the most abstruse propositions may be deduced from a few simple principles, yet few are found who entirely agree in their choice of such principles. The most advantageous, and indeed the most natural method, seems to be that wherein the relation between various forces in a state of equilibrium is first investigated, and then the consideration extended to a body in motion. If a body remain in equilibrium, at the same time that it is solicited by several forces, each force is supposed to produce only a tendency to motion, which is measured by the motion it would produce were it not checked by the power of the others: therefore, after expressing the effect of any one of the forces by unity, the relative force of the others may likewise be expressed by words or numbers.

La Place merely assumes the two foregoing principles, and speaks of them as experimental facts; while Dr. Young does not scruple to declare them capable of demonstration. (*See* his *Lectures.*) But this difference of opinion is of little importance, since the principles themselves are universally admitted.

La Grange has founded the whole doctrine of the equilibrium of forces on the well-known principle of the lever, the composition of motion, and the principle of virtual velocity; each of which we shall here notice.

The *principle of the lever* may be derived from the composition of forces, or even from much less complicated considerations.

Archimedes, the earliest author on record, who attempted to demonstrate the property of the lever, assumes the equilibrium of equal weights at equal distances from the fulcrum, as a mechanical axiom; and he reduces to this simple and primitive case that of unequal weights, by supposing them, when commensurable, to be divided into equal parts, placed at equal distances on different points of the lever, which may thus be loaded with a number of small equal weights, at equal distances from the fulcrum.

The principle of the straight and horizontal lever being admitted, the law of equilibrium in other machines may be deduced from it. Though it is not without difficulty that the inclined plane is referred to this principle; the laws relative to which have been but lately known.

Stevinus, mathematician to Prince Maurice of Nassau, first demonstrated the principle of the inclined plane by a very indirect, though curious mode of reasoning. He considers the case of a solid triangle resting on its horizontal base, whose sides then become two inclined planes: over these he supposes a chain to be thrown, consisting of small equal weights threaded together; the upper part of such chain resting on the two inclined planes, and the lower ends hanging at liberty below the foot of the base. His reasoning is, that if the chain be not in equilibrio, it will begin to slide along the plane, and would continue so to do, the same cause still existing, for ever; thus producing a perpetual motion. But as this implies a contradiction, we must conclude the chain to be in equilibrio; in which case, as the efforts of all the weights applied to one side would be an exact counterpoise to those applied to the other, and the number of weights would be in the same ratio as the lengths of the planes; he concludes that the weights will be in equilibrio on the inclined planes when they are to each other as the lengths of the planes; but that when the plane is vertical, the power is equal to the weight; and that therefore, in every inclined plane, the power is to the weight as the height of the plane to its length.

Virtual velocity is that which a body in equilibrium is disposed to receive whenever the equilibrium is disturbed; in other words, it is what a body actually receives in the first moment of its motion.

The principle of virtual velocity, in its most general form, is as follows: suppose a system in equilibrium composed of a number of points, drawn in any direction, by whatever forces, to be so put in motion, as that every point shall describe an infinitely small space, indicative of its virtual velocity; the sum of the forces being each multiplied by the space described by the point to which it is applied, in the direction of the force, will equal 0; the small spaces described in the direction of the forces being estimated as positive, and those in a contrary direction as negative. Galileo, in his *Treatise on Mechanical Science*, and in his *Dialogues*, proposes this principle as a general property in the equilibrium of machines; he appears to have been the first writer on mechanics, who was acquainted with it. His disciple Torricelli was the author of another principle, which seems to be but a necessary consequence of Galileo's. He supposes two weights to be so connected, that however placed, their centre of gravity shall neither rise nor fall; in every situation, therefore, they will be in equilibrio. He contents himself with applying this principle to inclined planes; but it equally applies to all machines.

Des Cartes deduced the equilibrium of different forces from a similar principle; but he presented it under another, and less general point of view, than Galileo had done; for he argues that to lift a given weight to a certain height, precisely the same force is requisite that would be sufficient to raise a heavier to a height proportionally less, or a lighter to a height proportionally greater; therefore two unequal weights will be in equilibrio, when the perpendicular spaces described by them are reciprocally proportioned to them. In the application of this principle, however, only the spaces described in the first instant of motion are to be considered; otherwise the accurate law of equilibrium will not be attained.

Another principle, recurred to by some authors in the solution of problems relative to the equilibrium of forces, arises out of the foregoing, *viz.* When a system of heavy bodies is in equilibrio, the centre of gravity is the lowest possible. For the centre of gravity of a body is the lowest, when the differential of its descent is 0, as can be demonstrated from the principle *de maximus et minimus;* that is, when the centre of gravity neither ascends nor descends by an infinitely small change in the position of the system.

J. Bernouilli first perceived the great utility of generalizing this principle of virtual velocity, and applied it to the solution of problems; in which he was followed by Varignon, who has devoted the whole of the ninth section of his *Nouvelle Mechanique* to demonstrate its truth and exemplify its utility in various cases in statics.

In the *Mémoires de l' Académie* for 1740, Maupertuis proposed another principle, originating in the same source, under the title of "The Law of Repose;" which was afterwards extended by Euler, and explained in the Memoirs of the Berlin Academy for 1751: and the principle assumed by Mons. Courtivron, in the *Mémoires de l' Académie* for 1748-9, is of the same nature: *viz.*, that of all the situations which a system of bodies can successively take, that wherein the system must be placed to remain in equilibrio, is that in which the *vis viva* is either a maximum or a minimum, because the *vis viva* is the sum of the respective masses composing the system, each multiplied into the square of its velocity.

Of all these methods, that of virtual velocity appears to be most generally useful; indeed all the others are derived from it, and are serviceable in proportion as they approach nearer to it. La Grange has given practical examples of the analytical processes for determining general formulæ or equations for the equilibrium of any system; and La Place has demonstrated the principle on which the calculus is founded.

In the foregoing observations, force is supposed to be the product of the mass of a material point, by the velocity it would receive if entirely free. By confining these considerations to the case of a single material point, the conditions of equilibrium will be found to be analogous to those above spoken of, but much simplified.

The most elementary equation to express the state of equilibrium of a material point, acted on by any number of forces, is, that every force, multiplied by the element of its direction, equals 0: thus, suppose the point to change its position in an infinitely small degree in any direction; then, in the case of equilibrium, if every force be multiplied by the elementary space approached to, or receded from by the point, the force being estimated in its direction, the product will be 0.

Here the point is supposed to be free; but if constrained to move on a curved surface, it will experience a reaction equal and contrary to the pressure which it exerts on such surface, but perpendicular to it, or in the direction of the radius of the curve. This reaction may be considered as a new force, which, multiplied by the elements of its direction, must be added to the former equation. But if the variation of position, instead of being taken arbitrarily, be taken upon the curve, so as not to alter the conditions of the problem, the preceding equation will still hold good, because the elementary variation of the radius is equal to 0, as is evident from inspection. Again, if the magnitude of any force, or its intensity, multiplied by the distance of its direction from any fixed point, be denominated its *moment*, relatively to such point, it will be found that the sum of the moments of the producing forces is always equal to that of the resulting force; and in case of equilibrium the sum of the moments of all the forces equals 0.

If the forces acting on a point, or on a system of points, be not so proportioned as to maintain the system in equilibrium, a motion must necessarily take place, the laws of which may be deduced from an extension of the principles laid down for investigating the state of equilibrium; a method pursued by La Grange, and after him by La Place. The former combines the principle of virtual velocities with that of D'Alembert, which is very simple, and, though long unobserved, may be considered as an axiom. It is as follows:

If several bodies have a tendency to motion, in directions, and with velocities, which they are constrained to change in consequence of their reciprocal reaction; the motion so induced may be considered as composed of two others, one of which the bodies actually assume, and the other such, that had the bodies been only acted upon by it, they would have remained in equilibrium. This theorem is not of itself sufficient to solve a problem, because it is always necessary to derive some condition relative to the equilibrium from other considerations; and the difficulty of determining the forces and the laws of their equilibrium, sometimes renders this application more difficult, and the process more tedious, than if the solution were performed upon some principle more complex and more indirect. To obviate this objection, therefore, La Grange attempted to combine the principle of D'Alembert with that of virtual velocity; in which he was so successful, that he was enabled to deduce the general equations relating to the forces acting on a system of bodies. His description of the method is as follows:

To form an accurate conception of the mode in which these principles are applied, it is necessary to recur to the general principle of virtual velocity, *viz.* When a system of material points, solicited by any force, is in equilibrium, if the system receive ever so small an alteration in its position, every point will naturally and consequently describe a small space; each of which spaces being multiplied by the sum of each force, according to the direction of such force, must equal 0.

Now, supposing the system to be in motion, the motion that each point makes in an instant may be considered as composed of two, one of them being that which the point acquires in the following instant; consequently, the other must be destroyed by the reciprocal action of the points or bodies upon each other, as well as of the moving forces by which they are solicited. There will therefore be an equilibrium between these forces and the pressures or resistances resulting from the motions lost by the bodies from one instant to another. Therefore, to extend to the motion of a system of bodies, the formulæ of its equilibrium, it is only necessary to add the terms due to the last-mentioned forces.

The decrement of the velocities, which every particle has in the direction of three fixed rectangular co-ordinates, represents the motions lost in those directions; and their increment represents such as are lost in the opposite directions. Therefore, the resulting pressures or forces of these motions destroyed will be generally expressed by the mass multiplied into the element of the velocity, divided by the element of the time; and their directions will be directly opposite to those of the velocities.

By these means the terms required may be analytically expressed, and a general formula obtained for the motion of a system of bodies, which will comprehend the solution of all the problems in dynamics; and a simple extension of it will give the necessary equations for each problem.

A great advantage derived from this formula is, that it gives directly a number of general equations, wherein are included the principles or theorems, known under the appellations of *conservation of the vis viva; conservation of the motion of the centre of gravity; conservation of equal areas;* and the *principle of the least action.*

Of these, the first, the *conservation of the vis viva*, was discovered by Huygens, though under a form somewhat different from that which we now give to it. As employed by him, it consisted in the equality between the ascent and descent of the centre of gravity of several weighty bodies, which descend together, and then ascend separately by the force they had respectively acquired. But by the known properties of the centre of gravity, the space it describes in any direction is expressed by the sum of the products of the mass of each body by the space such body has described in the same direction, divided by the sum of the masses. Galileo, on the other hand, has shown in his problems, that the vertical space described by a weighty body in its descent is proportional to the square of the velocity acquired, and by which it will reascend to its former elevation. The principle of Huygens is therefore reduced to this; that in the motion of a system of bodies, the sum of the masses by the squares of the velocities is constantly the same, whether the bodies descend conjointly, or whether they freely descend separately through the same vertical channel.

This principle had been considered only as a simple theorem of mechanics, till J. Bernouilli adopted the distinction, established by Leibnitz, between such pressures as act without producing actual motion, and the living forces, as they were termed, which produced motion; as likewise the measures of these forces by the products of the masses by the squares of the velocities. Bernouilli saw nothing in this principle but a consequence of the theory of the *vis viva*, and a general law of nature, in consequence of which, the sum of the *vis viva* of several bodies preserves itself the same, as long as they continue to act upon each other by simple pressures, and is always equal to the simple *vis viva*, resulting from the action of the forces by which the body is really moved. To this principle he gave the name of *conservatio vivium vivarum*, and successfully employed it in the solution of several problems that had not before been effected.

From this same principle, his son, D. Bernouilli, deduced the law of the motion of fluids in vases, which he explains in the *Berlin Memoirs* for 1748: a subject before but little understood.

The advantage of this principle consists in its affording immediately an equation between the velocities of the bodies and the variable quantities which determine their position in space; so that when by the nature of the problem these variable quantities are reduced to one, the equation is of itself sufficient for its solution, as in the instance of the problem relating to the centre of oscillation. In general, the conservation of the *vis viva* gives a first integral of the several differential equations of each problem, which is often of great utility.

The second principle above alluded to, *conservation of the motion of the centre of gravity*, is given by Sir Isaac Newton in his *Principia*, as an elementary proposition; where he demonstrates, that the state of repose or of motion of the centre of gravity of several bodies, is not altered by the reciprocal action of these bodies, in any manner whatever: so that the centre of gravity of bodies acting upon each other, either by means of cords or of levers, or by the laws of attraction, remains always in repose, or move uniformly in a direct line, unless disturbed by some exterior action or obstacle. This theorem has been extended by D'Alembert, who has demonstrated, that if every body in the system be solicited by a constant accelerating force, either acting in parallel lines, or directed towards a fixed point, but varying with the distance, the centre of gravity will describe a similar curve to what it would have done, had the bodies been free. And, it might be added, the motion of this centre will be the same as if all the forces of the bodies were applied to it, each in its proper direction. This principle serves to determine the motion of the centre of gravity, independently of the respective motions of the bodies; and thus it will ever afford three finite equations between the co-ordinates of the bodies and the times; and these equations will be the integrals of the differential equations of the problem.

The third principle, the *conservation of equal areas*, is more modern than the two former, and appears to have been separately discovered by Euler, D. Bernouilli, and D'Arcy, about the same period, though under different forms.

Euler and Bernouilli describe the principle thus: In the motion of several bodies round a fixed centre, the sum of the products of the mass of each body by the velocity of rotation round the centre, and by its distance from the same centre, is always independent of any mutual action exerted by the bodies upon each other, and preserves itself the same as long as there is no exterior action or obstacle. Such is the principle described by D. Bernouilli in the first volume of the *Memoirs of the Berlin Academy*, 1746; and by D'Alembert, in the same year, in his *Opuscula*. The Chevalier D'Arcy, also in the same year, sent his Memoir to the Academy of Paris, though it was not printed till 1752, wherein he says, "The sum of the products of the mass of each body by the area traced by its radius vector about a fixed point, is always proportional to the times."

This principle, however, is only a generalization of Sir Isaac's theorem of equality of areas described by centripetal forces: and to perceive its analogy, or rather its identity with that of Euler and Bernouilli, it is only requisite to recollect, that the velocity of rotation is expressed by the element of the circular arc divided by that of the time; and that the first of these elements multiplied by the distance from the centre, gives the element of the area described about it. It appears then that this latter principle is only the differential expression of that of the Chevalier, who afterwards gave the same principle in another form, which renders it more similar to the preceding, viz. The sum of the products of the masses by the velocities, and by the perpendiculars drawn from the centre to the direction of the forces, is always a constant quantity. Under this point of view, M. D'Arcy set up a kind of metaphysical principle, which he denominates the *conservation of action*, in opposition to, or rather as a substitute for, the principle of the least action.

But leaving these vague and arbitrary denominations, which neither constitute the essence of the laws of nature, nor are able to raise the simple results of the known laws of mechanics to the rank of final causes, let us return to the principle in question, which takes place in every system of bodies acting on each other in any manner whatever, whether by means of cords, inflexible lines, attractions, &c., and also drawn by forces directed to a centre, whether the system be entirely free, or constrained to move about it. The sum of the products of the masses by the areas described about this centre, and projected on any plane, is always proportional to the time; so that by referring these areas to three rectangular planes, we obtain three differential equations of the first order, between the time and the co-ordinates of the curves described by the bodies; and in these equations, the nature of the principle properly exists.

The fourth principle, that *of the least action*, was so denominated by Maupertuis, and has since been rendered celebrated by the writings of several illustrious authors. Analytically it is as follows: In the motion of bodies acting upon each other, the sum of the products of the masses by the velocities, and by the spaces described, is a minimum. Maupertuis has published two memoirs on this principle; one in the *Transactions of the Academy of Sciences*, for 1744; the other, in those of the Academy of Berlin, 1746; wherein he deduces from it, the laws of reflection and refraction of light, and those of the shock of bodies. It appears, however, that these applications are not only too partial for establishing the truth of a general principle, but they are in themselves too vague and arbitrary; so that the consequences attempted to be deduced become uncertain: this principle, therefore, deserves not to be classed with the three foregoing. There is, however, one point of view, in which it may be considered as more general and exact, and which alone merits the attention of geometricians. Euler first suggested the idea at the close of his *Treatise on Isoperimetrical Problems*, published at Lausanne, in 1744, wherein he shows that in trajectories described by central forces, the integral of the velocity multiplied by the element of the curve is constantly either a maximum or a minimum; but he knew of this property only as pertaining to insulated bodies. La Grange extended it to the motion of a system of bodies acting on each other, and demonstrated a new general principle, viz. That the sum of the products of the masses by the integrals of the velocities multiplied by the elements of the spaces described, is always a maximum or a minimum.

From a combination of this latter principle with that of the conservation of the *vis viva*, many difficult problems in dynamics may be solved; as exemplified by La Grange in the *Memoirs of the Academy of Turin*, vol. ii.

La Place, in the *Méchanique Céleste*, treats the doctrine of dynamics much in the same manner as La Grange, but he carries his investigations much farther. He agrees with that writer in adopting the principle of D'Alembert, and in resolving every motion into two; that which the particle had in the preceding instant, and that which would have maintained it in equilibrio: but he differs from him in not admitting the principle of virtual velocity to be assumed as a fundamental axiom; which he demonstrates by a regular train of inductions.

After having established nearly the same formulæ, or differential equations, and deduced all the general principles in the manner just described, he introduces others in the nature of corollaries, many of which merit peculiar consideration. From the principle of the conservation of areas, it follows, that in the motion of a system of bodies solicited only by their mutual attraction and by forces directed to the origin of the co-ordinates, there exists a plane passing through such origin, which possesses the following remarkable properties:

1. That the sum of the areas traced on the plane by the projections of the *radii vectores* of the bodies, and multiplied by their respective masses, will be the greatest possible.

2. That such sum is also equal 0 upon all the planes perpendicular to it.

As the principle of the *vis viva*, and that of areas, subsist relatively to the centre of gravity, even though the latter be supposed to have a rectilinear uniform motion, it follows, that a plane may be determined as passing through this moveable origin, on which the sum of the areas, described by the projections of the radii vectores, and multiplied respectively by their masses, may be the greatest possible. This plane being parallel to the one passing through the fixed origin, satisfies the same conditions; and another plane passing through the centre of gravity, and determined according to the foregoing conditions, will remain parallel to itself during the motion of the system; a circumstance of considerable utility and importance. To this we may add, that any plane parallel to the last-mentioned, and passing through any of the bodies, partakes of analogous properties.

La Place next examines how far these results would be changed, if other relations subsisted between the force and the velocity. Force, he observes, may be expressed in a great variety of ways relatively to the velocity, besides that of the simple law of proportionality, without implying any mathematical contradiction. Suppose the force to be some other function of the velocity, (analytically expressed by $F = \phi\, v$;) in this case the principle of the *vis viva* will be found to obtain in all the possible mathematical relations between the force and the velocity; the *vis viva* of a body being the product of its mass by double the integral of its velocity, multiplied by the differential of the function of the velocity indicative of the force.

The uniform rectilinear motion of the centre of gravity is preserved by the law of nature alone; by which also the conservation of areas subsists. But a principle analogous to that of the least action will be found to belong to every possible relation between force and velocity.

The principle of the least action is not so obvious as the others that have been mentioned, being more remote from the elementary theorems, from which they are all derived; nevertheless, if it be directly and mathematically deducible from the same simple principles, it must immediately be divested of all pretension to the dignity of a final cause; to which it can have no greater claim than any other remarkable numerical property; for the reverse would imply a mathematical contradiction. The fact, which is curious, may be thus analytically stated: Suppose a material point to move under the impulse of several forces from one point to another; the curve which it describes possesses the remarkable property of having the integral or continued product of the velocity (determined by previous considerations) when multiplied into the element of the curve, less than any other curve passing through the same points.

Maupertuis, who discovered this principle, carried it no further than to single bodies; Euler established its generality; and La Grange extended it to a system of bodies acting on each other, as already noticed. The principle of the least action being therefore admitted as an established theorem, it may be resorted to for the solution of problems, and for determining the trajectories of bodies moving in space; but in point of practical utility, the necessary calculations are so much more complex and difficult than the more usual methods of investigation, that the latter are greatly to be preferred to it.

Upon these leading principles of the doctrine of forces, as laid down by the most eminent writers on the subject, it is to be remarked, that they are for the most part mere developments of theorems easily deducible from the Newtonian laws of motion; and that many of them were even established by Newton himself. This generalization of mechanical principles possesses, however, the advantage of enabling us to take a more enlarged and comprehensive view of the subject, than we could do by the consideration of a single problem.

Forces, which become the subject of mathematical computation, may be appropriately divided into the three following classes:

1. Such as act instantaneously, or for a short interval of time, and impart uniform motion to a particle subjected to their action; provided it be not solicited by any force, and is free to move in any direction.

2. Such as, acting with a continued uniform intensity, oblige a material particle, at liberty to obey their impulse, to describe its path with a uniformly accelerated motion.

3. Those, whose intensities, perpetually varying, though according to some known law, produce a complicated action, whose circumstances can only be investigated by means of the integral calculus, or some analogous methods.

Forces whose mode of action is too arbitrary and uncertain to be included in either of these classes, may be considered as foreign to the present investigation.

The reader who wishes to have more scientific information on this subject, may refer to Gregory's Mechanics; Dr. Jackson's Theoretical Mechanics; and may also consult Marat's Mechanics, Wood's Mechanics, or Whewell's Mechanics. Professor Leslie also, (in his Elements of Natural Philosophy,) has given an excellent popular illustration, by supposing the threads to act on light spiral springs adapted to measure the forces, and commonly called spring steel-yards; but he acknowledges pulleys and weights have some advantages. By reversing the action of the springs, they might be applied, with much advantage, to show the relations of compressing forces, by lecturers on mechanical science.

Force, *Mechanical*. Desaguliers, in his *Experimental Philosophy*, has many curious and useful observations concerning the comparative forces of men and horses, and the best mode of applying them. And Dr. Young, in his *Lectures*, has given a table of a similar nature, compiled chiefly from the writings of Desaguliers and Coulomb, another writer, who has also displayed considerable ingenuity in pursuing the subject. The following extract cannot fail of being useful to all concerned in practical mechanics.

In his introduction to his Table, Dr. Young observes, that to compare the different estimates of moving power, it will be convenient to take an unit as the mean effect of the labour of an active man, and without impediment. This will be found, on a moderate estimation, sufficient to raise 10lb. to the height of 10 feet in a second, for 10 hours in a day; or to raise 100lb., which is the weight of twelve wine gallons of water, 1 foot in a second, or 36,000 feet in a day; or 3,600,000lb., or 432,000 gallons, 1 foot in a day. This we may call a force of 1 continued 36,000."

"*Immediate Force of Men without Deduction for Friction.*

	Force.	Continuation.	Days' Work.
A man, weighing 133lb. (French) ascended 62 feet (French) by steps in 34″, but was completely exhausted. *Amontons*......	2.8	34″	
A sawyer made 200 strokes of 18 inches (French) each, in 145″, with a force of 25lb. (French). He could not have gone on above 3 minutes. *Amontons*........	6.	145″	
A man can raise 60lb. (French) 1 foot (French) in 1″, for 8 hrs. a day. *Bernouilli.*	69.	8h	.552
A man of ordinary strength can turn a winch with a force of 30lb. and with a velocity of $3\frac{1}{2}$ feet in 1″, for ten hours a day. *Desaguliers*........................	1.05	10h	1.05
Two men working at a windlass, with handles at right angles, can raise 70lb. more easily than one can raise 30lb. *Desaguliers.*	1.22		1.22
A man can exert a force of 40lb. for a whole day, with the assistance of a fly, when the motion is pretty quick, as about 4 or 5 feet in 1″. *Desaguliers.* Lect. IV. But from the annotation, it appears doubtful whether the force be 40lb. or 20lb......	2.		.2
For a short time a man may exert a force of 80lb. with a fly, "when the motion is pretty quick." *Desaguliers*............	3.	1″	
A man going up stairs, ascends 14 metres in 1′. *Coulomb*......................	1.182	1	
A man going up stairs for a day, raises 205 kilogrammes to the height of a kilometre. *Coulomb*..................			.412
With a spade a man does $\frac{13}{20}$ as much as in ascending stairs. *Coulomb*.............			.391
With a winch a man does $\frac{5}{8}$ as much as in ascending a stairs. *Coul*..............			.258
A man carrying wood up stairs, raises, together with his own weight, 109 kilogrammes to one kilometre. *Coulomb*....			219.
A man weighing 150lb. (French) can ascend by stairs 3 feet (French) in 1″ for 15″ or 20″. *Coulomb*.....................	5.22	20″	
For half an hour, 100lb. (French) may be raised 1 foot (French) in 1″. *Coulomb*..	1.152	30′	
According to Mr. *Buchanan's* comparison, the force exerted in turning a winch being made equal to the unit, the force in pumping will be........................	.61		
In ringing..........................	1.36		
In rowing...........................	1.43		
Allowing the accuracy of *Euler's* force, confirmed by *Schulze*, supposing a man's action to be a maximum when he walks $2\frac{1}{2}$ miles an hour, we have $7\frac{1}{2}$ for his greatest velocity, .04 $(7\frac{1}{2}-v)^2$ for the force exerted with any other velocity, and .0160 $(7\frac{1}{2}-v)^2$ for the action in each case: thus, when the velocity is one mile an hour, the action is.......................	.676		
When two miles......................	.964		
Three...............................	.972		
Four................................	.784		
And when five.......................	.5		

"And the force in a state of rest becomes $2\frac{1}{4}$, or about 70lb.; with a velocity of two miles, 36lb.; with three, 24lb.; and with four, 15lb.

"It is obvious, that in the extreme cases this formula is inaccurate, but for moderate velocities, it is probably a tolerable approximation.

"Coulomb makes the maximum of effect when a man, weighing 70 kilogrammes, carries a weight of 53lb. up stairs; but this appears to be too great a load; he considers 145 kilogrammes as the greatest weight that can be raised. He observes, that in Martinique, where the thermometer is seldom below 68°, the labour of Europeans is reduced to one half.

"Harriot asserts that his pump, with a horizontal motion, enables a man to do one-third more work than the common pump, with a vertical motion.

"Porters carry from 200lb. to 300lb. at the rate of three miles an hour; chairmen walk four miles an hour with a load of 150lb. each; and it is said that in Turkey, there are porters, who, by stooping forward, carry from 700 to 900lb. placed very low on their backs.

"The most advantageous weight for a man of common strength to carry horizontally, is 112lb.; or, if he returns unladen, 135lb. With wheel-barrows, men will do half as much more work as with hods. *Coulomb.*

"*Performance of Men by Machines.*

	Force.	Continuation.	Days' Work.
A man raised by a rope and pulley, 25lb. (French) 220 feet (French) in 145″. *Amontons*........................	.436	145	
A man can raise, by a good common pump, a hogshead of water 10 feet high in 1′, for a whole day. *Desaguliers*............	.875		.875
By the mercurial pump, or another good pump, a man may raise a hogshead 18 or 20 feet in 1′, for 1 or 2 minutes........	1.61	1′	
In a pile engine, $55\frac{1}{2}$lb. (French) were raised 1 foot (French) in 1″, for 5 hours a day, by a rope drawn horizontally. *Coulomb*....	.64	5h	.82
Robison says, that a feeble old man raised 7 cubic feet of water $11\frac{1}{2}$ feet in 1′, for 8 or 10 hours a day, by walking backwards and forwards on a lever. *Enc. Br*......	.837	9h	.753
A young man, weighing 135lb. and carrying 30lb. raised $9\frac{1}{2}$ cubic feet $11\frac{1}{2}$ feet high, for 10 hours a day, without fatigue. *Robison*..........................	1.106	10h	1.106
Wynne's machine enables a man to raise a hogshead 20 feet in 1 minute. *Young*..	1.75	1′	

"*Force of Horses.*

	Force.	Continuation.	Days' Work.
Two horses attached to a plough on moderate ground, exerted each a force of 150 (French.) *Amontons.* We may suppose that they went a little more than two miles an hour for 8 hours.................	5.4	8′	4.32
A horse draws with the greatest advantage when the line of direction is level with his breast; and he can draw with a force of 200lb. $2\frac{1}{2}$ miles an hour, for 8 hours in the day..........................	7.33	8h	5.87
With a force of 240, only 6 hours. On a carriage, indeed, where friction alone is to be overcome, a middling horse will draw 1000lb. *Desaguliers*................	8.8	6h	5.28
The mean draught of four horses was 36 myriogrammes each, or 794lb. *Regnier.* This must have been momentary. Supposing the velocity 2 feet in 1″, the action would have been...................	15.88	1″	
By means of pumps, a horse can raise 250 hogsheads of water 10 feet high, in an hour. *Smeaton's Reports*............	3.64	1h	

"A horse can in general draw no more up a steep hill than three men can carry, that is, from 450lb. to 750lb.; but a strong horse can draw 2000lb. up a steep hill, that is but short. The worst way of applying the force of a horse, is to make him carry or draw up-hill; for, if the hill be steep, three men will do more than a horse, each man climbing up faster with a burden of 100lb. weight, than a horse that is loaded with 300lb., a difference arising from the position of the parts of the human body being better adapted to climbing than those of a horse.

"On the other hand, the best way of applying the force of a horse, is in an horizontal direction, wherein a man can exert least force: thus a man, weighing 140lb., and drawing a boat along by means of a rope coming over his shoulders, cannot draw above 27lb., or exert above one-seventh part of the force of a horse employed to the same purpose.

"The very best and most effectual posture in a man, is that of rowing; wherein he not only acts with more muscles at once for overcoming the resistance, than in any other position; but as he pulls backwards, the weight of his body assists by way of lever.—*Desaguliers.*

"The diameter of a walk for a horse-mill, ought to be at least 25 or 30 feet.—*Desaguliers.*

"Some horses have carried 650lb. or 700lb. seven or eight miles without resting, as their ordinary work; and a horse at Stourbridge carried 11cwt. of iron, or 1232lb. for eight miles.—*Desaguliers, Exp. Philos.* vol. i.

"*Work of Mules.*	Force.	Continuation.	Day's Work.
Cazanel says, that a mule works in the West Indies two hours, out of about 18, with a force of about 150lb. walking 3 feet in a second..................	4.4	$2^h\ 40'$	1.2

Force, *Inanimate.* "According to M. Coulomb, a windmill with four sails, measuring 66 feet (French) from one extremity to that of the opposite sail, and 6 feet wide, or a little more, is capable of raising 1000lb. (French) 218 feet in 1′ and of working on an average 8 hours in a day. This is equivalent to the work of 34 men, as it has been above estimated, 25 square feet of canvass performing about the daily work of a man.

"Robison says, that 1 cwt. of coals burned in a steam-engine will raise at least 20,000 cubic feet of water 24 feet high; this is equivalent to the daily labour of 8.32 men. A steam-engine in London, with a 24-inch cylinder, does the work of 72 horses, and consumes a chaldron of coals in a day; each bushel being equivalent to two horses, and each square inch of the cylinder performing nearly the work of a man.

"If we calculate the quantity of motion produced by gunpowder, we shall find that this agent, though extremely convenient, is far more expensive than human labour; but the advantage of gunpowder consists in the great rarity of the acting substance. A spring or a bow can only act with a moderate velocity, on account of its own weight. The air of the atmosphere, however compressed, could not flow into a vacuum with a velocity so great as 1,500 feet in a second. Hydrogen gas might move more rapidly, but the elastic substance produced by gunpowder is capable of propelling a very heavy cannon-ball with much greater velocity.

"It is said, that nine tons of water, falling 10 feet, will grind and dress a bushel of wheat; consequently a man might do the same in 33′ 36″."

FORE-FRONT, the principal or front entrance of a building.

FORE-GROUND, that part of the field of a picture which is nearest the observer.

FORE-PLANE, in carpentry and joinery, the first plane used after the saw or axe. See Tools.

FORE-SHORTEN, in perspective, the diminution which the representation of the side or part of a body has in one of its dimensions, compared with the other, occasioned by the obliquity of the corresponding side or part of the original body to the plane of projection.

FOREYN, an ancient term signifying a cesspool or drain.

FORGE, a smith's furnace.

FORM (from the Latin, *forma*) the external appearance, or the disposition of the surfaces of a body; in which sense it is synonymous with Figure, which see.

Form, in joinery, the long seats or benches in the choirs of churches, for the priests, canons, prebendaries, &c. to sit on. Du Cange supposes the name derived from the backs of the seats being anciently enriched with figures of painting and sculpture, called in Latin *formæ et typi.*

FORMERETS, (from the French) the arches which are next the wall in Gothic groins; these are only half the thickness of those that divide the vault into compartments.

FORM-PIECES, the lower ends of the mullions of windows which are worked upon the sills. The same as Stool-pieces.

FORT, (Latin, *fortis* strong) a fortified building; a building strengthened by artificial means. The term is usually applied to small detached buildings.

FORTALICE, a small castle.

FORNIX, (Latin) an arch or vault. *See* Arch, and Vault.

FORUM, (Latin) in Roman antiquity, the market-place for transacting the business of the public revenue, bankers, merchants, &c. The following description of it is given by Vitruvius:

"The Greeks made their forums square, with large double porticos, the columns close together, and adorned with stone or marble epistyliums, making ambulatories in the upper stories: but the cities of Italy follow not the same method; because, by ancient custom, the shows of gladiators are usually given in the forum. For this reason the intercolumns around the area are made wider; and in the surrounding porticos the shops of the bankers are disposed, with galleries in the upper floors, properly adapted for the use and management of the public revenue.

"The magnitude of the forum should be suitable to the number of the people, that it may not be too small for use, nor on account of the scarcity of people, appear too large. The proportion is so determined, that the length being divided into three parts, two are given to the breadth; for thus it will be of an oblong form, and convenient for the use of the shows.

"The upper columns are made a fourth part less than the lower; because, as the inferior sustains the greater weight, it should be stronger than the superior: also because it is proper to imitate nature; for in straight-growing trees, such as the fir, cypress, and pine, there are none thicker at the top than at the root; and as they grow in height, they gradually diminish to the uppermost point. Following therefore the example of nature, it is proper that the superior should be made less than the inferior, both in height and thickness.

"The basilica should be joined to the forum on the warmest side, that the negociants may confer together, without being incommoded by the weather. The breadth is not made less than the third, nor more than the half of the length, unless the

the nature of the place opposes the proportion, and obliges the symmetry to be different. But if the basilica have too much length, chalcidicæ are made at the ends, as they are in the basilica of Julia Aquiliana. The columns of the basilica are made as high as the porticus is broad. The porticus is the third part of the space in the middle. The upper columns are less than the lower, as above written. The pluteum, which is between the upper columns, should also be made a fourth part less than the same columns, that those who walk in the floor above may not be seen by the negociators below. The epistylium, zophorus, and coronæ, are proportioned to the columns in the manner explained in the third book.

"Nor will basilicas of the kind of that at the colony of Julia of Fanum, which I designed and conducted, have less dignity and beauty; the proportions and symmetry of which are as follow: The middle testudo between the columns is 120 feet long, and 60 feet broad. The porticus around the testudo, between the walls and columns, is 20 feet broad. The height of the continued columns, including their capitals, is 50 feet, and the thickness 5, having behind them parastatæ 20 feet high, $2\frac{1}{2}$ feet broad, and $1\frac{1}{2}$ foot thick, which sustain the beams that bear the floors of the porticos. Above these are other parastatæ 18 feet high, 2 feet broad, and 1 foot thick, which also receives beams sustaining the canthers of the porticos, which are laid below the roof of the testudo: the remaining space that is left between the beams which lie over the parastatæ, and those which lie over the columns, is left open in the intercolumns, in order to give light. The columns in the breadth of the testudo, including those of the angles to the right and left, are four; and in the length, on that side which is next the forum, including the same angle-columns, eight. On the other side, there are but six columns, including those of the angles, because the middle two on this side are omitted, that they may not obstruct the view of the pronaos of the temple of Augustus, which is situated in the middle of the side-wall of the basilica, looking towards the centre of the forum and temple of Jupiter. The tribunal in this building is formed in the figure of a hemicycle: the extent of this hemicycle in front is 46 feet, and the recess of the curvature inward 15 feet, so that those who attend the magistrate obstruct not the negociants in the basilica.

"Upon the columns, the compacted beams, made from three timbers of two feet are placed around; and those from the third columns which are in the interior part, are returned to the antæ that project from the pronaos, and on the right and left touch the hemicycle.

"Upon the beams, perpendicularly to the capitals, the pilæ are placed, three feet high and four feet broad, on every side. Over these, other beams, well wrought from two timbers, of two feet, are placed around; upon which, the transtræ and capreols, being placed coincident with the zophorus, antæ, and walls of the pronaos, sustain one culmen the whole length of the basilica, and another transversely from the middle over the pronaos of the temple: so that it causes a double disposition of the fastigium, and gives a handsome appearance to the roof on the outside, and to the lofty testudo within. Also, the omission of the ornaments of the epistylium, and of the upper columns and plutei, diminishes the labour of the work, and saves great part of the expense. The columns likewise being carried in one continued height up to the beams of the testudo, increases the magnificence and dignity of the work."

Forum is also used for any place in which the governor of a province convened the people, to give judgment according to the course of the law.

Forum also meant a public standing-place in the city of Rome, where causes were judicially tried, and orations delivered to the people.

The Roman foræ were of two kinds—Fora Civilia and Venalia; the former were for law and political affairs, the latter for the purposes of trade. Of the Fora Civilia, there were at first only three, viz., Romanum, Julianum, and Augustum; but their number was afterwards increased to six, by the addition of the transitorium, called also palladium, the Trajanum, and Salusti.

The first and most eminent of these was the *forum Romanum*, called also *forum vetus*. In the time of Romulus, this forum was only a large open space, without buildings or other ornament. It was first enclosed by Hostilius, adorned with porticos by Tarquin the Elder, and at length, by the additions of succeeding kings, consuls, and magistrates, it became one of the most elegant and noble places in the world. It was called *forum Romanum*, or simply *forum*, by way of eminence, on account of its antiquity, in comparison with the other fora, and from its more general use in public affairs. It was also called *forum Latinum*, *forum magnum*, and *old forum*. The comitium, used sometimes for holding the comitia, was a part of this forum, in which stood the *rostrum*, a sort of pulpit, adorned with the beaks of ships taken in a sea-fight from the inhabitants of Antium. In this the causes were pleaded, orations were made, and panegyrics were delivered on the merits of the dead.

A very beautiful restored view of the Forum Romanum was made by Mr. C. R. Cockerell, and a reduced view was engraved and published, with his permission, in the second volume of the "Pompeii," published by the Society for the Diffusion of Useful Knowledge, to which we refer our readers for an accurate notion of the splendour of the accumulated architecture of the Forum and the Capitol, and its vicinity.

The Julian forum, called also *Cæsar's forum*, was built by Julius Cæsar with the spoils taken in the Gallic war. Its area alone, according to Suetonius, cost 100,000 sesterces; and Dio affirms, that it much exceeded the Roman forum.

Augustus's forum, built by Octavius Cæsar, was reckoned by Pliny among the wonders of the city. The most remarkable curiosity it presented was the statues in the two porticos on each side of the main building. In one were all the Latin kings, beginning with Æneas. In the other, all the kings of Rome, beginning with Romulus; most of the eminent persons in the commonwealth, and Augustus himself among the rest, with an inscription upon the pedestal of every statue, descriptive of the chief actions and exploits of the person it represented. This forum was restored by the emperor Adrian.

Nerva's forum was begun by Domitian, but finished and named by the emperor Nerva. In this forum Alexander Severus set up the statues of such of the emperors as had been deified, in imitation of what Augustus had done in his forum. This forum was called *transitorium*, because it lay very convenient as a passage to the others, and *palladium*, from a statue of Minerva which was set up in it. Scarcely anything remains of this forum except a decayed arch, which the Italians, by a strange corruption, call *Noah's ark*, instead of *Nerva's arch*.

Trajan's forum was built by the emperor Trajan with the produce of the spoils taken in his wars. The porticos, which were exceedingly beautiful and magnificent, were covered with brass, and supported by pillars of more than ordinary size, and of exquisite workmanship.

The forum of Pompeii, which was constructed in the Greek style, cannot, however, be altogether considered, if we are guided by the authority of Vitruvius, a truly Greek

Agora, which this author states was to be made square in form. It has, however, many Greek features. The Pompeian forum is of an oblong shape, surrounded on three sides with rows of columns, forming, with the advanced columns of the various buildings, a colonnade or ambulatory ; above this there was a second, if we may judge from the remains of stairs at several places at the back of the colonnade. The fourth side of the forum is enclosed with two arches placed on each side of a large hypætral temple, called the temple of Jupiter. On the west side are the prisons and the granary, before these, and the temple of Venus, and the Basilica, is an enclosed court. On the narrow side, opposite the temple of Jupiter, are three buildings, generally considered to be the Curiæ and Ærarium. On the east side is an enclosure, (the use of which has not been determined,) the Chalcidicum, the temple of Mercury, the Senaculum, and a building supposed to be a large eating-house, generally known by the name of the Pantheon, in front of which are the Tabernæ Argentariæ. The enclosed area of the forum was paved with large square pieces of marble, and the sides of the area were adorned with statues. Opposite the Curiæ, and a short way from them, is a small triumphal arch. The forum was closed at night with iron-barred gates, and it does not appear that chariots were admitted into it, as the pavement of the streets terminates at the back of the colonnade. The columns of the ambulatory are of the Greek Doric order, and were being restored in the same style, though with better materials, at the time the city was destroyed. The columns were aræostyle, and the architraves were most probably of wood, as we may infer from their being destroyed, while the frieze and cornice of stone remain.

The forum of Constantinople was erected by Constantine when he established the city on the commanding eminence of the second hill, where he pitched his tent during the siege and conquest of Byzantium. The edifice was of an elliptic form ; the two opposite entrances formed triumphal arches ; the porticos on every side were filled with statues, and the centre of the edifice was occupied by a lofty column, of which only a mutilated fragment is now left, and is degraded by the appellation of *the burnt pillar*. This column was erected on a pedestal of white marble, 20 feet high. It was composed of 10 pieces of porphyry, each of which measured about 10 feet in height, and about 33 in circumference. On the summit of the pillar, above 120 feet from the ground, stood a colossal statue of Apollo, of bronze, which had been transported hither from Athens, or from the town of Phrygia, and was supposed to be the work of Phidias. The artist had represented the god of day, or, as it was afterwards interpreted, the emperor Constantine himself, with a sceptre in his right hand, the globe of the world in his left, and a crown of rays glittering on his head. This statue was thrown down in the reign of Alexis Comnenus.

FOSSE, a trench or ditch excavated round a fortified place, to secure it from attack.

FOSSES D'AISANCES, a term used to designate the cesspools of Paris. These cesspools are constructed of materials sufficiently impermeable to filtration, so that the matter contained in them shall not penetrate through the walls, to the injury of the adjoining property. So strictly is this condition observed, that any infiltration to a neighbour's premises, according to the French law, gives a title to damages, and the architect and builder are held responsible for ten years, not only to the proprietor, but also to the neighbours, should any nuisance arise from imperfect execution of the work.

The *Fosses d'Aisances* are usually made about 10 feet long by about 5 feet 7 inches wide, and 5 feet in height to the springing of the semi-circular head. The material employed in their construction, has of late years been *meulière* or mill-stone, bedded in mortar made of lime and cement ; the inside being well pointed, and rendered throughout with the same. These cesspools are cleansed out when necessary, under the inspection and by the authority of the board of health of the city ; the carts employed, as well as all the *materiel* of the nightmen, being under the same surveillance. The work is done between ten o'clock at night and six o'clock in the morning. The contents of the cesspools are generally sufficiently fluid to allow of their extraction by pumps ; but when this is not the case, they are conveyed from below in small iron vessels ; and great care is taken to prevent, as much as possible, the escape of the noxious effluvia during the operations. When the soil is pumped into carts, a small furnace is placed over the bung-hole of the cart, to burn the gas as it rises ; and directly the cart is filled, the bung is plastered over. The lids of the vessels used to remove the more solid matter, are also plastered over in a similar manner, before they are brought out of the cesspools. For a fuller description of the Fosses d'Aisances, *see* SEWER, SEWERAGE.

FOUNDATION, (from the French) the trench or trenches excavated in the ground, in order to rest an edifice firmly upon its base. The word also means the superstructure of a stone or brick wall under the lowest floor of a building, contained within the trenches.

Foundations, according to Palladio, ought to be twice as thick as the walls to be raised upon them, so that both the quality of the earth and the greatness of the building are to be regarded, making the foundation larger in a soft and loose ground, or where there is a great weight to be supported. The plane of the trench must be as level as possible, so that the weight may press equally, and not incline more on one side than the other. For this reason the ancients were accustomed to pave the plane with Tivertine ; but the moderns most commonly lay planks or beams to build on. The foundations ought to diminish in width as they rise ; but in such a manner that the middle of the wall above may fall plumb with the middle of the lowest part ; this must also be observed in the diminution of walls above ground, because by that means the building becomes much stronger than by making the diminution any other way.

The various methods of treating the building of a foundation, according to the heterogeneous texture or uniformity of the ground, as may happen in the excavation, will be found under BRICKLAYING. Under the same head also will be found ample directions for making a foundation of CONCRETE, as now so generally used by builders. But should the foundation prove unsound, or of that character that dependence cannot be placed upon it, recourse must be had to piling, in the following manner. Good sound piles must be prepared, of such dimensions, that their thickness may be about a twelfth part of their length ; the distances at which those piles should be disposed, and the momentum requisite to drive them, will depend on the nature of the building to be erected ; and the weight they will have to bear ; the weight of the ram ought not to be more than sufficient for driving the piles, as the heavier the ram, the greater the number of men required to work it, and consequently the greater the expense. When the piling is completed, so as to be sufficient for supporting the intended structure, some builders lay a level row of cross bearers, called *sleepers*, ram the interstices with stone or brick up to the level of their faces, and then plank them over. This planking, however, may be dispensed with, if the piling be sufficiently attended to, and the expense of the foundation will thus be materially lessened. Timber should not be used with its thickness standing vertical, as it is liable to shrink, which will make the building crack or split at the junctions with the return parts.

Where the ground is not very soft, and where the wall is to be supported upon narrow piers, a piece of timber, or balk, is sometimes slit in halves, and those are either laid immediately at the bottom, or at the height of two or three courses from the bottom of the wall; which will frequently prevent settlements when the wall is to be so supported.

Forced earth, or made ground, remains unfit for the foundation of a wall, for a considerable time.

The breadth of a substructure should be proportioned to the weight of the superstructure, and to the softness of the ground on which it rests; if the texture of the ground is supposed to be constant, and the materials of the same specific gravity, the breadth of the foundation will be as the area of the vertical section passing through the line on which the breadth is measured; thus, for example, Suppose a wall 40 feet high, 2 feet thick, to have a sufficient foundation of 3 feet in breadth, what should be the breadth of the foundation of a wall 60 feet high, $2\frac{1}{2}$ feet thick? By proportion, it will be $40 \times 2 : 3 :: 60 \times 2\frac{1}{2}$: the answer$=5\frac{5}{8}$ feet. This calculation will give the breadth of the foundation of the required wall, equal to the breadth of the insisting wall itself; when the height of the required wall is equal to the ratio, which is the first term $(40 \times 2 = 80)$ divided by the second term $(3) = \frac{80}{3} = 26\frac{2}{3}$. Thus a wall of $26\frac{2}{3}$ feet would have the breadth of its foundation equal to its thickness above the foundation, and less than $26\frac{2}{3}$ feet would have a thinner foundation than even the superstructure. But though the calculation in this case gives the foundation less in breadth than the thickness of its superstructure, it must be considered that it only calculates the true breadth of the surface that should be opposed to the ground, in order to prevent the wall from penetrating by its weight: though the rule gives all the width that is necessary, on account of the weight of the insisting wall, yet the breadth of the footing should always be greater than that of the superstructure; as it will stand more firmly on its base when affected by lateral pressure, and be less liable to rock by the blowing of heavy winds. The least breadth that is commonly given to the bottom course of stone walls is one foot thicker than the superstructure. In damp situations, the superstructure should always be separated from the substructure by layers of lead, tarred paper, &c. Slate also may be used with advantage for such purposes.

FOUNTAIN, (from the French *fontaine*,) literally signifies a spring or issuing of water from the earth, but the word is also applied to a machine or artificial contrivance by which water is made to spout or dart up, called by the French a *jet d'eau*. There are various kinds of artificial fountains, but they are all formed by some description of pressure on the water, that is, the water of the fountain is made to spout up, by the weight of a head of water; by the pressure arising from the spring and elasticity of condensed air, or by machinery.

FOX-TAIL WEDGING, a method of fastening a tenon in a mortise, by splitting the end of the tenon and inserting a projecting wedge, then entering the tenon into the mortise, and driving it home; the bottom of the mortise will then resist the wedge, and force it farther into the tenon, which will expand in width, so as not only to fill the cavity at the bottom, but be firmly compressed by the sides of the mortise.

FRACTION, in arithmetic and algebra, is a part or parts of something considered as a unit or integer. Fractions are distinguished into vulgar fractions and decimal fractions. Vulgar fractions consist of two parts or quantities written one over the other, thus $\frac{2}{3}$, $\frac{3}{4}$, &c.; the quantity above the line is called the numerator, and that below the line the denominator. *See Decimal.*

FRAME, in carpentry, a combination of timber-work, composed of one or more triangular compartments, or of a mixture of triangles and quadrilaterals, the timbers being either joined together by joggles, or by being halved or let into each other.

Three pieces of timber are the least number that can constitute a frame, for the same reason that less than three straight lines cannot constitute a space. *See* the articles FLOORING, NAKED-FLOORING, PARTITION, TRUSS, and TRUSS-PARTITION.

FRAME, in joinery, an assemblage of various pieces of wood-work, forming certain compartments, according to the design, surrounding panels of wood, which are inserted in grooves made in every edge of each compartment of the frame, and thus filling up the interstices. This mode is a substitute for a board, which could not be procured in one breadth; and even if such a board could be obtained, framing would be preferable, as being much lighter, stronger, and less liable to warp. The stiffness of a frame in carpentry depends chiefly upon the triangles in its composition; but a frame in joinery depends upon the inflexibility of the joints, taking every two pieces separately, by which each joint is formed.

FRAMING, of a house, all the timber-work, *viz.*, the carcase-flooring, partitioning, roofing, ceiling, beams, ashlering, &c.

FRANKING, in sash-making, cutting a small excavation on the side of a bar for the reception of the transverse bar, so that no more of the wood be cut away than what is sufficient to show a mitre when the bars are joined to each other; by this means, the strength is impaired only in the smallest possible degree.

FRATERY, OR FRATER-HOUSE, the dining-hall of monastic buildings, otherwise termed REFECTORY.

FREEMASON, in ancient times was the term applied to a person supposed to be skilled in the art of building, more particularly in ecclesiastical construction. A freemason travelled from place to place, and by his learning in the science, and his taste in the construction of edifices, executed works celebrated for beauty and grandeur. In the present day the word is identified with the society of Freemasons, whose various ramifications are said to extend throughout the known world.

FREEDSTOOL, FRIDSTOOL, OR FRITHSTOOL, a seat placed at the east of some churches, near the altar, for those who sought the privilege of sanctuary. They were usually of stone, specimens of them in this material are still existing at Beverley and Hexham.

FREE-STONE. *See* STONE.

FREE-STUFF, that which works easily in the operation of planing, without tearing.

FREEZE, a part of the entablature of an order; more correctly spelt FRIEZE, which see.

FRENCH CASEMENTS, windows turning upon two vertical edges attached to the jambs, which when shut lap together upon the other two parallel edges, and are fastened by means of long bolts extending their whole height.

French casements are made in the form of the old English windows, the two meeting styles, which lap together, forming a munnion about four inches in breadth. The lower part only is moveable, the upper is fixed, and has a corresponding munnion, the lower rail of the fixed part and upper rail of the moveable part forming a transom.

FRESCO PAINTING, a peculiar mode of painting, performed by employing colours mixed and ground with water upon a stucco, or plaster, sufficiently fresh and wet to imbibe and embody the colours with itself. The term *fresco*, as applied to painting, is said to have been adopted because the practice of it is used in the open air; *andare al fresco* signifying "to take the air," or "walk abroad in the air:" but it seems more probable that another meaning of the word *fresco* has given rise to this particular adoption of it, viz., new, or fresh, relative to the state of the plaster on which it is wrought. Vitruvius (lib. vii. cap. 4.) calls it *udo tectorio.* It is very ancient, having been practised in the earliest ages of Greece and Rome.

The theory of the art of painting extends its principles to all modes of execution, because theoretic rules are drawn from nature, which is the object of all imitation, and are independent of the means employed in producing the intended effect. We propose, therefore, in this place, only to treat of the mode of execution, and of the materials employed in fresco painting; such observations as the recent revival of the art has rendered necessary, being deferred till after our description of the practice.

Previously to the commencement of a painting in fresco, it is necessary that a careful examination should be made of the fitness of the place to receive it. The artist must assure himself, therefore, in the first place, of the perfect construction of the walls, or ceilings, on which he intends to employ his genius, and entrust his reputation: above all, he must be careful to make it secure from damp.

Satisfied with the construction of the wall, it is then necessary the artist should see to the proper management of the first layer of plaster with which it is covered. The materials employed for building in different countries will vary according to the nature of those most easy to be obtained: and therefore it will, of course, be necessary to adopt means for rendering those not perfectly proper in themselves to receive fresco painting, more so by artificial means. Brick is certainly the one best calculated to hold the plaster perfectly; both on account of its absorbing quality, and from the smallness of the size of the bricks causing a number of interstices between them; which irregularity in the surface greatly assists in retaining the plaster in adherence. A wall built of rough stones full of holes may also be relied upon as a good foundation for fresco; but if, instead of that, it be constructed of smooth or polished stones, it will then be necessary to render it uneven by making holes in it, fastening nails, and small wedges of wood, to hold the plaster together, and prevent its falling off. These precautions are of the utmost consequence to prevent its bending or cracking, which the least alteration that happens to the materials, or even a change of weather, producing alternately wet or dry, may occasion.

The first layer of plaster may be composed of well-washed chalk made into a cement with pounded brick, or river sand; the last is better, being rather the coarsest, and producing thereby a roughness of surface which will better retain the second coat.

Tarras, composed of pounded sea-sand and chalk or lime, would perhaps be better still. The ancients had certainly a better compost for this purpose than that at present known; if we may judge from that which still covers many of their buildings; particularly the aqueduct they constructed near Naples, and the walls of the ruins of Herculaneum.

Before the second layer is given, the first must be perfectly dry, on account of a disagreeable and noxious vapour which issues from the lime in drying; but when it is so, and you proceed to give it the second coating, upon which the painting is done, it must be wetted with water, that the two may more completely incorporate. This layer, which requires to be more carefully prepared than the first, is made by mixing river-sand of an even and fine grain with chalk, which has been burnt several months before, and exposed to the air, as by that means the artist may be more sure of its general decomposition and freedom from stony parts.

It requires considerable skill in the person who prepares this ground, to lay it perfectly even, and he must be very careful in judging of the quantity proper to be laid on at once. This ought not to be more than the painter can cover and completely finish in a day; and it requires great skill and activity in spreading, to clean it from lumps and polish it evenly, so as to receive the painting with the promptitude requisite to leave the artist as much time as possible. The painter, however, should himself superintend this part of the process, for he alone can judge properly as to the rapidity with which he can work, or the advantages he may make of accidental occurrences.

The operation of laying on the ground is performed with a trowel, and in doing this, care must be taken to clean it properly, that the surface may be even, particularly in those parts most exposed to view. The mason's labour is finished by his polishing the surface to receive the painting; this is done by applying a piece of paper on the face of the wall, and passing the trowel over it. It is very necessary that this should be well done, for small inequalities in the surface might, in certain views, produce great irregularities in the drawing of the work.

When the second ground is thus prepared, cleaned, and polished, in the quantity, and on the part of the wall which the artist requires, he begins to trace his design upon it, and proceeds to the colouring of it; completely covering the quantity prepared, and finishing so much of the picture in the course of the day, in such a manner that he may not have occasion to re-touch it when the ground is dry. This is the characteristic peculiarity of painting in fresco, which, by this mode of operation, is incorporated with the mortar, and drying along with it, becomes extremely durable, and brightens in its tones and colour as it dries.

From the necessity there is in the progress of this style of art, that it should be executed with rapidity, and from the impossibility of retouching it without injuring the purity of the work; the artist, unless he be endowed with very extraordinary powers of imagination and execution indeed, is obliged to prepare a finished sketch of the subject, wrought to its proper hue and tone of colour, and so well digested, that there may be no necessity for making any essential alterations in the design. This, which is a very useful mode of proceeding in all historic works of painting, is absolutely indispensable in fresco, to those who are not determined to give the rein to their ideas, and leave as perfect whatever may first present itself. There is no beginning in this, by drawing the whole of the parts at one time, and correcting them at leisure, as is the custom in oil painting, where the artist may proceed to work without a sketch. Here all that is begun in the morning must be completed by the evening; and that almost without cessation of labour, while the plaster is wet; and not only completed in form, but also (a difficult, nay, almost impossible task, without a well-prepared sketch,) must be performed, viz., the part done in this short time must have so perfect an accordance with what follows, or has preceded of the work, that when the whole is finished, it may appear as if it had been executed at once, or in the usual mode, with sufficient time given to harmonize the various forms and tones of colour. Instead of proceeding by slow degrees to illuminate the objects, and increase the vividness of the colours, in a manner somewhat similar to the progress of nature in the rising day, till at last it shines with all its intended effect, which is the course of painting in oil; the artist working in fresco must at once rush into broad daylight; at once give all the force in light and shade and colour, which the nature of his subject requires. This, be it observed also, must be without the assistance (at least in the commencement) of contrast to regulate his eye; and therefore may be considered almost impossible, as we have before said, unless he be assisted by a well-digested and finished sketch.

The sketch being completed, the next process is to prepare a cartoon or drawing of the design on paper pasted together to the size of the intended fresco. This cartoon should be perfected in the outline to save time, and the artist has then nothing to do but to trace the line of the figures or other objects which the design may be composed of, on to the plaster, by either pricking with a pin through the paper, or by passing a hard point over the lines of the cartoon. By this means he saves himself the trouble of drawing the figures, and also the time which would be required for doing it, and proceeds at once to the painting; to facilitate the execution, and ensure the success of which, several precautions are requisite.

The colours being ground fine in water, and a sufficient quantity of the tints most likely to be employed prepared, they should be arranged in pots or basons, and several pallettes with raised edges should be ready at hand to work from, and assist in compounding the varieties of hues necessary for producing brilliancy and harmony. A few pieces of tile or brick, or of any absorbent stone, should also be provided, to prove the tints upon, because all colours ground in water become much lighter when dry, than they appear when wet. To be certain therefore of their hue, before he begins to use them on the picture, and to avoid the trouble and necessity of much changing or labouring them, (as the painters term the blending of colours,) the artist should apply some of each tint with his brush to the dry brick, &c., which, absorbing the water, the colours immediately appear very nearly of the same hue they will be of when the fresco is dry. Hence he may proceed with great security in his work, and is sure to have it much more fresh and vigorous in effect, than it would be if much labour had been employed to obtain the tone on the wall.

It will be requisite also to have at hand a vase or bason of water, or a wet sponge, and to take care not to begin to paint till the layer of mortar is hard enough to resist the impression of the finger: otherwise the colours would spread upon it, and prevent all possibility of neatness or clearness in the execution, which should be effected with great rapidity and lightness of hand.

With respect to the colours employed in fresco, they are fewer in number than those which may be used in oil painting, on account of the combined action of the lime and the air upon the component parts of many of the latter. Those most generally in use are the following, viz.:—

Lime-White.—This, when made of well-washed burnt chalk or lime, is the best and most simple white that can be used; it mixes freely with all the other colours, and works in itself with a full body. The preparation of it requires that the chalk should be slacked a twelvemonth before it is used, or at least, six months. It should then be dissolved in common water, and poured carefully off, (after letting it fall some short time,) into a vessel to settle.

Another white is made by mixing one-third of white marble powder with two-thirds of chalk; but it must be used with caution, as it is apt to change. If the proportion of marble dust be too strong for the chalk, it will become black. The artist will therefore do well to confine himself to chalk white, provided it has been well prepared, and kept a long time. As this, however, has frequently been used, we deemed it proper to be mentioned, that artists may, if they choose, make experiments upon its nature, and endeavour, if they find any peculiarly valuable quality in it, to ensure its continuance in clearness and perfection.

Egg-shell White.—There is also a third white, made of egg-shells, which, though it has not the full texture of the chalk, is yet very clear and good for use in fresco. It is made by boiling egg-shells in water with a little quick-lime. They are then put into a pot, and washed with pure water. Then pounded fine, washed again till no tint is given to the water, and then ground by the muller and stone to the degree fit for use; it is afterwards formed into little cakes, which are dried in the sun. Care must be taken not to let the powder of the shells remain too long in the same water, as it will exhale a fetid vapour almost insupportable, which cannot be dissipated but by roasting it in a close vessel, well luted.

Red—produced by burnt vitriol, in colour approaching to Indian red, and ground in spirits of wine, acts well with the lime, resists the action of the air, and mixes cleanly with the other colours. This forms an excellent preparation to receive the bright red of cinnabar or vermilion, when the whole wall is covered.

Colours of earthy textures, such as the ochres, whether burnt or not burnt, umber, both raw and burnt, Spanish red, Verd de Verona, Venice black, and blue black, made by bruising vine-stalks, or shells of peach-nuts, are all excellent for the purposes of fresco painting.

Blues.—The best is the ultramarine, as it never suffers any change. Smalt or enamel blue is good as to preserving its tone, and, if used early in the work, will adhere; but if the ground should become too dry before it is used, it is apt not to incorporate strongly with it, but to come off on the least friction.

White lead, lake, verdigris, masticot, Naples yellow, the orpiments, and bone black, are all unfit for this purpose, being liable to change.

Painting in fresco, when carefully executed, is of all others the most durable, and therefore the most proper to be employed in adorning public buildings. The use of it for this purpose appears to be very ancient. Norden speaks of paintings in Egyptian palaces 80 feet high, which Winkelman quoting, concludes they were in fresco, from the description given of the prepared grounds, and of the manner in which the colours appear to have been used. And all the paintings found at Herculaneum, at Portici, and at Rome, of ancient date, are of the same materials. No other kind of painting would so effectually have resisted the action of the air for so great a length of time, and more particularly the excessive aridity which those of Herculaneum must have endured, being shut up entirely from the light, and amidst glowing embers from Vesuvius, emitting of course, especially at first, an intense heat around them. That, however, in one point of view, was favourable to the preservation of those that escaped its immediate action; for damp is the most powerful destroyer of them, against which no caution taken can make them too secure. In this case of Herculaneum, damp must have been effectually excluded, first by the heat of the ashes, and afterwards, as the stratum of those ashes was so thick, water from above could not penetrate so low as to the pictures, particularly after the upper part was covered with the close cake formed by the decomposed parts, on and near the surface.

In ordinary situations, the choice of materials is the most important part, to secure the durability of the work, and particularly the greatest care is necessary in the preparation of the ground, and of the wall, to cause it to adhere.

Fresco painting has been chiefly employed in palaces, temples, and other public edifices. For large and important places no other kind of painting is so good. As the artist is obliged, from its nature, to proceed with rapidity in its production, it has necessarily more spirit and vigour in the execution, than paintings in oil, which may be repeated, and re-touched, as often as the artist fancies he can improve, or heighten their effect. In fresco there is not time to meddle, and disturb the freshness of the colour, or the fulness and freedom of the touch. But there can be no minute detail of forms, or extensive variety in the gradation of tints; the beauties of neatness, and delicacy of finishing, make no part of the excellencies of this branch of the art; it will not bear the close examination which well-finished pictures in oil do; there is something dry and rough in its appearance, unpleasing, to the common observer, on too close an inspection. It lacks the full rich sweetness of hue and texture which oil paintings possess; and though it has more freshness, and retains it, yet from the confined number of colours which can be employed in it, it is not equal to oil in the perfection of the imitation of nature.

Whoever seeks to be pleased with fresco painting, must learn justly to estimate the best, and not the most agreeable qualities of the art. Character, contour, expression, are within its powers; and are the points which the great artists who practice it, knowing its limits, will endeavour most to exhibit in their productions. Harmony of colouring, chiaro-oscuro, and the minute graces of execution, have never yet been rendered in it, or but very partially, in comparison with works in oil.

In the early part of the restoration of painting, a species of fresco was the only mode of practising the art, in use. A ground of chalk was prepared on tablets of wood, and the colours laid on it, ground and mixed in water only, or with some gluten soluble in it. The surface of the picture was afterwards covered with a varnish, to secure it from rubbing, and to give the tints more force and lustre.

"Fresco," observes a writer in *The Builder*, "was much used in England some four or five centuries since, in both ecclesiastical and civil structures of importance; the subjects being chiefly scriptural, with occasional deviations in favour of some legendary achievement, or as a pictorial record of some well-contested battle-field. With these bold and beautiful, but unresisting memorials of things sacred, and deeds that redounded to national glory, the fanatical spirit of the sixteenth and seventeenth centuries warred to extermination; neither the enrichments of the temple bestowed by the constant piety of our ancestors, nor the grateful reminiscences of heroic services of the state, were permitted to escape the devilries enacted by the factitious saints of the Puritan calendar: the frescoes perished; but better taste and better feelings have supervened, bidding fair to re-establish both the art itself, and the influential purposes to which it was anciently devoted."

The report of Mr. Barry on the proposed decorations of the interior of the new Houses of Parliament, is really a splendid programme of the association of sculpture and painting, upon an occasion too so fertile in appliances and means, that the principles of taste will, it is presumed, be developed in a manner to serve as examples for much of future time. With reference to painting, Mr. Barry says—"I would that the walls of the several halls, galleries, and corridors of approach, as well as the various public apartments throughout the building, should be decorated with paintings, having reference to events in the history of the country; and that these paintings should be placed in compartments formed by such a suitable arrangement of the architectural designs of the interior, as will best promote their effective union with the arts of sculpture and architecture. With this view, I should consider it to be of the utmost importance, that the paintings should be wholly free from gloss upon the surface, that they may be perfectly seen and fully understood from all points of view." "By paintings with surfaces free from gloss or glaze, we understand those wherein the colours employed are mixed in other mediums than oils or varnishes; and though fresco is not named, yet the magnitude of the surfaces to be covered, and the exception to those which are glazed, leads us to suppose that it is intended to revive this branch of art. Now, though the buildings to be thus adorned are progressing with considerable rapidity, much time must elapse before the interior is prepared to receive the embellishments contemplated; meanwhile, many will have their longings to share in these distinguished labours, and, generally, the revival will open a new field for talent, in which there will shortly be no want of encouragement for those who may have successfully cultivated it; so oblivious, however, has the art become, that we have repeatedly heard the question put as to its nature and mode of execution, and we think an explanation will be useful to many of our readers. Fresco is the art of painting in relievo with water-colours on fresh plaster; the amalgamation thus formed of the decorative material with the body to which it is applied, is endued with unchangeableness and permanence of a very extraordinary kind."

The appointment of "A Commission on the Fine Arts," especially directed "to inquire into the mode in which, by means of the interior decorations of the Palace of Westminster, the fine arts of this country can be most effectually improved," has no doubt led to the revival of the art of fresco-painting. The various reports of the commission contain a great deal of valuable information on the subject, and the employment of several artists to furnish specimens, has brought forward some beautiful examples of fresco-painting, and elicited talent that might, but for these circumstances, have been lost to the world. In addition to the encouragement thus afforded, the stimulus of a public competition, and the distribution of rewards to the successful candidates, Her Majesty and Prince Albert had given the advantage of their countenance to the art, by ordering the decoration of a summer-house in the gardens of Buckingham Palace with fresco paintings.

The idea of this experiment, for so it must be called, was surely a happy one; and not the less seasonable, that every one who had considered the subject (at least every one who understood it), felt that it was a method which presented peculiar difficulties to some of the ablest and most distinguished of our painters, whose habitual style of treatment of their subject and effect, had been precisely the reverse of what is required in fresco.

The application of fresco-painting, it may be observed, to the decoration of architecture demands the adaptation of parts to a whole; a preconcerted mode of treatment, in which the painting shall seem to be in union with the original design of the edifice; the harmonious combination of many minds, working under the direction of one mind, to one purpose; and with regard to the mechanical part of the process, it requires much thought and study in the preparation of the materials, and great care and precision, as well as great rapidity, in the execution.

The summer-house in question is very small, and is situated on an artificial mount in the gardens, overlooking the ornamental waters.

The entrance to the pavilion opens into the principal apartment, an octagon 15 feet 9 inches from side to side, and 14 feet 11 inches in height, to the centre of the vaulted ceiling. It is here, in eight lunettes at the foot of the vault, that the frescos from "Comus" appear, of which for the most part types have been exhibited in the rooms of the Royal Academy, by the respective artists. Over the entrance-door, is Stanfield's, illustrative of the following passage :—

"Yet some there be that by due steps aspire
To lay their just hands on that golden key,
That opes the palace of Eternity.
To such my errand is." Comus, v. 12—17.

It is admirably transparent, and exhibits more power over the material than the majority of the works. Passing round with the sun, Mr. Uwin's follows, having for motto,

"This is the place as well as I may guess,
Whence even now the tumult of loud mirth
Was rife."

Then comes Leslie: Ross follows. Eastlake's is over the mantlepiece; Maclise, Edwin Landseer, and Dyce, complete the eight. A copy of Mr. Maclise's work was in the Academy exhibition of 1845, and will be remembered by all. The lines illustrated are,

"If virtue feeble were,
Heaven itself would stoop to her."

Maclise shows the lady spell-bound in the marble chair, and displays much of his usual power. Mr. Landseer has found in the following lines an opportunity to exhibit his great skill in depicting the brute form :—

"Their human countenance
Th' express resemblance of the gods, is changed
Into some brutish form of wolf or bear,
Or ounce or tiger, hog or bearded goat."
Comus, v. 68—71.

Comus, surrounded by his crew, is terrified by the approach of the brothers, who appear behind in the act of rushing upon them. A bacchante, with a beautiful female form, and the head of a hound, has thrown herself in affright upon the arm of Comus. Other monsters, half brute, half human, in various attitudes of mad revelry—grovelling, bestial insensibility—confusion and terror—are seen round him; the pathetic, the poetical, the horrible, the grotesque, all wildly, strangely mingled. In the spandrils are two heads—a grinning ape, and a bear drinking.

Mr. Dyce winds up the illustrations with the presentation of the lady and her two brothers to their parents, who come forth to receive them, and he has produced what must be considered the best fresco, although perhaps wanting exactly the right sentiment.

The operations of the Fine Arts Commission seem tohave been highly satisfactory to the public in general, and, in respect to fresco-painting in particular, must be viewed as eminently successful. The exhibitions in Westminster Hall presented numerous paintings in this so long-disused art, of a highly artistic character; and the number of the prizes awarded, testify the great merit of the productions. The result of the preliminary competition was shown in the selection of several eminent artists to execute fresco-paintings in the new Palace of Westminster, and in the completion by those gentlemen of some of the finest pictures in this peculiar style, that have been seen since the days of the great painters of former times.

It would extend this article beyond the limit assigned to it, to give a full description of these admirable works; we must therefore confine ourselves to a list of the artists selected, and the subjects allotted to each for illustration.

The commissioners having decided that six compartments in the new House of Lords should be decorated with fresco-paintings, proceeded to allot the several works in the following manner :—

To Mr. Horsley, the subject of Religion.
To Mr. Thomas, the subject of Justice.
To Mr. Maclise, the subject of Chivalry.
To Mr. Dyce, the subject of the Baptism of Ethelbert.
To Mr. Redgrave, the subject of Prince Henry, afterwards Henry V., acknowledging the authority of Chief Justice Gascoigne.
And to Mr. Cope the subject of Edward the Black Prince receiving the Order of the Garter from Edward III.

In the Upper Waiting Hall, or, as it is to be called, the "Hall of Poets," the eight available panels which it affords, are appropriated to frescoes illustrative of Chaucer, Spenser, Milton, Shakspere, Dryden, Pope, Byron, and Scott. Such of these paintings as are finished at the time we write, are noble works, full of power and beauty, and fully justifying the commissioners in the selection they have made of the artists employed.

The principal works that have been produced in former times in fresco, are the series of biblical and evangelical historic pictures which adorn the walls and ceiling of the chapel of Sixtus V. at Rome, by M. A. Buonarotti; the chambers of the Vatican, known by the name of the Stanze of Raphael; which consist principally of religious histories interspersed with some legendary tales, relative to the popes; and the cupola of the duomo of Parma, or church of St. Giovanni in that city, by A. Correggio. It represents the Ascension of the Virgin, amidst a choir of angels, and with a number of figures of saints below regarding it. One beautiful and grand work, by Daniel Ricciarelli, commonly called Da Votterra, at the altar of the church of Trinita da Monte, the subject of which is taking Christ down from the cross, is said to have been destroyed by the French, in their endeavours to remove it to France. Dorigny has engraved a large print of the design; and the picture has been thought so well worthy of attention, that an infinite multitude of copies have been made of it.

FRET, (from the Latin, *fretum*,) a species of guillochi, made of straight grooves or channelures at right angles to each other; the section of each channel being that of a rectangle. A fret is generally one connected groove with some of its parts in the same straight line. The labyrinth fret is that which consists of many turnings or windings, but in all cases the parts are parallel and perpendicular to each other. The prominent parts or interstices are generally of the same breadth throughout. In several Grecian examples, intervals are left in regular positions throughout the length of the fret.

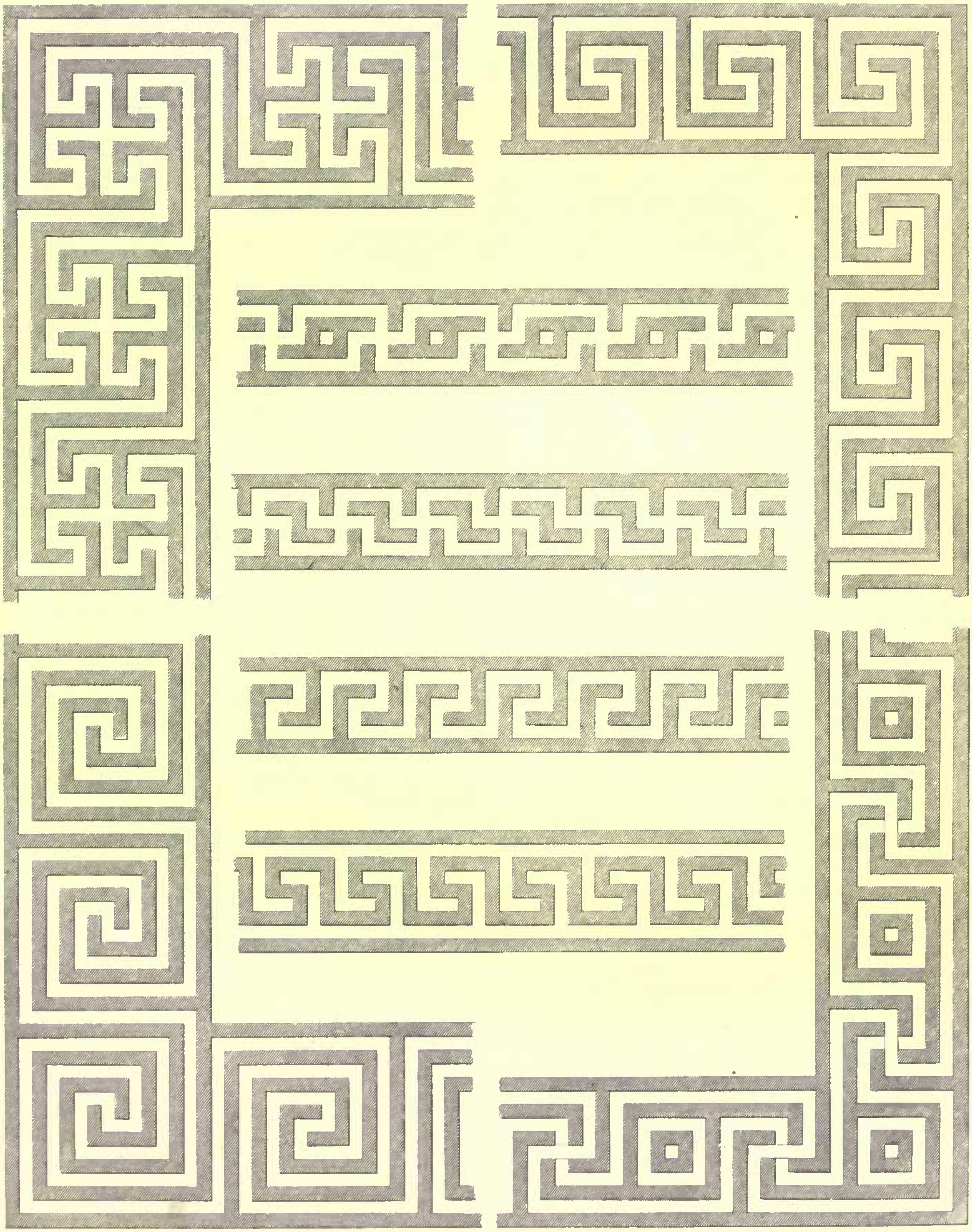
Fret is also elaborate carved-work, the same as Entail.

FRIARY, the building inhabited by a fraternity of friars.

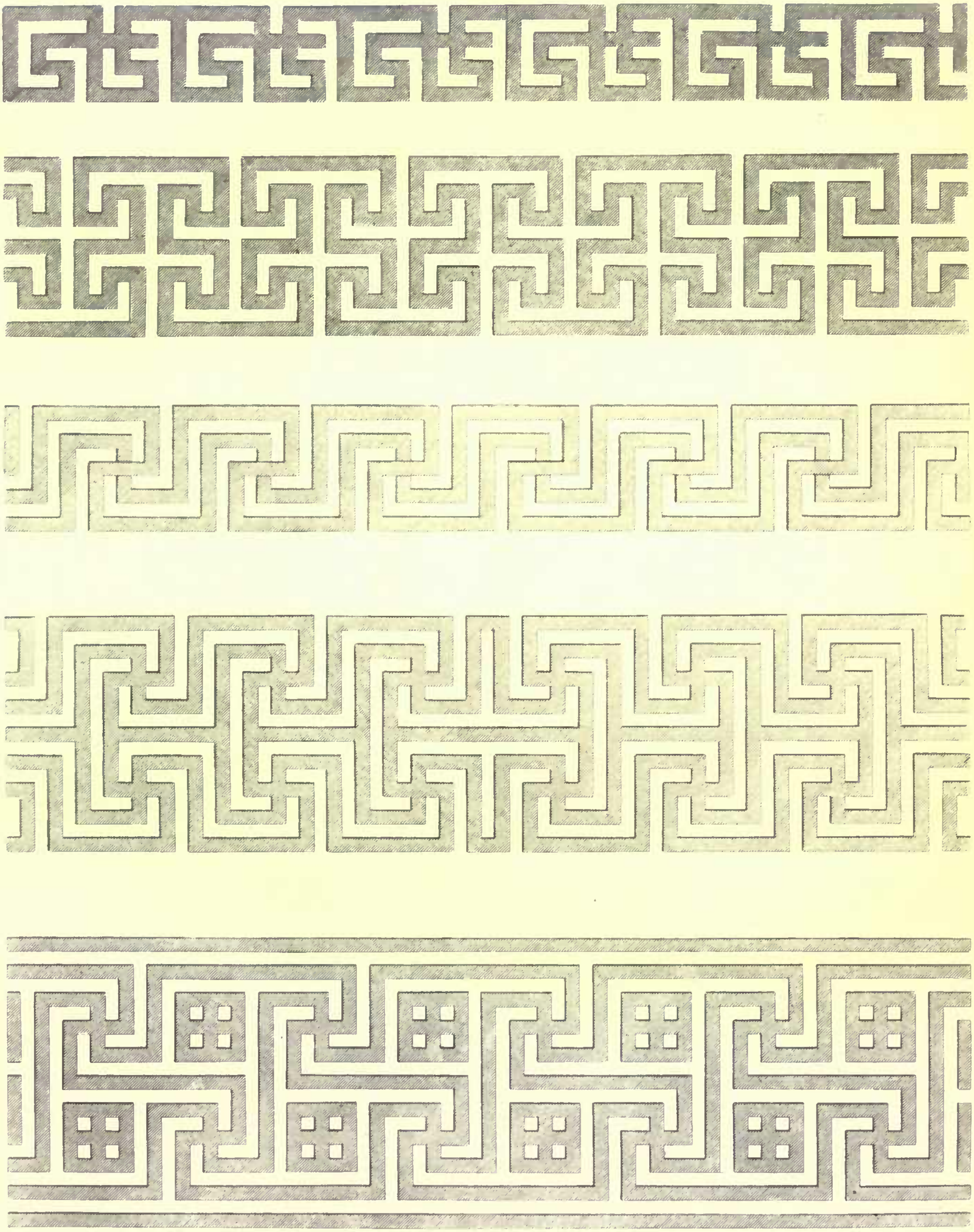
FRIEZE, or Frize, (called by the Greeks *zoophorus*) the middle principal member of the entablature which separates the cornice from the architrave.

The frieze was supposed to be originally formed by the transverse beams, which were necessary to prevent the walls or sides from spreading outwards by the pressure of the rafters of the roof.

The Doric is the only order that has an enriched frieze peculiar to the order itself. The ornaments with which the friezes of the Ionic, Corinthian, and Roman orders are frequently decorated, are only accidental, and when introduced are accommodated to the circumstances or use of the building. When the frieze is charged with ornament, it ought to be higher than when plain. Vitruvius directs the frieze



FRETS.



of the Ionic to be one-fourth part less than the epistylium, when it is plain; and one-fourth part greater when ornamented; this seems reasonable, in order to set off the decorations to greater advantage.

Ancient examples show no authority for a general proportion in all the orders. In the Grecian Doric, the frieze is very high, being equal to the altitude of the architrave, and each of these greater than the cornice; the Corinthian, on account of the numerous members of the cornice, has its frieze less than one-third of the height of the entablature.

Vitruvius makes the line of separation between the frieze and the cornice immediately under the dentils, and not at the bottom of the cymatium, as by Palladio, Perault, and others; for the frieze must have a terminating member as well as the architrave.

Friezes are either *convex* or *pulvinated:* examples of the latter are to be met with as follow: at Rome, in the Composite order of the temple of Bacchus; Corinthian order of the basilica of Antoninus; and in the Composite order of the Goldsmiths' arch: in all which the curves are circular, and not very prominent. At Spalatro, in the Corinthian order of the portico of the vestibulum of the Periostilium; in the same order, exterior and interior, of the temple of Jupiter, and of the entrance of the temple of Æsculapius: where the curves are all circular, and very prominent. In Wood's *Ruins of Balbec* (as represented in plate 31) of the Corinthian order, where the curve is elliptical. In the Corinthian order of Wood's *Ruins of Palmyra,* (plates 23 and 46), the curve is elliptical; and in plates 33 and 40, it is circular. In the *Ionian Antiquities;* (vol. ii., plates 27 and 45) the curves are of a contrary flexure, with the concave part above; and in plate 50, the curve is circular.

Swelled friezes are to be found among the examples of antiquity, particularly during the decline of the Roman empire; but these precedents ought not to influence their use, as they are unnatural, and defeat the purpose they were intended to answer, namely, to form a relief to the eye between the cornice and the architrave.

Frieze, *Panel,* the upper panel of a six-panelled door.

Frieze, *Rail,* the top rail but one of a six-panelled door.

Friezes, *Flourished,* such as are enriched with reeds or imaginary foliages, as in the Corinthian frieze of the frontispiece of Nero.

Friezes, *Historical,* those which are adorned with bas-relievos, representing histories, or sacrifices, as those of the Parthenon and the temple of Theseus at Athens, and the arch of Titus at Rome.

Friezes, *Marine,* such as represent sea-horses, tritons, and other attributes of the sea; or shells, baths, grottos, &c.

Friezes, *Rustic,* those whose courses are rusticated, as the Tuscan frieze of Palladio.

Friezes, *Symbolical,* such as are adorned with the attributes of religion, as the Corinthian of the temple behind the Capitol at Rome, whereon are represented the instruments and apparatus of sacrifice.

Frieze of the Capital, the same as Hypotrachelion, which see.

FRIGERATORY, (from the Latin, *frigidus,* to cool) a place in a house intended to keep things cool in summer.

FRIGIDARIUM, (Latin) an apartment in which to keep things cool.

It also means the cold bathing-room in the baths of the ancients, as well as the vessel in which the cold water was received. The word has been likewise applied to the reservoir of cold water in the hypocaustum or stove-room, which was termed *ahenum frigidarium.*

FRIZE. *See* Frieze.

FRONT, (from the Latin, *frons,* the face,) any side or face of a building. The principal front should be that which commands the best prospect, or may be seen to the greatest advantage; and is generally the entrance-front.

FRONTAGE, the front part of an edifice.

FRONTAL, the hanging suspended over the front of the altar. It was made of the richest material, silk, velvet, and cloth of gold, and worked in the most costly manner in embroidery. Otherwise termed *Antependium.*

FRONTON, (French) a pediment, or other ornament over doors, niches, &c.

FROSTED, a species of rustic work, imitative of ice formed by irregular drops of water.

FROWEY TIMBER, such as works freely to the plane without tearing, and consequently has the grain nearly in the same direction.

FRUSTUM, (Latin) the part of a geometrical parallelogram next to the base, after cutting away the upper part, which contains the apex. Thus we have frustums of pyramids, cones, conoids, hemispheres, &c.

To measure the frustum of a square pyramid.

To the rectangle of the sides of the two bases, add one-third of the square of their difference; their product being multiplied by the height, will give the solidity.

Example.—In the frustum of a square pyramid, one side of the base A B or B C is 3 feet 6 inches, each side of the top 2 feet 3 inches, and the perpendicular height H I, 8 feet 9 inches, the solidity is required.

By Duodecimals.

3 ·· 6
Deduct 2 ·· 3 the less side of the top.

1 ·· 3 difference.
1 ·· 3

3 ·· 9
1 ·· 3

3) 1 ·· 6 ·· 9 square of difference.

6 ·· 3

3 ·· 6
2 ·· 3

0 ·· 10 ·· 6
7 ·· 0

Add { 7 ·· 10 ·· 6
6 ·· 3 one-third of the square of the difference.

8 ·· 4 ·· 9
8 ·· 9

6 ·· 3 ·· 7 ·· 7
67 ·· 2 ·· 0

73 ·· 5 ·· 7 ·· 7 the solidity required.

By Decimals.

3 ·· 6 = 3.5
2 ·· 3 = 2.25
8 ·· 9 = 8.75

3.5
2.25
———
1.25 difference of the two bases.
1.25
———
625
250
125
———
3) 1.5625 sq. of the difference of the two bases.
———
.5208
———
2.25
3.5
———
1125
675
———
7.875
Add .5208 being $\frac{1}{3}$ of the squ. of the difference.
———
8.3958
8.75
———
419790
587706
671664
———
73.463250 the solidity required.

To measure the frustum of a cone.

To the rectangle of the two diameters, add one-third of the square of their difference: multiply the sum by .7854, and the product by the length.

Example.—What is the solidity of the frustum of a cone, the diameter of the greater end being 3 feet, that of the lesser end being 2 feet, and the altitude 9 feet?

3
2
—
1 difference of the diameters.
1
—
1 sq. of the difference of the diameters.

3
2
—
6
Add $\frac{1}{3}$
———
Sum $6\frac{1}{3}$

.7854
$6\frac{1}{3}$
———
47124
2618
———
4.9742
9 the length.
———
44.7678 the solidity of the frustum.

FULCRUM, in mechanics, that by which a lever is sustained.

FUMARIUM, an upper room used by the Romans for collecting the smoke from the lower ones. The Fumarium was chiefly used, however, for smoking or ripening wines.

FUNNEL, that part of a chimney which is contained between the fire-place and the summit of the shaft. *See* Chimney.

FURCATED, having a forked appearance.

FURLONG, a measure of length, the eighth part of a mile, forty poles.

FURNITURE, the fastenings of doors and windows with brass knobs, &c.

FURRING, when the edges of any number of timbers in a range are out of the surface they were intended to form, either from their gravity, or in consequence of an original deficiency of the timbers in their depth; the fixing of thin scantlings or laths upon the edges, so as to form that surface, is called *furring*. Thus the timbers of a floor, though level at first, are often obliged to be *furred:* in the reparation of old roofs, the rafters have mostly to undergo this operation: and the ceiling joists, both of new and old floors, frequently require it.

FURRINGS, the pieces of timber employed in bringing any piece of work in carpentry to a regular surface, when the work is deficient through the sagging of the timbers, or other causes.

FUR-UP. *See* Furring.

FUST, (from the French) the shaft of a column, or trunk of a pilaster.

Fust, a term used in Devonshire, and perhaps in some other counties, for the ridge of a house.

FUSTIC, sometimes called Yellow Wood. This wood, the *Morus tinctoria*, is a native of the West Indies, and affords much colouring-matter, which is very permanent. The yellow given by fustic without any mordant, is dull and brownish, but stands well. The mordants employed with weld, act upon fustic in a similar manner, and by their means the colours are rendered more bright and fixed. The wood of this tree is also used in mosaic cabinet-work and turnery.

FUSUROLE, or Fusarole, (from the Latin) a semi-circular member cut into beads, generally placed under the echinus of the Ionic and Roman capitals.

G.

GABION, a hollow cylinder of wicker-work, resembling a basket, but having no bottom. It is formed by planting slender stakes vertically in the ground, at intervals from each other, on the circumference of a circle, and interweaving with them osiers or other flexible twigs.

Such gabions are used during a siege, in executing trenches by the process of sapping: for this purpose, they are placed on end, with their sides inclining a little outwards, on that side of the line of approach which is nearest to the fortress; and, being filled with earth obtained by the excavation of the trench, they form a protection against the fire of the enemy. After the gabions are filled, the required thickness is given to the parapet of the trench by throwing the earth below the line.

GABLE, (from the British, *gravel*) the upper portion of the end of a building wall, which closes the end of the roof, in shape similar to a triangle, and answering, in some respects, to the term Pediment, applied to classic architecture. The gable forms a prominent feature in mediæval buildings, and its shape conforms to that of the roof; which is various at different periods. In Norman buildings, the angle of the roof is as nearly as possible a right angle, while in Early English edifices the gable is frequently an equilateral triangle. In the Decorated the roof is somewhat depressed, which depression increases in the Perpendicular and later buildings. The finish to Norman gables was probably a flat coping, to Early English a moulded coping, sometimes further ornamented with crockets and finials; but these were more frequently introduced in the later styles, in which also the gables were sometimes finished with a pierced parapet or battlement. In Domestic architecture, gables with overhanging roofs were ornamented with Barge-Boards.

The term is also applied to the entire wall at the gable-end of a building.

Gable-roofed, having a roof abutting against a gable wall.

Gable-window, a window in the gable end of a building.

GABLET, a small gable; an ornament in shape like a gable, frequently introduced over tabernacles, niches, buttresses, &c.

GAGE, (French) in carpentry and joinery, an instrument for drawing one or more lines on any side of a piece of stuff, parallel to one of the arrises of that side.

There are four kinds of gages: the common gage, the mortise-and-tenon gage, the internal gage, and the flooring gage. The common gage and the flooring gage are both applied to the drawing of a line parallel to an arris.

The common gage consists of two pieces of wood, one of which passes through a mortise in the other, and has an iron or steel tooth fixed near one of its extremities; so that the point may be placed at any distance from the mortised piece: then the piece which passes through the mortise is fixed by a wedge also through that piece: the piece through which the mortise passes is called *the head*, and the piece passing through the mortise, in which the iron tooth is fixed, is called *the staff.*

When a line is drawn from the arris upon one side, at a given distance, the head is a fence that always keeps the staff at right angles to the arris, and equidistant, in moving it to and fro.

The mortise-and-tenon gage is a common gage with a longitudinal slider, moveable in a dovetail groove: the slider has also a tooth fixed as near to the end next the tooth in the end of the staff as possible; so that the teeth may be brought almost to any distance from one another.

The internal gage is constructed similar to the staff of the mortise-and-tenon gage: it has a longitudinal slider, the whole length of the staff, without a head, or any other tooth than that of the slider.

The flooring gage consists of a head and staff fixed together, at a very obtuse angle: on the head are a number of equidistant furrows at right angles to the staff: the section of each furrow is an internal right angle, one side of which is in a straight line with the tooth, and the other becomes a fence in the act of gaging.

This gage is made to answer battens or deals of various widths: Each width is numbered, according to the furrow that is applied as a fence; so that a flooring board, which is not sufficiently long, may be extended, by a piece of the same breadth, to the length required.

GAIN, the bevelled shoulder of a binding-joist for the purpose of giving additional resistance to the tenon below. *See* Tusk.

GALILEE, a porch, usually built at or near the west end of the great abbey-churches, where the monks collected themselves, and drew up in returning from some of their processions; where dead bodies were deposited previous to their interment; and where, in certain monasteries, females alone were allowed to see the monks to whom they were related, or to attend divine service.

Galilees exist in England in the cathedrals of Durham, Ely, and Lincoln. In the former instance, it is a large chapel at the west end of the nave, measuring 80 feet by 50, and divided into five aisles by semi-circular arcades on clustered columns; it likewise contained three altars. The galilee at Ely is in the same position, but of much smaller dimensions, while that at Lincoln is on the west side of the south transept.

Many improbable conjectures have been formed concerning the derivation of the name. The real occasion of it seems to be this: when any female applied at the abbey-gate for leave to see her relative, who was a monk, she was directed to the western porch of the church, and told, in the terms which so frequently occur in the service of the pascal time, alluding to Matt. xxviii. 10, and Mark xvi. 7, that she should see him in Galilee. This explanation is confirmed by a passage of Gervasius the monk of Canterbury. *De Combust. et Repar. Dorob. Ecc. Twysd. X. Script.*

GALLERY, an apartment of a house, not always destined to answer the same purpose: the term is applied, in a general way, to any passage or apartment, the length of which greatly exceeds its breadth. A common passage to several rooms in one range, in any upper story of a house, is called a gallery; a long room for the reception of pictures is called a gallery; the platform raised upon pillars, or projected from the wall of a church, open in the front to the central space, for the accommodation of a greater number of people than the body of the church would admit, is called a gallery. The whispering-gallery of St. Paul's, as also that of the chapel of Greenwich Hospital, are projected, and supported by cantalivers from the wall. The whole, or a portion of the uppermost story of a theatre, is likewise called a gallery. The appellation is also frequently given to porticos formed with long ranges of columns on one side.

Savot, in his *Architecture*, derives the gallery from *Gaul*, as supposing the ancient Gauls to have been the first who used them: Nicod, from the French, *aller*, to go; q. d. *allerie:* others bring it from *galère*, galley, because it bears some resemblance thereto in respect of health.

The length of galleries is (according to Palladio) from eight to ten times their breadth.

GANG-LADDER, in canal-making, a frame answering the same purpose as a horsing block.

GANG-WAY, a temporary stair, made with planks set edge to edge of each other, having transverse pieces of wood nailed over for steps; used particularly by masons, bricklayers, and carpenters, for ascending or descending the various stories of a building, before the stairs are put up.

GAOL, (from the French, *géole*, formed of the Latin, *geola*, *gaola*, or *gayola*, a cage) a prison, or place of legal confinement; the word is now generally written Jail.

Every county has two gaols; one for debtors, which may be any house where the sheriff pleases; the other for the peace and matters of the crown, which is the county gaol.

By 22 and 23 Car. II. c. 20, the gaoler shall keep debtors and felons separate, on pain of forfeiting his office, and treble damages to the party aggrieved; and by 31 Geo. III. c. 46, transports are to be kept separate from other prisoners. As the gaol is intended, in most cases, for custody, and not for punishment, it is enacted by 14 Geo. III. c. 59, that the justices, in their several quarter-sessions, shall order the walls and ceilings of the several cells and wards, both of the debtors and felons, and of any other rooms used by the prisoners in their respective gaols, where felons are usually confined, to be scraped and whitewashed once in the year, at least, and to be regularly washed and kept clean, and constantly supplied with fresh air by hand-ventilators or otherwise; and shall order two rooms in each gaol, one for the men and another for the women, to be set apart for sick prisoners; and order a warm and cold bath, or commodious bathing-tub, to be provided in each gaol, and direct the prisoners to be washed in such warm or cold baths, or bathing-tubs, &c., and they shall appoint an experienced surgeon and apothecary, at a stated salary, to attend the gaol, and to report, at each quarter-sessions, the state of the health of the prisoners; order clothes for the prisoners when they see occasion, prevent their being kept under ground, when it can be done conveniently, and from time to time make orders for restoring or preserving the health of the prisoners; the expenses to be paid out of the county rates, or out of the public stock of any city, franchise, or place to which the gaols belong. The gaoler is subject to fine for neglect or disobedience of the orders of justices, by complaint to the judges of assize, or to the justices in their quarter-sessions. By 31 Geo. III. c. 46, visiting-justices are appointed for inspecting gaols at least three times in each quarter of a year, in order to prevent abuses, &c., and they are to report to the quarter-sessions. The justices in sessions may also appoint clergymen to officiate in gaols, and allow them a salary to be paid out of the county rates.

If a gaol be out of repair, insufficient, &c., the justices of the peace in their quarter-sessions may agree with workmen for rebuilding or repairing it; and by warrant under their hands and seals, order the sum agreed upon to be levied upon the several hundreds and divisions in the county, by a proportionate rate; and the justices in sessions may borrow, on mortgage of the said rates, any sum not less than £50 nor more than £100, and discharge the whole by yearly payments. 11 and 12 Will. III. cap. 19. 24 Geo. III. c. 54. *See* Prison.

GARD, *Pont du.* *See* Aqueduct, Bridge.

GARDEN, *Hanging*, a sort of ancient garden, which is said to have been formed in a raised manner, on arches, by Nebuchadnezzar king of Babylon, with the view of gratifying his wife Amyctis, who was the daughter of Astyages, king of Media. These gardens are supposed by Quintus Curtius to have been equal in height to the city, which is 50 feet. They contained on every side a square of 400 feet, and were carried up in several terraces, surmounting each other, to which there were ascents by different flights of stairs or steps that had 10 feet in width. The arches that sustained the whole of this pile were raised above each other, being strengthened by a wall on every side of above seven yards in thickness. The floors of the several terraces were laid first with large flat stones, of considerable lengths and breadths, over which was placed a stratum of reed mixed very fully with bitumen, then two rows of bricks closely cemented together with mortar, and the whole afterwards covered with thick sheet-lead, upon which the mould of the garden was deposited, to such a depth as to admit large trees to take root and establish themselves in it. Trees, plants, and flowers of various kinds, were introduced into these gardens. The upper terrace was likewise provided with an aqueduct or engine, by which the water was drawn up from the river, and dispersed over the whole of the gardens when necessary.

Some have condemned these gardens as unnatural, while others have considered them as deserving of a portion of praise; but whatever merit may have been allowed them, they could certainly never have had anything of the natural or rural character about them.

Garden-Sheds, erections for containing garden implements, flower-pots, hot-bed frames, and glass sashes; also for working in, during bad weather. They are best placed on the back-wall of the tool-house, by which means they may be made to hold the furnaces, fuel, and other articles.

GARGOYLE, Gargle, Gargyle, and Gurgoyle, a stone projecting from the wall of Gothic buildings, and serving for a spout to convey the water from the roof, and throw it off the wall. These stones are more frequently carved into grotesque figures or animals, through the mouth of which the water passes; sometimes, however, the water is carried through a leaden pipe above or below the figure. Their usual position is in the cornice of buildings, but they are found also in other positions, such as buttresses, &c.

GARLANDS, (from the French, *guirlande;* from the Latin, *garlanda*, or Italian, *ghirlanda*,) ornaments of flowers, fruits, and leaves, anciently used at the gates of temples, where feasts or solemn rejoicings were held. Garlands of festoons were also put on the heads of victims, in the ancient heathen sacrifices.

GARNETS, *Cross*, a species of hinge, used in the most common works, formed in the shape of the letter T, turned thus, ⊢⊣, the vertical part being fastened to the style or jamb of the door-case, and the horizontal part to the door or shutter.

GARRET, (from the French, *garite*, the tower of a citadel) the uppermost story of a house, when taken either partially or wholly from the space within the roof.

GARRETING, the insertion of small pieces of stone between the joints of rough masonry, as in rubble and flint walls.

GARRISON, a fort, castle, or fortified town, furnished with troops to defend it.

GATE, a large door for shutting the entrance of parks, fields, towns, castles, palaces, or any other considerable buildings.

The width of gates is from eight to twelve feet: the height depends upon the purpose to which they are applied. *See* Door.

Gate, in *Rural Economy*, a frame of wood constructed with a number of bars, and fixed in such a manner as to swing upon hinges, for the purpose of affording convenient passage into and out of inclosed grounds, or other places.

In the constructing of gates, of whatever kind or form they may be, the materials should constantly be well prepared by proper seasoning before they are put together; as, where this is not the case, they soon become much injured by their constant exposure to the effects of the sun and wind. They also require that the different parts be put together with considerable accuracy and correctness. In respect to durability, there can be no doubt but that oak is by much the best sort of wood to be employed; but some of the more light kinds of wood, such as those of the deal, willow, and alder sorts, answer the purpose extremely well, and are very durable, as, on account of their lightness, they do not destroy themselves so much in shutting. It is found by experience that the lighter gates can be made in their foreparts, so that they be sufficiently strong for the intended purpose, the better they answer. For this reason, in some cases, as where horses are chiefly to be confined, the top bars, by being left of more strength, may admit of the others having less substance; but if this be not done, they are apt to be broken by the horses rubbing their necks upon them, unless where they are made of great height.

The width of gates for general purposes is mostly from eight and a half to nine feet, and the height from five to six feet; the bars being five or six in number, and each four or five inches in breadth. Hence they are frequently denominated five or six-barred gates. In cases where fowls or other small animals are to be guarded against, it is better to run a smaller bar between the two lowermost ones, as by this means their passage is prevented.

Gate, in *Engineering*, is applied to the close-boarded doors of locks or sluices on canals or rivers, for penning up the water: in a lock these are distinguished by upper-gates and lower-gates, according as they are placed at the head or tail of the lock.

Gate-House, a building erected over a gate, or that through which entrance was obtained into the main building. Gate-houses were very usual in the erections of the middle ages, and were employed in all large buildings, ecclesiastical, military, and civil, also as entrances to fortified cities; thus in London we still preserve the names of several gate-ways in the old wall, as New-gate, Bishops-gate, Lyd-gate, &c., at each of which places was formerly a gate-house, through which entrance was obtained within the city. These buildings were often of an imposing character; and in military works consisted, for the most part, of a large arch-way with groined ceiling, and a portcullis at each end, flanked by two massive projecting towers, pierced with loop-holes, through which to annoy the enemy, and surmounted by a battlemented parapet. Those attached to civil and ecclesiastical buildings were generally of a more ornamental description, sometimes consisting of only a square tower with a turret at one or more angles, having a large arch-way in the centre with groined ceiling and room above, the window of which—frequently an oriel—formed a picturesque addition to the elevation. The forms of these gate-houses were, however, various, and admitted of different degrees of ornamentation. In some cases, there was a small arch-way by the side of the principal one for foot-passengers, and in others a similar one on either side; they were called posterns. Remains still exist in most of the old towns, amongst the most remarkable of which are those of Battle Abbey, Sussex, Bristol, Bury St. Edmund's, St. John's Gate, Clerkenwell, and St. Augustine's College, Canterbury.

Gate-way, the passage through which entrance is obtained into a town, building, &c.

GATHERING OF THE WINGS, in a chimney, the sloping part above the fire-place, where the funnel contracts or tapers till it reaches the tube or flue.

GAVEL, the same as Gable, which see.

GAUGE, *See* Gage.

Gauge, a term applied to signify the width between the rails on a railway.

GEMMEL, Gymmer, or Chymol, an ancient term for a hinge.

GENERATING LINE, or Plane, in geometry, is a line, or plane, moving according to a given law, either round one of its extremities, as a fixed point or axis, or parallel to itself, in order to generate a plane figure or solid, which is formed by the space it has gone over.

GENESIS, (from the Greek, *γένεσις*, *origin*, or *beginning*) in geometry, the formation of a line, plane, or solid, by the motion of a line, plane, or surface; thus, a sphere is conceived to be generated by the motion of a semicircle revolving on its diameter, which is called *the axis of circumvolution*. A triangle may be conceived to be generated by the motion of a line parallel to its base, in such a manner that the describing line must be a fourth proportional to the base, the altitude, and the distance of the line from the vertex of the triangle.

In the genesis of figures, the moving point, line, or surface, is called *the describent*, and the line round which, or according to which, the revolution is made, *the dirigent*.

GENTESE, in Early English architecture, cusps or featherings in the arch of a doorway.

GEOD'ESY, that branch of applied mathematics which determines the figures and areas of large portions of the earth's surface, the general figure of the earth, and the variations of the intensity of gravity in different regions by means of direct observation and measurement.

GEOLOGY, the science which treats of the internal structure of the earth as far as we have been able to penetrate below its surface, of the arrangement of the materials of which it is composed, and of the changes which have taken place in them.

GEOMETRICAL, something that has a relation to geometry: thus we say, geometrical method, geometrical genius, geometrical strictness, geometrical construction, geometrical demonstration, &c.

Geometrical Locus, or Place. *See* Locus.

Geometrical Pace, a measure of five feet.

Geometrical Plan. *See* Plan.

Geometrical Plane, in perspective, the same as *ground plane*, or *original plane*.

Geometrical Solution of a Problem, a solution according to the strict principles of geometry, by lines that are truly geometrical.

In this sense, we say, *a geometrical solution*, in contradistinction to *a mechanical* or *an instrumental solution*, where the problem is only solved by ruler and compasses.

Geometrical problems are distinguished into three kinds, viz., plane, solid, and linear.

Plane problems are such as may be solved by a right line and a circle.

Solid problems are derived from the consideration of a solid that is a cone.

Linear problems are derived from lines more compounded.

Geometrical Stair, such as is only supported by the wall at the one end of the steps, with a continued string at the other.

GEOMETRY, (from the Greek, *γεωμετρια*, formed of *γεα* or *γη*, *earth*, and *μετρεω, to measure*) the doctrine, or science of extension, or things extended, viz. of lines, surfaces, or solids. Geometry has also been defined in general terms as the science of space.

According to Herodotus, Strabo, and Diodorus, the Egyptians were the first inventors of geometry, and it is asserted by these ancient writers, that to the annual inundations of the Nile, we are to attribute the first steps in this science. That river, in its overflowings, bearing away all the bounds and landmarks of men's estates, and covering the whole face of the country, the people were obliged to distinguish their lands by the consideration of their figure and quantity; and thus, by experience and habit, they formed to themselves a method, or art, which was the origin of geometry. A farther contemplation of the draughts of figures of fields thus laid down, and plotted in proportion, might, naturally enough, lead them to the discovery of some of their excellent and wonderful properties; and as these speculations continually improved, so the art gradually improved also, until it attained the perfection of the present day. Josephus, however, seems to attribute the invention to the Hebrews; and others, among the ancients, make Mercury the inventor.

From Egypt, geometry passed into Greece, being carried thither, as some say, by Thales, where it was much cultivated and improved by himself, Pythagoras, Anaxagoras of Clazomene, Hippocrates of Chios, and Plato. The latter testified his conviction of the necessity and importance of geometry, in order to the successful study of philosophy, by the following inscription on the door of his academy: "*Let no one ignorant of geometry enter here.*" Plato, conceiving that geometry was too mean and restricted an appellation for this science, substituted for it the more extensive name of *mensuration;* and others have denominated it *pantometry.* Other more general and comprehensive appellations are perhaps more suitable to its extent, especially in the present advanced state of the science; and accordingly, some have defined it as *the science of inquiring, inventing, and demonstrating all the affections of the magnitude.* Proclus calls it *the knowledge of magnitudes and figures, with their limitations;* as also of their ratios, affections, positions, and motions of every kind. About fifty years after Plato, lived Euclid, who collected together all those theorems which had been invented by his predecessors in Egypt and Greece, and digested them into fifteen books, intitled the *Elements of Geometry;* and those propositions which were not satisfactorily proved, he more accurately demonstrated. The next to Euclid, of those ancient writers whose works are extant, is Apollonius Pergæus, who flourished in the time of Ptolemy Euergetes, about two hundred and thirty years before Christ, and about one hundred years after Euclid. The third ancient geometer, whose writings remain, is Archimedes of Syracuse, who was famous about the same time with Apollonius. We can only mention Eudoxus of Cnidus, Architas of Tarentum, Philolaus, Eratosthenes, Aristarchus of Samos, Dinostratus, the inventor of the quadratrix, Menechmus, his brother, and the disciple of Plato, the two Aristeuses, Conon, Thrasideus, Nicoteles, Leon, Theudius, Hermotimus, and Nicomedes, the inventor of the conchoid; besides whom there are many other ancient geometers, to whom this science is indebted.

The Greeks continued their attention to geometry, even after they were subdued by the Romans. Whereas the Romans themselves were so little acquainted with this science, even in the most flourishing time of their republic, that they gave the name of mathematicians, as Tacitus informs us, to those who pursued the chimeras of divination and judicial astrology. Nor were they more disposed to cultivate geometry, as we may reasonably imagine, during the decline, and after the fall of the Roman empire. The case was different with the Greeks; among whom we find many excellent geometers, since the commencement of the Christian era, and after the translation of the Roman empire. Ptolemy lived under Marcus Aurelius; and we have, extant, the works of Pappus of Alexandria, who lived in the time of Theodosius; the commentary of Eutocius, the Ascalonite, who lived about the year of Christ 540, on Archimedes' mensuration of a circle; and the commentary on Euclid, by Proclus, who lived under the empire of Anastasius.

The consequent inundation of ignorance and barbarism was unfavourable to geometry, as well as to the other sciences; and those few who applied themselves to this science, or indeed to any branch of learning incomprehensible by the vulgar, were calumniated as magicians. In those times of European darkness, the Arabians were distinguished as the guardians and promoters of science; and from the ninth to the fourteenth century they produced many astronomers, geometers, geographers, &c., from whom the mathematical sciences were again received into Spain, Italy, and other parts of Europe, somewhat before the beginning of the fifteenth century. Some of the earliest writers after this period, are Leonardus Pisenus, Lucas Paciolus or de Burgo, and others who flourished between 1400 and 1500. After this period appeared many editions of Euclid, or commentaries upon his *Elements; e.g.*, Orontius Fineus, in 1530, published a commentary on the six first books; as did James Peletarius in 1557; and about the same time, Nicolas Tartaglia published a commentary on the whole fifteen books. We might also mention other editions or commentaries; such as those of Commandine, Clavius, Billingsly, Scheubelius, Harlinus, Dasypodius, Ramus, Herigon, Stevinus, Saville, Barrow, Tacquet, Dechales, Furnier, Scarborough, Keill, Cann, Stone, and many others.

At the revival of letters, there were few Europeans capable of translating and commenting on the works of the ancient geometers; and geometry made consequently but little progress till the time of Des Cartes, who published his *Geometry* in 1637. However, not to mention all those who extended geometry beyond its elementary parts, such as Theodosius, in his *Spherics*, Serenus, in his *Sections of the Cone and Cylinder;* Kepler, in his *Nova Stereometria*, &c.; in 1635, Bonaventure Cavalerius, an Italian, of the order of Jesuits, published his *Geometry of Indivisibles;* Torricelli, his *Opera Geometrica;* Viviani, his *Divinationes Geometricæ*, *Exercitatio Mathematica*, *De Locis Solidis*, *De Maximis et Minimis*, &c.; Vieta, *Effectio Geometrica*, &c.; Gregory St. Vincent, in 1647, published his treatise, intitled *Quadratura Circuli et Hyperbolæ*, a work abounding with excellent theorems and paralogisms; and Pascal, about the same time, published his *Treatise of the Cycloid.* Geometry, as far as it was capable of deriving aid and improvement from the arithmetic of infinites, was indebted to the labours of Fermat, Barrow, Wallis, Mercator, Brounker, J. Gregory, Huygens, and others; to whom we may add Newton and Leibnitz. But Sir Isaac Newton contributed to the progress of pure geometry by his two treatises, *De Quadratura Curvarum*, and *Enumeratio Linearum Tertii Ordinis:* and still farther by his incomparable and immortal work, intitled, *Philosophia Naturalis Principia Mathematica*, which will always be considered as the most extensive and successful application of geometry to physics.

The modern Geometers are innumerable; and the names of Cotes, Maclaurin, R. Simpson, T. Stewart, T. Simpson, &c. not to mention living writers, will always be held in esteem and veneration by those who are devoted to the study of geometry and mathematics.

The province of geometry is almost infinite: few of our ideas but what may be represented to the imagination by lines, upon which they become of geometrical consideration: it being geometry alone that makes comparisons and finds the relations of lines.

Architecture, mechanics, astronomy, music, and in a word, all the sciences which consider things susceptible of more and less, *i. e.* all the precise and accurate sciences, may be referred to geometry; for all speculative truths consisting only in the relations of things, and in the relations between those relations, they may be all referred to lines. Consequences may be drawn from them; and these consequences, again, being rendered sensible by lines, become permanent objects, which may be constantly exposed to a rigorous attention and examination: thus affording to us infinite opportunities both of inquiring into their certainty, and pursuing them farther.

Geometrical lines and figures are not only proper to represent to the imagination the relations between magnitudes, or between things susceptible of more and less; as spaces, times, weights, motions, &c., but they may even represent things which the mind can no otherwise conceive, for example, the relations of incommensurable magnitudes.

It must be observed, that this use of geometry among the ancients was not strictly scientifical, as among us; but rather symbolical: they did not argue, or deduce things and properties unknown, from lines, but represented or delineated by them things that *were* known. In effect, they were not used as means or instruments of discovering, but as images or characters, to preserve, or communicate, the discoveries already made.

The ancient geometry was confined to very narrow bounds, compared with the modern. It only extended to right lines and curves of the first order, or conic sections; whereas in modern geometry new lines, of infinitely more and higher orders, are introduced.

Geometry is commonly divided into four parts, or branches; Altimetry, Stereometry, Planimetry, and Longimetry. See those words.

It is again distinguished into *theoretical* or *speculative*, and *practical*. The first contemplates the properties of continuity; and demonstrates the truth of general propositions, called *theorems*. The second applies those speculations and theorems to particular uses in the solution of *problems*. Speculative geometry, again, may be distinguished into *elementary* and *sublime*. The former is that employed in the consideration of right lines and plane surfaces, and solids generated from them. The *higher* or *sublime* geometry is that employed in the consideration of curve lines, conic sections, and bodies formed of them.

The science of geometry is founded on certain axioms, or self-evident truths; it is introduced by definitions of the various objects which it contemplates, and the properties of which it investigates and demonstrates, such as points, lines, angles, figures, surfaces and solids:—lines again are considered as straight or curved; and in their relation to one another, either as inclined or parallel, or as perpendicular:—angles, as right, oblique, acute, obtuse, external, vertical, &c.:—figures, with regard to their various boundaries, as triangles, which are in respect to their sides equilateral, isosceles, and scalene, and in reference to their angles, right-angled, obtuse-angled, and acute-angled; as quadrilaterals, which comprehend the parallelogram, including the rectangle and square, the rhombus and rhomboid, and the trapezium and trapezoid; as multilaterals or polygons, comprehending the pentagon, hexagon, heptagon, &c.; and as circles;—also as solids, including a prism, parallelopipedon, cube, pyramid, cylinder, cone, sphere, and the frustum of either of the latter.

For practical geometry, the fullest and most complete treatises are those of Mallet, written in French, but without the demonstrations; and of Schwenter and Cantzlerus, both in high Dutch. In this class are likewise to be ranked Clavius's, Tacquet's, and Ozanam's *Practical Geometries;* De la Hire's *Ecole des Arpenteurs;* Reinholdus's *Geodæsia;* Hartman Beyers's *Stereometria;* Voigtel's *Geometria Subterranea;* all in high Dutch: Hulsius, Galileus, Goldmannus, Scheffelt, and Ozanam, *on the Sector*, &c. &c. An excellent treatise on practical geometry, particularly with reference to the study of architecture and perspective, was published some years ago by Mr. Peter Nicholson, and still holds its ground in public estimation, notwithstanding the numerous works on the subject which have appeared from time to time. The following short essay on Practical Geometry, containing the formation of plain figures arising from straight lines and circles, will also be found exceedingly useful in the study of architectural construction. Curves of variable curvature, as those arising from the sections of a cone by a plane, will be found under their respective heads; as, Conic Sections, Ellipsis, &c.

Geometry, *Analytical*, or *Descriptive*, the method of finding the situation of a point in a plane. *See* Descriptive Geometry.

Geometry, *Practical*, the method of reducing or applying the rules of the science to practice, examples of which will be found in the following problems.

Problem I.—*In a right line,* A B, *from any given point,* C *to erect a perpendicular.*

Figure 1.—When the given point is near the middle of the line. On each side of the point C, on the line A B, take any two equal distances, as C *d*, C *e;* from *d* and *e*, with any radius greater than C *d*, or C *e*, describe arcs of equal radii, cutting each other in F; through the points F and C, draw the right line F C, and it will be the perpendicular required.

Figure 2.—When the given point is at or near the end of the line. Take any other point, as *d*, in A B; from *d*, with the distance *d* C, describe an arc, C *e f;* take the portion C *e*, of the arc, at pleasure, and make the portion *e f* equal to C *e;* draw the chord C *g f;* from C, with the radius C *e*, describe the arc *g e* H; make *e* H equal to *e g;* and through the points C and H draw the right line C H, which is the perpendicular required.

Figure 3.—Another method. Take any other point, *d*, as before: from C, with the distance C *d*, describe an arc, *d e f;* from *d*, with the same radius, describe an arc at *e;* from *e*, with the same radius, describe an arc at G; draw *d e* G, and through the points G and C draw G C, which is the perpendicular required.

Problem II.—*From a given point,* C, *to drop a perpendicular upon a given right line,* A D.

Figure 4.—In A B, take any two points, *f* and *g;* and from either point, *f*, with the radius *f* C, describe an arc, C E; from *g*, with the distance *g* C, describe arcs at C and E, of equal radii; and draw the right line C E, which is the perpendicular required.

Figure 5.—Another method. From the point C, describe an arc, *f g*, cutting A B at *f* and *g;* from the points *f* and *g*, with any equal radii greater than the half of *f g*, describe two arcs, cutting each other in D; draw C D, and C D is perpendicular to A B, and drawn from the point C, as required.

PROBLEM III.—*To draw a right line parallel to a given right line,* A B, *at a given distance,* C D.

Figure 6.—Take any points, as *e* and *f*, in the right line A B; then, with the distance C D, from the points *e* and *f*, describe arcs, G and H, of equal radii; draw the right line G H to touch the arcs at G and H; and G H will be parallel to A B, at the distance C D, as required.

PROBLEM IV.—*Through a given point,* C, *to draw a right line parallel to a given right line,* A B.

Figure 7.—In A B, take any two points, as *d* and *e*, and draw C *d;* make the angle B *e* F equal to the angle B *d* C; make *e* F equal to *d* C; and draw the right line C F, which passes through the point C, and is parallel to A B, as required.

Figure 8.—Another method. Take any point, as *e*, in A B, and from *e*, with the distance *e* C, describe an arc, C *d*, cutting A B in *d;* from C, with the same distance, C *e*, describe an arc, *e* F; make *e* F equal to *d* C; draw the right line C F, and it will pass through C, parallel to A B, as required.

PROBLEM V.—*To bisect a right line,* A B, *by a perpendicular.*

Figure 9.—Take any distance greater than the half of A B; from the points A and B, describe arcs of equal radii, cutting each other at C and D; draw C D, and it will be perpendicular to A B, and bisect A B at the point E, as required.

PROBLEM VI.—*At a given point,* E, *in a right line,* E F, *to make an angle equal to a given angle,* A B C.

Figures 10 *and* 11.—From B, with any radius, describe an arc, as *g h*, cutting B C at *g*, and B A at *h;* from E, with the same radius, describe another arc, *i k*, meeting E F at *i;* make *i k* equal to *g h;* draw the right line E *k* D; and the angle D E F is equal to the angle A B C, as required.

PROBLEM VII.—*To bisect a given angle,* A B C.

Figure 12.—From A B, cut off any part, as B *d;* take the part B *e* from B C, equal to B *d;* from the points *d* and *e*, with any distance greater than the half of *d e*, describe arcs of equal radii, cutting each other at F; draw F B, and it will bisect the angle A B C, as required.

PROBLEM VIII.—*To bisect a given arc,* A B C, *of a circle.*

Figure 13.—Draw the chord A C; bisect A C by a perpendicular, B D; and the point B will divide the arc A B C into two equal arcs, A B, B C.

PROBLEM IX.—*A circle,* A B C A, *and a tangent,* D E, *to the circumference, being given to find the point of contact.*

Figure 14.—Let the centre, F, be given; draw F A perpendicular to D E; and the point, A, where it cuts the tangent, is the point required.

Figure 15.—If the centre be not given, draw the chord F G, parallel to the tangent D E; bisect F G by a perpendicular, H A, meeting the tangent at A; then A is the point of contact required.

PROBLEM X.—*An arc,* A B C, *and a point* B, *in the circumference being given; to draw a tangent through the point,* B.

Figure 16.—From the point B, cut off two equal arcs, B D, and B E; draw the chord D E; through B, draw F G, parallel to D E; and F G is the tangent sought.

PROBLEM XI.—*Given a circle,* A B C, *and a straight line,* D E, *equal to, or less than the diameter; from a given point,* A, *in the circle, to inscribe a chord equal to* D E.

Figure 17.—From the point A, with a radius equal to D E, describe an arc, cutting the circumference at B; draw A B, which is the chord required.

PROBLEM XII.—*In a given circle,* A D C D, *to inscribe an equilateral triangle; or to divide the circle into three equal parts.*

Figure 18.—With the radius of the circle cut off the arcs A D, D B; join A B; from A, with the radius A B, describe an arc, cutting the circumference at C; join A C, C B; and A B C is the equilateral triangle required.

PROBLEM XIII.—*In a given circle,* A B C D A, *to inscribe a square; or to divide the circumference into four equal parts.*

Figure 19.—Through the centre, E, and any point, A, in the circumference, draw the diameter A C; and the diameter B E D, perpendicular to A E C; draw the chords A B, B C, C D, D A; and A B C D A will be the square required.

PROBLEM XIV.—*In a given circle,* A B C D E A, *to inscribe a pentagon; or to divide the circumference into five equal parts.*

Figure 20.—Draw the diameters A *i f* and *g i h* at right angles to each other; bisect the radius *g i* at *k;* from *k*, with the distance *k* A, describe an arc A *l*, cutting *g h* at *l;* and from A, with the distance A *l*, describe an arc cutting the circle at B; draw the chord A B; make the successive chords, A B, B C, C D, D E, each equal to A B; join E A, and A B C D E A will be the pentagon required.

PROBLEM XV.—*In a given circle,* A B C D E F A, *to inscribe a hexagon; or to divide the circle into six equal parts.*

Figure 21.—From any point, as A, draw the successive chords A B, B C, C D, D E, E F, each equal to the radius, and join the last, F A; then A B C D E F A will be the hexagon required; or the circle will be divided into six equal parts.

COROLLARY.—Hence, by the first of the three last problems, the circle may be divided into eight equal parts; by the second, it may be divided into ten equal parts; and by the third, it may be divided into twelve equal parts, only by bisecting the arcs: and if each arc be again bisected, each circle will be divided into four times the number of equal parts, as at first. The above are the only truly geometrical methods of dividing circles into equal parts, no general method having been discovered.

PROBLEM XVI.—*Upon a given straight line,* A B, *to describe an equilateral triangle.*

Figure 22.—From the points A and B, with the distance A B, describe arcs, cutting each other in C; draw C A and C B; and A B C is the equilateral triangle required.

PROBLEM XVII.—*Upon a given straight line,* A B, *required to describe a square, or tetragon.*

Figure 23.—Bisect A B by a perpendicular *e i;* make *e i* equal to the half of A B; from *i*, with the distance *i* A or *i* B, describe a circle; draw the chords B C, C D, equal to A B; join D A; and A B C D is the square or tetragon required.

PROBLEM XVIII.—*Upon a given straight line,* A B, *to describe a regular pentagon.*

Figure 24.—Draw B *f* perpendicular and equal to the half of A B; produce A *f* to *g*, making *f g* equal to *f* B; from the points A and B, with the radius B *g*, describe arcs, cutting each other at *i;* from *i*, with the radius *i* A, or *i* B, describe a circle; inscribe the successive chords B C, C D, D E, each equal to A B; join E A; and A B C D E A is the pentagon required.

PROBLEM XIX.—*Upon a given straight line,* A B, *to describe a regular hexagon.*

Figure 25.—From the points A and B, with the distance A B, describe arcs, cutting each other at *i;* from *i*, with the distance C A, or C B, describe a circle, A B C D E F A; make the successive chords B C, C D, D E, E F, each equal to A B, and join F A; and A B C D E F is the hexagon required.

PROBLEM XX.—*Upon a given straight line,* A B, *to describe an octagon, a decagon, or a dodecagon.*

Figures 26, 27, *and* 28.—Find the centre, *i*, of a circle, by such of the three last Problems as will contain a polygon of half the number of sides required; draw *i k* upwards, perpendicular to A B, equal to *i* A or *i* B; and the point *k* will

GEOMETRY.

PRACTICAL.

PLATE. I.

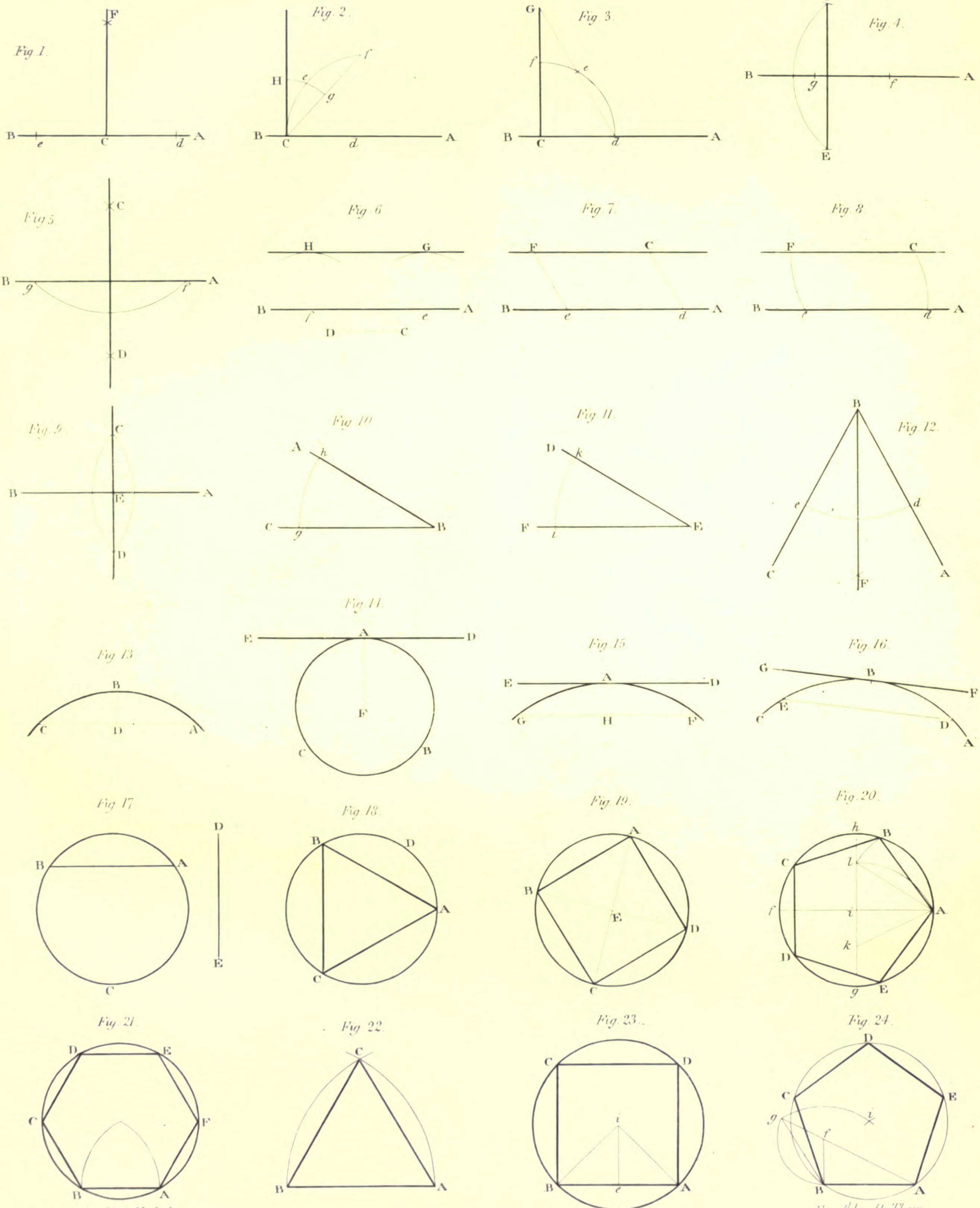


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Fig. 25.

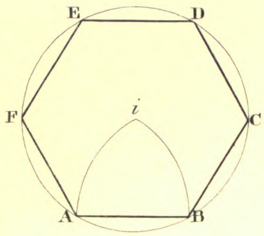


Fig. 26.

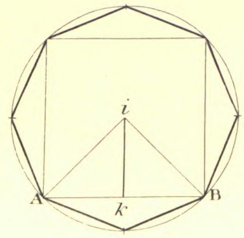


Fig. 27.

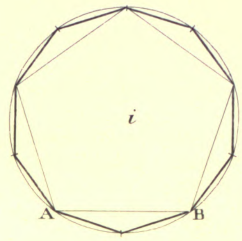


Fig. 28.

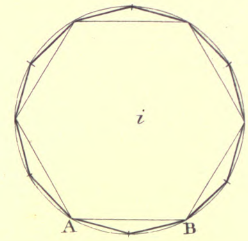


Fig. 29.

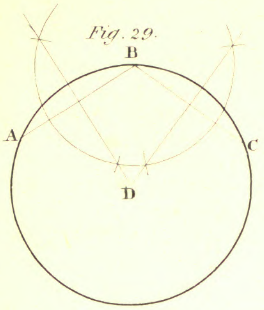


Fig. 30

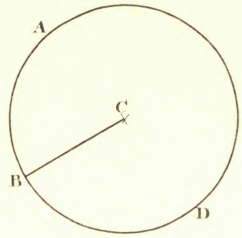


Fig. 31.

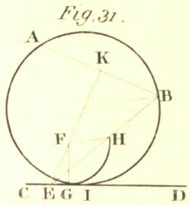


Fig. 32.

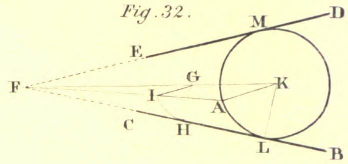


Fig. 33.

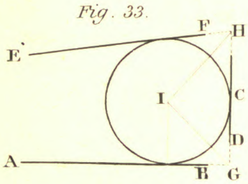


Fig. 34.

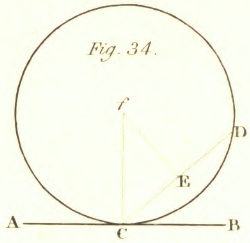
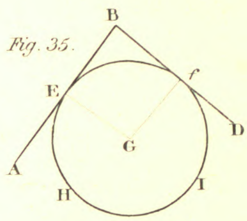


Fig. 35.



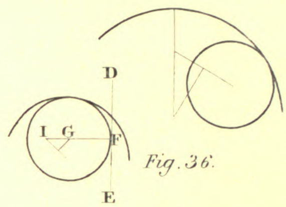


Fig. 36.

Fig. 37.

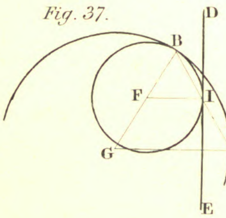


Fig. 38

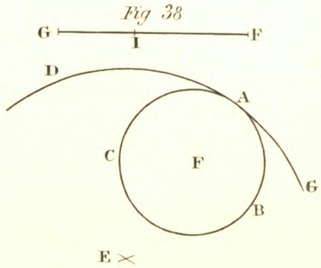


Fig. 39.

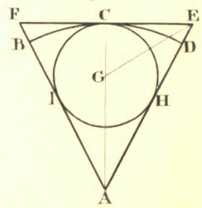


Fig. 40.

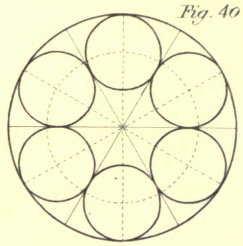


Fig. 41.

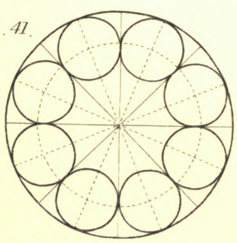


Fig. 42.

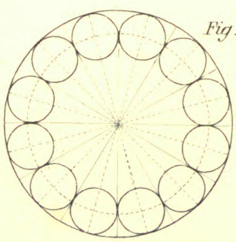


Fig. 43.

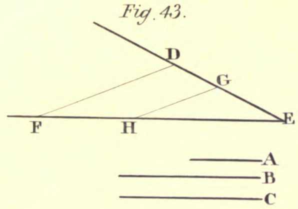


Fig. 44.

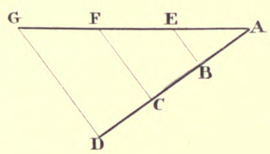


Fig. 45.

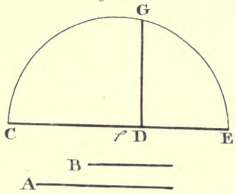


Fig. 46.

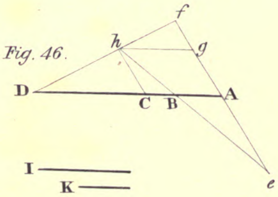


Fig. 47.

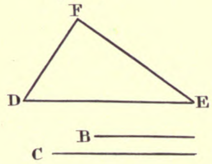
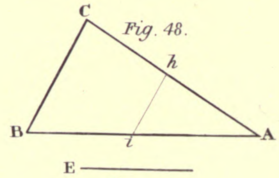


Fig. 48.



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be the centre of a circle that will contain the polygon required.

EXAMPLE I. *Figure* 26.—For an octagon, find the centre, *i*, as in Problem XIII.

EXAMPLE II. *Figure* 27.—For a decagon, find the centre, *i*, as in Problem XIV.

EXAMPLE III. *Figure* 28.—For a dodecagon, find the centre, *i*, as in Problem XV.

Complete the remaining parts as above directed; and thus a circle may be found to contain any duplical multiple of these sides.

PROBLEM XXI.—*Through three given points*, A, B, C, *to describe the circumference of a circle, provided the three points be not in the same straight line.*

Figure 29.—Join A B and B C, and bisect them by perpendiculars meeting each other at D; from D, with the distance A D, of either point, describe a circle, and its circumference will pass through the other two points B and C.

PROBLEM XXII.—*To describe a circle of a given radius through two given points*, A *and* B, *provided the radius be greater than half the distance between the two given points.*

Figure 30.—From A, with the given radius, describe an arc from B; with the same radius, describe another arc, cutting the former at C; from C, with the distance C A, or C B, describe the circle A B D; and it will be the circle required.

PROBLEM XXIII.—*To describe a circle to pass through two given points*, A *and* B, *and touch a straight line*, C D; *provided the two points and the straight line be not in the same straight line.*

Figure 31.—Produce A B and D C, to meet in E; bisect the angle A E D by the straight line E F; bisect A G by the perpendicular G F; from the point of concourse, F, with the radius F G, describe a circle, G H I K, which is the circle required.

PROBLEM XXIV.—*To describe a circle to pass through a given point*, A, *and touch two straight lines*, B C *and* D E, *provided that the point be situated between the two lines.*

Figure 32.—Let the two lines, B C and D E, if not parallel, meet in F; join A F; bisect the angle B F D, by the straight line F K; in F K, take any point, as G, and draw G H, perpendicular to B C; from G, with the distance G H, describe an arc, H I, cutting A F at I; join I G, and draw A K parallel to I G and K L parallel to G H; cutting D F at L; from K, with the radius K L, describe a circle L A M, which will be the circle required.

PROBLEM XXV.—*To describe a circle that shall touch three straight lines*, A B, C D, E F, *provided all the three lines be not parallel.*

Figure 33.—Produce the lines, so that one of them, as C D, may meet the other two, A B and E F; and let the meeting of A B with C D, be at G, and of C D with E F at H; bisect the angles B G H and G H F by the straight lines G I and H I; from I, drop a perpendicular, I C, to any one of the three lines, C D; from I, with the distance I C, describe a circle, and it will touch the three straight lines A B, C D, E F, as required.

PROBLEM XXVI.—*To describe a circle that may touch a straight line*, A B, *at a given point*, C, *and pass through another given point*, D.

Figure 34.—Draw C *f* perpendicular to A B; join C D, which bisect by a perpendicular, E *f*; from *f*, with the distance *f* C, describe a circle, which will be the circle required.

PROBLEM XXVII.—*To describe a circle that shall touch a straight line*, A B, *at a given point*, E, *and another straight line*, B D, *provided that the two straight lines be not in the same straight line.*

Figure 35.—Make B *f* equal to B E; draw E G perpendicular to A B, and *f* G perpendicular to B D; from G, with the radius E G, or *f* G, describe the arc, H E *f* I, and it will touch A B at E and B D, as required.

PROBLEM XXVIII.—*To describe an arc that shall touch a given circumference*, A B C, *and a straight line*, D E, *in a given point*, F.

METHOD I.—*Figure* 36. Draw F I perpendicular to D E; from F I, produced if necessary, cut off F G, equal to the radius of the circle A B C; join K G, which bisect by a perpendicular cutting F I at I; from I, with the radius I F, describe an arc, or circumference, A F H, which is the arc required.

METHOD II.—*Figure* 37. Draw F I perpendicular to D E, and A G parallel to F I; draw A F B and B I G; from I, with the distance I F, or I B, describe an arc, F B H, which is the arc required.

PROBLEM XXIX.—*With a given radius*, G H, *to describe an arc or circumference that may touch a given arc or circumference*, C A B, *and pass through a given point*, D.

Figure 38.—From G H cut off G I, equal to the radius of the given circle; from F, with the distance I H, describe an arc; from D, with the distance G H, describe another arc, cutting the former at E; from E, with the distance E A or E D, describe an arc, G A D, and the problem is solved.

PROBLEM XXX.—*In a given sector*, A B C D, *to inscribe a circle.*

Figure 39.—Bisect the angle B A D by A G C; draw E C F tangent to the circle; produce A B to E, and A D to F; bisect the angle E A F by A G, and the angles A E F by E G; from G, with the radius G C, describe a circumference, C H I, which is the solution required.

PROBLEM XXXI.—*In a given circle to inscribe any number of equal parts.*

Divide the given circumference into as many equal parts as the number of inscribed circles: from the points of division, draw radii, and the circle will be divided into equal sectors; in any one of these sectors inscribe a circle by the last Problem; bisect the angle contained by each two radii; from the centre of the given circle, with the distance of the centre of the circle inscribed in the sector, describe a circumference, cutting the lines which bisect the sectorial angles; and the points so cut are the centres.

EXAMPLES.

Figure 40.—The given circle contains six equal inscribed circles.

Figure 41.—The given circle contains eight equal inscribed circles.

Figure 42.—The given circle contains twelve equal inscribed circles.

PROBLEM XXXII.—*Any three straight lines* A B C, *being given, to find a fourth proportional.*

Figure 43.—Make any angle, as D E F; on the straight line E D, make E G equal to A, and E D equal to B; on the straight line E F, make E H equal to C; join G H; draw D F parallel to G H; and E F is the fourth proportional sought; or E G : E D : : E H : E F; that is, A : B : : C : E F.

N.B. When the lines B and C happen to be equal, the result or fourth term is called *a third proportional;* therefore, suppose B equal to C, then A : B : : B : E F. So that finding a third proportional is the same as finding a fourth, and may be considered as only a particular case of it; and in this construction E D and E H would be equal.

PROBLEM XXXIII.—*To divide a straight line*, A G, *in the same proportion as another line*, A D, *is divided by the points* B *and* C, &c.

Figure 44.—Join D G; draw B E and C F parallel to D G, cutting A G at E and F; then will A G be divided by E and F, as A D is by B and C; or A E, E F, F G are to one another and to the whole A G, as A B, B C, C D are to one another and to the whole A D. In the same manner may any given line be divided into equal parts.

PROBLEM XXXIV.—*Between two straight lines,* A *and* B, *to find a mean proportional.*

Figure 45.—Draw the straight line C D E; make C D equal to A, and D E equal to B; bisect C E in *f*; from *f*, with the distance *f* C or *f* E, describe the semi-circle C G E; draw D G perpendicular to C E; and D G is the mean proportional required. Then C D : D G : : D G : D F; that is, A : D G : : D G : B.

PROBLEM XXXV.—*To divide a straight line,* A B C D, *harmonically in the given ratio of* I *to* K.

Figure 46.—Draw any straight line, as *e* A *g f*; make A *e* and A *f* each equal to I, and A *g* equal to K; join *f h* D; draw *g h* parallel to A D, and *h* C parallel to *e f*; join *h* B *e*; then A D : D C : : A B : B C.

PROBLEM XXXVI.—*Any three straight lines,* A B C, *being given, to describe a triangle, provided the sum of any two be greater than the third.*

Figure 47.—Draw the straight line D E equal to A; from D, with the distance B, describe an arc; and from E, with the distance C, describe another arc, cutting the former at F; draw D F and E F; and D E F is the triangle required.

PROBLEM XXXVII.—*Given the base,* A B, *of a triangle, the angle,* B A C, *and the ratio,* E *to* F, *of the other two sides, to describe the triangle, provided that* E *be to* F *in a greater ratio than the radius to the sine of the given angle* B A C.

Figure 48.—Make A *h* equal to E; from *h*, with the distance F, describe an arc, cutting A B at *i*; draw *i h*, and B C parallel to *i h*; and A B C will be the triangle required.

PROBLEM XXXVIII.—*To make a rectilinear figure equal and similar to a given rectilinear figure.*

RULE.—Divide the given rectilinear figure into triangles, by lines drawn from some one of its angles; take any one of its sides, and make a straight line in any situation equal thereto; upon the straight line thus posited, constitute a triangle, equal to the triangle on the corresponding line of the given figure; upon the side of the triangle which is to form a diagonal of the figure required, constitute another triangle, equal to the corresponding one of the given figure; proceed to form triangles on each succeeding diagonal in the same manner, till all the triangles are constructed; and the figure thus composed will be equal and similar to the given figure.

PROBLEM XXXIX.—*To make a quadrilateral equal and similar to a given one,* A B C D.

Figure 49.—Divide the given quadrilateral into two triangles, by the diagonal A C; make E F, equal to A B; and describe the triangle E F G, having its sides respectively equal to the triangle A B C; upon E G, as a base, describe another triangle, E G H, equal to A C D; and the quadrilateral E F G H is equal and similar to the given one, A B C D, as required.

PROBLEM XL.—*To make a rectilinear figure similar to a given one,* M N O P Q, &c., *upon a given straight line,* A B; *the extremity,* A, *being given, but unlimited towards* B.

Figures 50 *and* 51.—From the extremities, M, of the side of the given figure, corresponding to the given point, A, draw diagonals to every angular point; cut off a part, A *n*, equal to the corresponding side, M N, of the given figure; upon A *n* construct a figure, A *n o p q*, &c., equal and similar to the given figure, M N O P Q, &c., by the preceding problem; from A B cut off A D equal to the side of the rectilinear figure to be described; draw D E parallel to *n o*, cutting the diagonal A E at E; draw E F parallel to *o p*, cutting the diagonal A F at F; proceed in this manner to draw each successive side parallel to the corresponding side of the figure constructed; from the extremity of the last diagonal, cut the next diagonal, and from the last diagonal, in the same manner, to the other side, adjoining the given point A; and the figure A D E F G, thus constructed, will be similar to the figure M N O P Q, &c. as required.

PROBLEM XLI.—*Given two adjoining sides,* A B, B C, *of a parallelogram in position and magnitude, to describe the parallelogram.*

Figure 52.—From C, with the opposite side A B, describe an arc; from A, with the opposite side B C, describe another arc, cutting the former at D; join A D and D C, and A B C D is the parallelogram required.

N.B. If the angle C B A be given in quantity, but not in position, make it equal to the given angle by Problem VI.

PROBLEM XLII.—*Given two sides,* A *and* B, *of a rectangle, to describe the rectangle.*

Figure 53.—Draw a straight line, C D, equal to A; draw C F perpendicular to C D; and make C F equal to B; then proceed as in the last Problem, and the parallelogram C D E F will be the rectangle required.

PROBLEM XLIII.—*Given the diagonal,* A B, *of a rectangle, and one of the sides, not exceeding the diagonal, to describe the rectangle.*

Figure 54.—On the diagonal A D, describe the circumference A C B D A; make the chords A C and B D equal to the given side; join A D and B C; and A D B C A is the rectangle required.

Figure 55.—If the rectangle be a square, bisect the diameter A B by another, C D; and draw the four equal chords, which will form the square required.

PROBLEM XLIV.—*To make a triangle equal and similar to a given trapezium,* A B C D.

Figure 56.—Draw the diagonal B D, and draw C E parallel to B D, meeting the side A B produced at E; join D E, and A D E will be the triangle required.

PROBLEM XLV.—*To make a triangle equal to any given right-lined figure,* A B C D E.

Figure 57.—Produce A B on both sides of its extremities towards F and G; draw the diagonals A D and B D; through E draw E F, parallel to A D; and through C draw C G parallel to B D; join D F and D G, then D F G is the triangle required.

PROBLEM XLVI.—*To reduce a triangle,* A B C, *to a rectangle.*

Figure 58.—Bisect the altitude C G in D; through D draw E F parallel to A B, and from B draw B F perpendicular to A B; draw A E and B F perpendicular to A B; then A B F E will be the triangle required.

PROBLEM XLVII.—*To make a rectangle, having a side equal to a given straight line,* A B, *equal to a given rectangle,* C D E F.

Figure 59.—Produce the sides C F, D E, F E, and C D of the rectangle; make E G equal to A B; through G draw L H parallel to F E, cutting C F produced at L; draw L E, the diagonal, which produce to cut C D at K; draw K H parallel to E G, and E I H G will be the rectangle required.

PROBLEM XLVIII.—*To make a parallelogram with a given angle equal to a given parallelogram,* A B C D.

Figure 60.—Make the angle B A E equal to the given angle, and let A E cut C D, produced if necessary at E; draw B F parallel to A E, cutting D C at F; then will the parallelogram A B F E be equal to the given parallelogram, A B C D.

PROBLEM XLIX.—*To make a square equal to a given rectangle,* A B C D.

Figure 61.—Produce A B, the side of the rectangle, and make B E equal to B C; bisect A E in I; on I, as a centre, with the radius I E or I A, describe a semicircle, A H E; produce the other side, C B, of the rectangle, to cut the circle in H; describe a square, B H G F, upon B H; then B H G F is the square required.

PROBLEM L.—*To make a square equal to two given squares.*

Figure 62.—Let A and B be the two given squares. Construct the right-angled triangle *c a b;* let one of the sides, *c a*, containing the right angle, be equal to the side of the square, A; and let the other, *a b*, be equal to the side of the square B. On *c b*, describe the square C, which is the square required.

In the same manner may a circle be made equal to two given circles; for, if *c a*, *a b*, be considered as diameters, or radii of the two given circles, *c b* will be a diameter or radii of a circle, equal in area to them both: and also in the same manner, if two similar rectilinear figures be given, a rectilinear figure may be found similar to either, and equal to both; for, if *c a* and *a b* be considered as homologous sides, that is, those which are opposite to the equal angles, *c b* will be the homologous side of the figure required.

PROBLEM LI.—*To make a square equal to three given squares.*

Figure 63.—Let A, B, C, be three given squares. Make a right angle, *c a b;* let *a c* be equal to the side of the square A, and *a b* equal to the side of the square B; join *b c*, and it will be the side of a square equal to A and B. Draw *b d* perpendicular to *b c*, and make *b d* equal to the side of the remaining square C; join *d c*, and it will be the side of a square equal to the three given squares, A, B, C, as was required.

From this process, it is evident that a square may be found equal to any given number of squares, by first finding one equal to any two of them, and then another equal to the square found, together with one of the remaining squares; then find another equal to the square last found, together with one of the other remaining squares; and so on, till all the squares are made use of, and the last square found will be equal to all the given squares.

SCHOLIUM.—It frequently happens in the description of the segment of a circle, when the height of the segment is very small in proportion to the chord, that there is no room to find the centre; the following problems show how to describe the arc without finding the centre:

PROBLEM LII.—*Having the chord and height of the segment of a circle, to describe the segment without finding the centre.*

Figure 64.—First Method.—Let A B be the chord of the segment, and C D its height; join D A and D B; make an instrument, E F G, so that the angle E F G may be equal to the angle A D B, and the sides F E and F G at least equal to the chord A B; put a pin at A, and another at B; slide the instrument along the pins, keeping the side F E close to the pin A, and F G to the pin B; a pencil being held at the angular point F will describe the arc A F B, as was to be done.

Figure 65.—Second Method.—Join D B, and draw D H parallel to B A; make an instrument, E F G, so that the angle E F G may be equal to the angle H D B, and the sides E F and E G at least equal to the half chord D B; put pins in the points A and D, and sliding the instrument along them, a pencil at F will describe half of the arc; and by moving the pin out of A, and putting it in B, the other half will be described in the same manner.

The former of these Problems depends on *Prop.* XXI. b. iii. *Euclid*, viz., that all the angles in the same segment of a circle are equal; and the latter, on *Prop.* XXXII. b. iii. *Euclid*, viz., that if a straight line touch a circle, and from the point of contact a straight line be drawn, cutting the circle, the angles made by such line with the line touching the circle, will be equal to the angles in the alternate segments.

Either of these instruments, in the description of flat segments, may be applied occasionally; but the latter, by reason of the obtuseness of the angle, slides with less friction along the pins, takes up much less room, and can be applied in any cases where it is impossible to use the other.

N.B.—If C D is very small, the instrument may be made in one piece.

Besides the methods here shown for the description of the segment of a circle from the rules of geometry, the following arithmetical rule will be found eligible on many occasions, particularly, where there is a want of a floor to draw the lines upon, or a want of space at the ends of the curve.

RULE.—Divide the square of the half chord by the versed sine, or height of the segment; add the height of the segment to the quotient; then half the sum is the radius of the circle.

EXAMPLE.—Suppose the chord of the segment of a circle to be 24 feet, and the versed sine or rise of the segment 5 feet; the radius of the circle is required.

```
2) 24
   ——
   12 half chord.
   12
   ———
5) 144
   ———
   28.8
    5
   ———
2) 33.8
   ———
   16.9 the radius required.
```

This is derived from *Prop.* XXXV. b. iii. *Euclid*, where it is shown, that if two straight lines in a circle cut each other, the rectangle under the segments or parts of the one, is equal to the rectangle of the segments of the other; and consequently, if the segments of one of the lines be equal to each other, the rectangle under the parts of the other line will be equal to the square of either part of the line, which is divided equally; but the contents of a rectangle, divided by one of its sides, gives the other side; or the area of the square, which is equal to the rectangle, being divided by the given side of the rectangle, gives the other side of the rectangle; and adding the versed sine, gives the diameter.

The method of dividing the circumference of a circle into any number of equal parts, or to inscribe any polygon therein, according to the approximation of Renaldinus, will be found under the article CIRCLE, Figure 5.

The various methods of describing the ellipsis upon a plane, will be found under the article ELLIPSIS; but, besides what is there shown, the following problems, concerning this curve, will also be found necessary in the art of perspective delineation.

PROBLEM LIII.—*Given the trapezium,* A B C D, *and a point,* E, *in one of the sides, to find a point in each of the other sides, so that if an ellipsis were to be inscribed, it would touch the trapezium in those points.*

Figure 66.—Produce the sides of the trapezium till they meet at K and L; then draw the diagonals A C and B D, cutting each other at F; produce B D, till it cut K L, at M. Through F, and the given point E, draw E G, cutting B C at G; and from M, through the points E and G, draw M H and M G, cutting the other two sides in the points I and H, then E, H, G, I, will be the four points required.

PROBLEM LIV.—*A trapezium*, A B C D, *being given, and a point*, E, *in one of the sides, to find the centre of an ellipsis that may be inscribed in the trapezium, and pass through the point of contact*, E, *without drawing any part of the ellipsis.*

Figure 67.—Find the points of contact H, G, I, E, as in the last Problem. Join the points G and E, by the right line G E; bisect it in M, and from K, where the opposite sides A D and B C meet, and through the point M, draw K M indefinitely; also join any other two points of contact, as H I; bisect H I and N from L, where the opposite sides B A and C D meet; draw L N, meeting K M at P; then P will be the centre of the ellipsis required.

In like manner, if the points G and H were joined, and bisected at Q, and a line being drawn from B, where the opposite sides A B and C B meet, through Q, it would also meet in P, the centre, &c.

PROBLEM LV.—*Given a trapezium*, A B C D, *and a point*, E, *in one of the sides, to find the two axes of an ellipsis that may be inscribed in the trapezium. and pass through the point*, E, *without drawing any part of the ellipsis.*

Figure 68.—Find the opposite points of contact, H, E, F, G, by Problem LIII.; from thence, find the centre, P, by the last Problem. From E, and through the centre P, draw E M, making P M equal to P E; and through H or any other point of contact, draw H K, parallel to D C, cutting E M at K; then K H is an ordinate to the diameter E M. Through P, the centre, draw P R parallel to H K; then find the extremities, R and S, of the diameter R S, by Problem 3, of ELLIPSIS. The conjugate diameters, E M and R S, being now found, then find the two axes, V W and X Y, by Problem 4, of ELLIPSIS.

GIBLEA CHEQUE, GIBLE CHECK, or JIBLET CHEEK, a recess made by cutting away the right angle formed by the front and returns of the aperture of a stone door-case, in the form of a rebate or reveal, so as to make the outside of the door, or closure, flush with the face of the wall. The term is used by stonemasons in Scotland.

GIGANTIC ORDER, a name given by Scamozzi to the Tuscan order.

GILDING, the art of applying to various substances an extremely thin coating of gold. If the substances to be gilt be metallic, this is effected by simple adhesion of the surfaces, but if not, the gold is attached by means of some adhesive medium. The use of gilding in the ornaments and decorations of an apartment, adds greatly to the richness of its appearance, but unless applied judiciously, and sparingly, it is apt to have a tawdry effect, most offensive to good taste.

GILL, a measure, the fourth part of a pint. The imperial gill now in use contains 8.6648125 cubic inches.

GIMLET, or GIMBLET, (from the French) a piece of steel of a semi-cylindrical form, hollow on one side, having a cross handle at one end, and a worm or screw below at the other: its use is to bore a small hole in a piece of wood. The screw draws the instrument forward into the wood while it is turned by the handle, and the excavated part, forming a sharp angle with the exterior, cuts the fibres across, and contains the core of wood cut out.

GINÆCONITES, (Greek) apartments in the surrounding porticos of the Greek houses, which contained the family rooms tricliniums and cubiculums. *See* HOUSE.

GIOCONDO, an architect, who flourished in the sixteenth century, was a native of Verona, where he first taught languages for a subsistence, and was also well qualified in mathematical learning. On visiting France, he was employed to build two bridges over the Seine. He very soon afterwards obtained the title of architect royal to the French king, but did not live long after; the exact period of his death is uncertain. He published several works which did him much credit as a writer, and extended his fame as an artist. Amongst others, an edition of Pliny's *Epistles*, and a correct edition of Vitruvius, illustrated with figures, the latter he dedicated to Pope Julius II. He assisted in editing many other works of the ancients, and was the first person who gave a design for Cæsar's bridge over the Rhine. In 1506, he wrote four dissertations, addressed to the magistracy of Venice, concerning the waters of that city. He was employed with Raphael and San Gallo, in superintending the erection of St. Peter's. His last work was probably the rebuilding of the stone bridge at Verona.

GIRANDOLE, (Italian) a chandelier; a large kind of branched candlestick.

GIRDER, (from the Saxon) a large beam, either of one entire piece, or consisting of several, in order to shorten the joists of a floor, which would otherwise have too great a bearing.

When girders are made double, they should be turned the contrary way to that in which they were sawn, that the stronger end may support the weaker. If it be found necessary to truss girders, the truss should be similar to that of a roof. The best form of girder for floors of moderate dimensions, consists of two braces and a straining piece, having one-third of the whole length, excepting the part at each end, which is necessary for the butment or wall-hold.

The two braces are strained by means of queen-bolts, and resisted at the other end by iron butments, which are formed to the same section as the braces, and are made to go through on each side, so as to have a bolt at either end; the braces and straining piece being let into each beam.

When girders have a very great bearing, and have only the depth of a single piece, it is well known that the strain at the joggles and abutments is prodigious: girders of long bearing should therefore be made into two flitches, one above the other, and braced as above.

By this plan, the depth allowing of an upper and lower beam, the girder will be infinitely more stiff than one of the depth of a single piece, and consequently more able to support the naked flooring and boarding.

No summers or girders should be over the heads of doors or windows.

No summer or girder should lie less than ten inches into the wall; nor joists less than eight inches.

The ceiling joists ought to be framed about half an inch below the girder, and the girder ought to be furred to the level of the ceiling joists.

Girders ought to be made of heart wood, as free from knots as possible, because they destroy the continuity of the fibres, and impair the strength of the girder.

The following rules for finding the scantlings, are given by Tredgold in his *Elementary Principles of Carpentry.*

"*Case* 1.—To find the depth of a girder when the length of bearing and breadth of the girder are given.

"*Rule.*—Divide the square of the length in feet, by the breadth in inches; and the cube root of the quotient multiplied by 4.2 for fir, or by 4.34 for oak, will give the depth required in inches.

"*Case* 2.—To find the breadth when the length of bearing and depth are given.

"*Rule.*—Divide the square of the length in feet, by the cube of the depth in inches; and the quotient multiplied by 74 for fir, or by 82 for oak, will give the breadth in inches.

"*Example to Case* 2.—Let the bearing be 20 feet, and the depth 13 inches; to find the breadth, so that the girder shall be sufficiently stiff.

GEOMETRY
PRACTICAL

PLATE III.

Fig. 49.

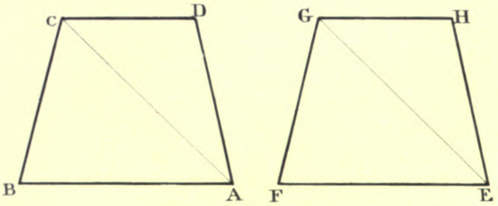


Fig. 50.

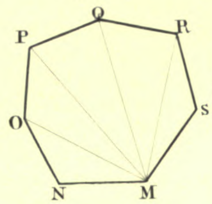


Fig. 51.

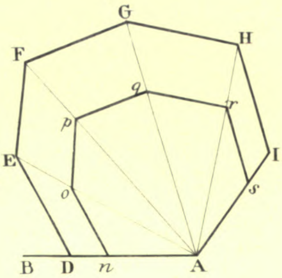
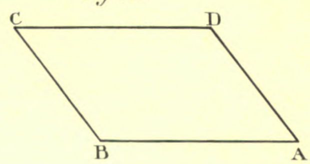


Fig. 52.



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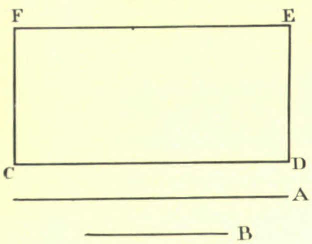

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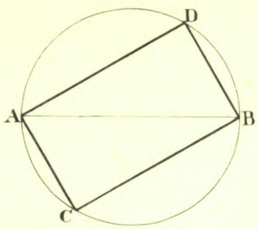

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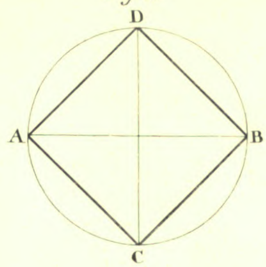


Fig. 56.

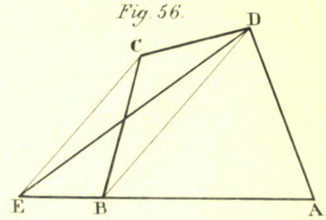
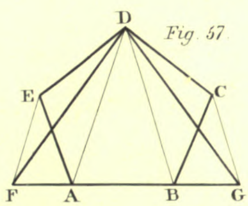


Fig. 57.



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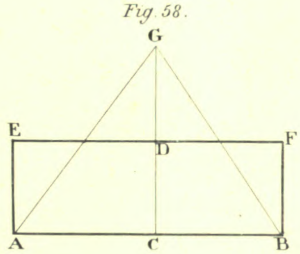


Fig. 59.

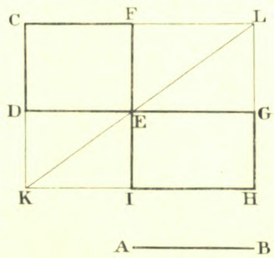


Fig. 60.

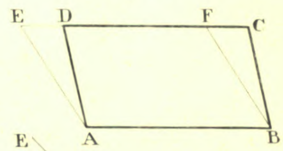


Fig. 61.

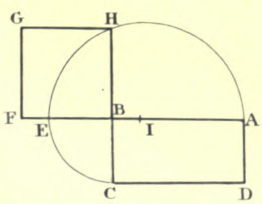


Fig. 62.

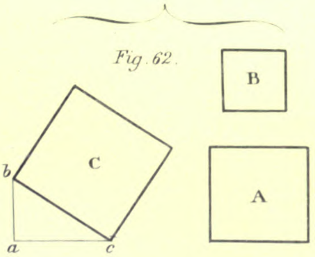


Fig. 63.

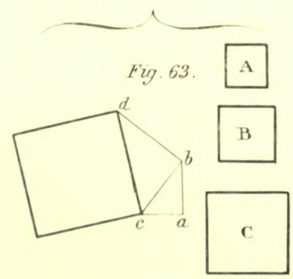


Fig. 64.

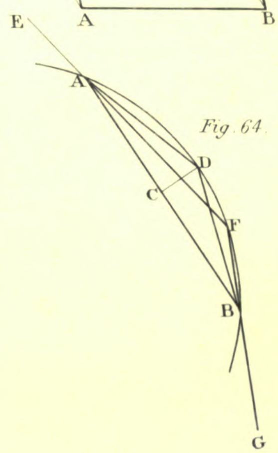


Fig. 65.

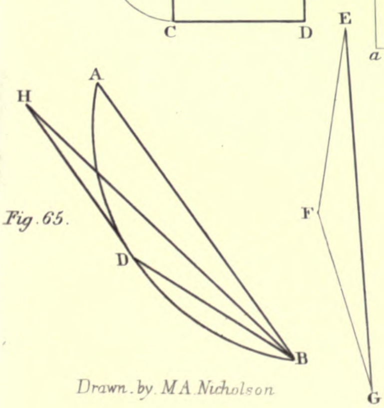


Fig. 66.

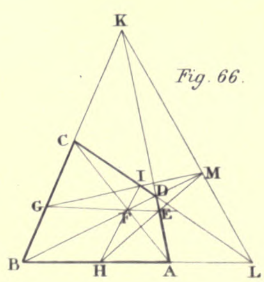


Fig. 67.

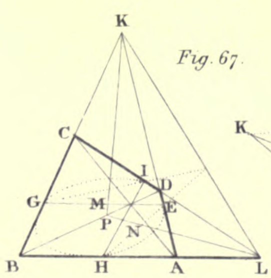
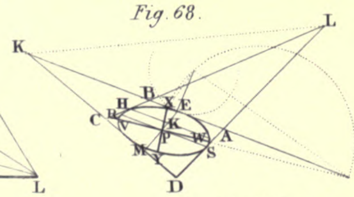


Fig. 68.



Drawn by M.A. Nicholson

Eng^d by R. Thew.

The cube of the depth is 2197, and the square of the length is 400; therefore $\frac{400}{2197} \times 74 = 13.47$ inches, the breadth required.

"In these rules, the girders are supposed to be 10 feet apart, and this distance should never be exceeded; but should the distance apart be less or more than 10 feet, the breadth of the girder should be made in proportion to the distance apart.

"When the bearing exceeds about 22 feet, it is very difficult to obtain timber large enough for girders; and it is usual, in such cases, to truss them. The methods in general adopted for that purpose, have the appearance of much ingenuity; but in reality, they are of very little use. If a girder be trussed with oak, all the strength that can possibly be gained by such a truss, consists merely in the difference between the compressibility of oak and fir, which is very small indeed; and unless the truss be extremely well fitted at the abutments, it would be much stronger without trussing. All the apparent stiffness produced by trussing a beam, is procured by forcing the abutments, or, in other words, by cambering the beam. This forcing, cripples and injures the natural elasticity of the timber; and the continual spring from the motion of the floor, upon parts already crippled, it may easily be conceived, will soon so far destroy them as to render the truss a useless burden upon the beam. This is a fact that has been long known to many of our best carpenters, and which has caused them to seek for a remedy in iron trusses; but this method is quite as bad as the former, unless there be an iron tie as an abutment to the truss; for the failure of a truss is occasioned by the enormous compression applied upon a small surface of timber at the abutments. The defects of ordinary trussed girders are very apparent in old ones, as it is not simply strength that is required, but the power of resisting the unceasing concussions of a straining force, capable of producing a permanent derangement in a small surface at every impression." Girders of wrought and cast iron are now used extensively in railway and canal works, for bridges, &c.

GIRDING BEAM. *See* Girder.

GIRDLE, (from the Saxon) a circular band or fillet surrounding a part of a column.

GIRT, the same as Fillet, which see.

Girt, in timber measure, according to some, the fourth part of the circumference, and is generally taken for the side of a square, equal in area to the section of the tree cut through where the perimeter is taken in order to obtain the girt.

GIVEN DATUM, a term frequently used in mathematics, signifying a thing supposed to be known, whether in position or magnitude; which is accordingly said to be *given in position*, or *in magnitude*, or both, as one or the other, or both, are known.

GLACIS, (French) an easy slope or declivity.

GLASS, (from the Saxon, *glaes*) a hard, brittle, transparent lactitious substance, formed by the fusion of silicious matter, such as powder flint or fine sand, blended with alkaline earth, metallic oxide, and other substances. In building, glass is used in thin transparent plates for windows, which admit light, while they exclude wind and rain.

The time at which glass was invented, is very uncertain. "It was known," says Dr. Ure, "to the Phenicians, and constituted for a long time an exclusive manufacture of that people, in consequence of its ingredients, (natron, sand, and fuel,) abounding upon their coasts. It is probable that the more ancient Egyptians were unacquainted with glass, for we find no mention of it in the writings of Moses. But, according to Pliny and Strabo, the glass-works of Sidon and Alexandria were famous in their times, and produced beautiful articles, which were cut, engraved, gilt, and stained of the most brilliant colours, in imitation of precious stones. The Romans employed glass for various purposes; and have left specimens in Herculaneum, of window-glass, which must have been blown by methods analogous to the modern. The Phenician processes seem to have been learned by the Crusaders, and transferred to Venice in the 13th century, where they were long held secret, and formed a lucrative commercial monopoly. Soon after the middle of the 17th century, Colbert enriched France with the blown mirror glass manufacture."

The application of glass to the glazing of windows, is of comparatively modern introduction, at least in northern and western Europe. In 674, artists were brought to England from abroad to glaze the church windows at Wearmouth in Durham; and even in the year 1567, this mode of excluding cold from dwellings was confined to large establishments, and by no means universal even in them. An entry then made, in the minutes of a survey of Alnwick Castle, the residence of the Duke of Northumberland, informs us that the glass-casements were taken down during the absence of the family to preserve them from accident. A century after that time, the use of window-glass was so small in Scotland, that only the upper rooms in the royal palaces were furnished with it, the lower part having wooden shutters to admit or exclude the air.

At an early period of its history in this country, the glass-manufacture became an object of taxation, and duties were from time to time imposed on it, which operated most injuriously, not only on the manufacture itself, but on building generally, by preventing the more extensive use of so ornamental an article. Within the last few years, however, a more enlightened policy has prevailed; and so great a reduction of the duties on glass has been granted, that an enormous increase in the manufacture and use of it has taken place. The result is seen in the improved appearance of our dwelling-houses, in the great superiority of the quality of the glass used at present, and in the magnificent plate-glass windows now so generally adopted in shop-fronts.

Of the glass used in building, there are three qualities in common use, denominated *best*, *second*, and *third*. The best is that which is of the purest metal, and free of blemishes, as blisters, specks, streaks, &c. The second is inferior, from its not being so free of these blemishes. The third is still inferior, both in regard to quality and colour, being of a greener hue. They are all sold at the same price per crate, but the number of tables is different, according to the quality: best, 12 tables; second, 15 tables; third, 18 tables.

These tables are circular when manufactured, and about four feet in diameter; in the centre is a knot, to which, in the course of the process, the flashing rod was fixed, but, for the safety of carriage and conveniency of handling, as well as utility in practice, a segment is cut off, about four inches from the knot: the large piece with the knot, still retains the name of *table*, the smaller piece is technically termed *a slab*. From these tables being of a given size, it is reasonable to suppose that when the dimensions of squares are such as cut the glass to waste, the price should be advanced.

Crown glass is the best description of window-glass. It is made without any mixture of metallic oxide, and is both specifically lighter, and much harder, than flint glass. Broad glass is an inferior kind of window-glass, made with a cheaper kind of alakli. Plate-glass is superior in quality and in appearance to all other glass. From the quantity of metal it contains, it must be almost, if not altogether, colourless—that sort which is tinged, being of an inferior quality. It is both blown and cast. Plates which are blown are limited in dimensions, while those that are cast are made of very great size, the limit being caused by the expensiveness of the machinery required for the management of very large masses of the material. Plate-glass is necessarily costly, because of the numerous and laborious operations which it undergoes, and of the risks of fracture while subjected to them. In sashes it has a magnificence peculiar to itself; objects seen through it are not distorted; and objects seen in it, have the same fair appearance. It is now made of very large dimensions.

Glass has also been introduced as a material for the manufacture of pipes. Mr. James Hartley, of Bishopwearmouth Glass Works, has, after extensive experiments, succeeded in establishing the practicability of making glass pipes, suitable for the conveyance of gas or water, and has, it is also said, proved that pipes, stronger than the ordinary metal ones, and much cheaper, may be made of glass.

A still more novel application of this material is noticed in *The Builder*, viz., the importation from Antwerp of a small parcel of glass-tiles. These tiles are similar in form to the common clay-tile for roofing buildings, the advantage held out being their lightness, and being pervious to the rays of the sun. The latter quality is presumed to render them suitable for the roofs of green-houses, as they will not interrupt the heat and light, whilst they are sufficiently strong to resist the effects of hail-storms, which will much reduce the cost of insurance on green-houses. They have the appearance of the common green glass, they vary in price from eleven to sixteen shillings per dozen, according to their thickness and weight. *See* STAINED GLASS.

GLAZING, the business of the glazier, consisting in fitting glass in sashes, frames, and casements, and fixing it either in putty or lead.

It may be classed under the denominations following:—*Sash-work*, *lead-work*, and *fret-work*.

The tools necessary for sash-work are, a diamond, a ranging-lath, a short-lath, a square, a rule, a glazing-knife, a cutting chisel, a beading hammer, duster, and sash-tool; and in addition, for stopping-in squares, a hacking knife and hammer. The diamond is a speck of that precious stone, polished to a cutting point, and set in brass in an iron socket, to receive a wooden handle, which is so set as to be held in the hand in the cutting direction; the top of the handle goes between the root of the fore-finger and middle-finger, and the under part, between the point of the fore-finger and thumb; there is, in general, a notch in the side of the socket, which should be held next the lath. *See* DIAMOND.

Some diamonds have more cuts than one.

Plough diamonds have a square nut on the end of the socket next the glass, which on running the nut square on the side of the lath, keeps it in the cutting direction. Glass benders have these plough diamonds without long handles, as, in cutting their curious productions, they cannot apply a lath, but direct them by the point of their middle finger gliding along the edge of the glass. The ranging lath must be long enough to extend rather beyond the boundary of the table of glass. Ranging of glass, is the cutting it in breadths, as the work may require, and is best done by one uninterrupted cut from one end to the other. A short lath is applied to stripping the square to suit the rebate of a sash; as in ranging, they are generally cut full. A square is used in cutting the squares from the range, that they may be more certainly cut at right angles. The carpenter's chisel is used in paring away some of the rebate of the sash, when the glass does not lie so flat as to allow a proper breadth for front putty. The glazing knife is used for laying-in the putty in the rebates, for bedding-in the glass, and for finishing the front putty. A bradding-hammer is made with a head in the form of a small parallelopiped, with a socket for the handle, rising at an obtuse angle from the middle of one of its sides; the square edges of the head drive the brads in a horizontal position, and is less liable to accident than if performed by another tool: some use the basil of the chisel.

Brass points are esteemed the best; small cut brads are also used. All new work should be bradded, to prevent the glass being moved out of its bed.

The duster is used in brushing up the front pulleys, and taking off the oil from the glass. The sash-tool is used in taking off the oil from the inside, after the back pulleys are cleaned off, and is generally used wet. The hacking-knife is for cleaning out the old putty from rebates, where squares are to be stopped in. The use of the rule needs no explanation.

N.B.—Glaziers' rules are two feet long, in four different pieces. Lead-work is used in inferior offices, and is in general practice throughout the country.

Frames are made to receive these lights, with bars across, to which the lights are fastened by leaden bars: these bars are called *saddle bars*, and where openings are wanted, a casement is introduced, either of wood or iron. Sometimes a sliding frame answers the same purpose. Church windows are in general made in this manner, in quarries or in squares. The tools which this work, in addition to the former, require, are these: a vice, with different cheeks; and cutters, to turn out the different kinds of lead, as the magnitude of the window or the squares may require.

In common there is broad and narrow lead. The German vices are esteemed the best, and turn out a variety of lead in different sizes.

There are moulds belonging to these vices, in which bars of lead are cast; in which form the mill receives them, and turns them out with two sides parallel to each other, and about three-eighths of an inch broad, with a partition connecting the two sides together, about an eighth of an inch wide, forming, on each side, a groove nearly $\frac{3}{16}$ by $\frac{1}{8}$ of an inch, and about six feet long.

The remainder of the tools, besides a vice and moulds, are, a setting-board, a latterkin, setting-knife, rosin-box, tin, glazing-irons, and clips.

The setting-board is that on which the ridge of the light is marked and divided into squares, and struck out with a chalk line, or drawn with a lath, which serve to guide the workman. One side and end are squared, with a projecting bead or fillet.

The latterkin is a piece of hard wood, pointed, and so formed as to clear the groove of the lead, and widen it for the more readily receiving the glass.

The setting-knife is a blade with a round point, loaded with lead at the bottom of the blade, with a long square handle. The square end of the handle serves to force the squares home tight in the lead; being loaded with lead, it is of greater weight, and also cuts off the ends of the lead with greater ease, as, in the course of working these lights, the lead is always longer than necessary, till trimmed.

The rosin-box contains powdered rosin, which is put on all the joints previous to soldering.

Tin is for preparing the glazing before soldering.

The clips are for holding the irons.

All the intersections are soldered on both sides, except the outside joints of the outer side, *i. e.* where they come to the outer edge. These lights should be cemented, which is done by thin paint being run along the lead bars, and the chasm filled with dry whiting, and after it has stood a short time, till the oil is secreted a little, a small quantity of dry red or white lead is dusted over it again; it then dries hard, and will resist the weather well.

Fret-work is the ornamental part, and consists of working ground and stained glass, in fine lead, into different patterns. In many cases, family arms and other devices are worked in it. It is a branch capable of great improvement, but at present neglected.

Old pieces are very much esteemed, and valued high. The same expense would, doubtless, were it not for prejudice, furnish elegant modern productions. They are placed in halls, and stair-case windows, or in some particular church windows; in many instances, they are introduced where there is an offensive aspect in a place of particular or general resort.

Glaziers clean windows; and in London it is a great part of their work.

GLOBE, (French) a spherical body, more usually called a sphere. *See* SPHERE.

GLUE, (from the French) a tenacious viscid matter, made of the skins of animals, for cementing two bodies together.

Glue is bought in cakes; and is better, as the skin of the animal from which it is made is older: that which swells much when steeped in water, without dissolving in it, is of the best quality.

To prepare glue; break the cakes into small fragments of convenient size: soak them in as much water as will just cover them; after it has remained about twelve hours, boil the whole in a copper or leaden vessel, over a gentle fire, till the glue is dissolved in the water, stirring it constantly with a wooden stick: it should then be poured through a sieve, to separate it from the scum and other filth: and lastly, it should be boiled over a smart fire, and put into a wooden vessel, in which it is to remain for use.

To make good glue for external work: grind as much white lead with linseed oil as will just make the liquid of a whitish colour, and strong but not thick; and it will then be fit for use.

The following is given by Mr. Clennel as a good method of making glue. The materials above enumerated are "first digested in lime-water, to cleanse them from grease or dirt; they are then steeped in clean water with frequent stirring, and afterwards laid in a heap, and the water pressed out. They are then boiled in a large brass cauldron with clean water, scumming off the dirt as it rises, and it is farther cleansed, by putting in, after the whole is dissolved, a little melted alum, or lime, finely powdered. The scumming is continued for some time, after which the mass is strained through baskets, and suffered to settle, that the remaining impurities may subside. It is then poured gradually into the kettle again, and farther evaporated by boiling and scumming, till it becomes of a clear dark-brownish colour. When it is thought to be strong enough, it is poured into frames or moulds about six feet long, one broad, and two deep, where it gradually hardens as it cools, and is cut out when cold by a spade into square cakes. Each of these is placed in a sort of wooden box, open in three divisions to the back; in this, the glue, while yet soft, is cut into three slices, by an instrument like a bow, with a brass wire for its string. The slices are then taken out into the open air, and dried on a kind of coarse net-work, fastened in moveable sheds, four feet square, which are placed in rows in the glue-maker's field. When perfectly dry and hard, it is fit for sale."

Mr. Austin, of Hatton Garden, some time since, took out a patent for "*a new method of glueing or cementing certain materials for building and other purposes.*" The mode of manufacture and applying it, is thus described in the specification:—

"The cement used by the patentee is made by mixing India-rubber with cold naphtha, in the proportion of eight ounces of India-rubber cut into small pieces, to each gallon of naphtha, stirring it from time to time, until the India-rubber is dissolved; then, to one part, by weight, of this mixture two parts of lac are added, and the whole is thoroughly blended together by the application of heat, accompanied with occasional stirring. When greater elasticity is required, a larger proportion of the India-rubber solution is used; if greater hardness is necessary, a larger proportion of lac is employed; and where the India-rubber would be liable to injury from great exposure and pressure, a much less proportion is used, and it is sometimes dispensed with altogether; asphalte, pitch, or resin, or other materials of that nature, may in some instances be substituted for the lac.

The materials for building-purposes to which this cement is applied are, slate, tiles, stone, glass, and metal-plates. When being used, the cement is kept in a heated state in a dish or vessel containing a narrow trough, termed a stamper, which slides up and down therein between guides; the slate or other material is brought to the heat of 150 degrees Fahrenheit, and placed upon the dish, and the stamper being then raised, imprints or stamps a margin of cement thereon. The requisite margins of cement for forming overlapping joints being thus applied to the slate or other material, the cemented portions or margins are laid in contact with each other, and in a short time become firmly united, forming water-tight surfaces. Sometimes, to expedite the process, a coating of naphtha, or other spirit that will act upon the cement, or a solution made by dissolving the cement in naphtha or other spirit, is applied to the cemented portions, or margins. The cement may also be used for securing the above materials to the building, as well as to each other."

"The patentee connects pieces of glass together with the above cement when making skylights, conservatories, frames for horticultural purposes, &c.; he also cements slate, stone, metal, and manufactured clays and cements, together, or to wood, or to woven and other fabrics, to wood for building or other purposes; he likewise cements pieces of leather for making boots and shoes, and hose or pipes for fire-engines; also leather and cork together, or to wood, metal, or woven or other fabrics, and woven and other fabrics to wood, for the manufacture of trunks, portmanteaus, packing cases, and other purposes. When joining these materials, the parts must be dry and free from dust, and should be warmed previous to receiving a coat of the cement, in order that it may not be chilled at the moment of application. If the joint is to be made at once, the parts must be expeditiously put together and pressed, as the cement rapidly loses its heat, and becomes solidified, but the junction may be effected at any subsequent period by the application of heat, or the spirit or solution before described."

GLYPH, any canal or cavity used as an ornament; hence the tablets in the frieze of the Doric order are called *triglyphs*, from their having three vertical channels; that is, two whole ones and a half one at each edge of the triglyph.

GNEISS, is the name of one of the great mountain formations, being reckoned the oldest of the stratified rocks. It is composed of the same substances as granite, viz.: quartz, mica, and feltspar. In gneiss, however, they are not in granular crystals, but in scales, so as to give the mass a slaty structure. It abounds in metallic treasures.

GOBELIN, the term applied to the celebrated tapestry, introduced into France by the brothers Gobelin. In the year 1677, Colbert purchased the dye-houses from the Gobelin family, in virtue of an edict of Louis XIV., styled it the *Hotel Royal des Gobelins*, and established on the ground a great manufactory of tapestry, similar to that of Flanders. The celebrated painter Le Brun was appointed director-in-chief of the weaving and dying patterns. Under his administration were produced many magnificent pieces of tapestry, which have ever since been the admiration of the world; such as Alexander's battles, the four seasons, the four elements, and the history of the principal events in the reign of Louis XIV. There is an academy within the Gobelins for the instruction of youth in the various branches of the fine arts, in physical science, and mechanics, subservient to the improvement of the manufacture.

GNOMONIC COLUMN, *See* Column.

Gnomonic Projection of the Sphere, that in which the eye is situated in the centre of the sphere, and projects all the circles upon a plane touching its surface.

It is evident, that in this projection, all the great circles of the sphere are projected into straight lines, since they all pass through the centre of the sphere. Every lesser circle parallel to the plane of projection is projected into a circle, and any lesser circle not parallel to the plane of projection, is projected into one of the conic sections.

A very excellent tract upon the projection of the sphere, by Mr. Emerson, contains the full theory of the gnomonical projection.

GOCCIOLATOIO, *See* Corona.

GOLA, Gola-Diretta, Gola-Rovescia, *See* Cymatium.

GOLDMAN, an architectural writer, as also a mathematician, born at Breslaw, in Silesia, in the year 1623, and died at Leyden, 1665. He published his *Elementa Architectura Militaris*, 1643: another treatise of his, on the same subject, was published in 1696, accompanied with numerous engravings, and a life of the author.

GONIOMETER, (from γωνια, *an angle*, and μετρω, I *measure*) an instrument for measuring solid angles. A most convenient instrument for this purpose was invented by Dr. Wollaston.

GONIOMETRICAL LINES, lines used in order to determine the quantity of an angle. Such are the lines of sines, tangents, and secants, commonly placed upon plane scales, the sector, Gunter's scale, &c.

GORGE, (French) a concave moulding, much less recessed than a scotia, used chiefly on frames, chambranles, &c.

Gorge is sometimes used for the cyma recta. It is used for the neck of a column; but it is more properly called *collarino*, *gorgerin*, or *gorge*.

GORGERIN or Gorge, in architecture the little frieze in tne Doric capital, between the astragal at the top of the shaft of the column, and the annulets. Some call it *collarino*. Vitruvius gives it the name of hypotrachelium.

GOTHIC ARCHITECTURE, a title generally understood in the present day to apply to that style of building in which the Pointed arch is the most prominent, though not the only characteristic. The term has been variously applied at different times, and by different writers, whether contemporaneous or otherwise; indeed, so great is the confusion on the subject, that it is not always easy to define the class of buildings alluded to under this title. Some authors include under the term all styles of building which differ from those adopted by the Greeks and Romans, embracing all modes of building which were in vogue from the decline of Classical architecture to its revival in the sixteenth century. Others limit the phrase to those modes which prevailed from the decline of Roman art to the introduction of the Pointed arch, including the Romanesque, Lombardic, Saxon, and Norman styles, in all of which the semi-circular arch was employed. A third class of writers apply the name solely to the Pointed style, under which restriction the term is for the most part employed in the present day, though some would still farther limit the application by adopting it solely for that division of Pointed architecture which is by most writers designated Pure or Decorated Gothic.

The term Gothic seems to have been first brought into use by the Italians, who applied it to all styles of building then prevalent which deviated from the Classic. Vasari, an Italian architect who lived at the commencement of the sixteenth century, after speaking of Greek orders, says, "there is another kind called Gothic (Tedesca) which differs materially both as to ornament and proportion from that of ancient and modern date. So deficient is it in systematic rules, that it may be deemed the order of confusion and inconsistency. The portals of this description of buildings, which has so much infested the world, are adorned with slender columns entwined like vine-branches, and unequal to sustain the weight, however light, which is placed above them. Indeed, the whole exterior, with its other decorations, its profusion of canopied niches raised above one another, with so many pyramids, leaves, and points, renders it apparently impossible, not only that they should be durable, but that it should support itself—giving the whole an air of being made of pasteboard rather than of stone and marble. This style was invented by the Goths, who spread the contagion through Italy. May God deliver every country in future from the adoption of plans, that substituting deformity for beauty, are unworthy of further attention."

From the description which he gives in this passage, it will be very reasonably inferred, that he refers to the Pointed style of architecture, but it is evident that he also includes the modes adopted on the decline of Roman art, for he cites, as examples, the palace of Theodoric at Ravenna, and the churches of St. John the Evangelist, and of St. Vitalis, in the same city, as also other buildings of Lombardic and Byzantine architecture. Amongst the first writers who introduced the term into England was, we believe, Evelyn, and he gives the following description:—"Gothic architecture," says he, "is a congestion of heavy, dark, melancholy, monkish piles, without any just proportion, art, or beauty;" and elsewhere he describes it as "a fantastical light species of building." Sir Christopher Wren confirms the use of this term, for, after describing edifices erected after this mode of building as "mountains of stone, vast gigantic buildings, but not worthy the name of architecture," he says, "This we now call the Gothic manner; so the Italians called what was not after the Roman style." In another place our author applies the term *Saracenic* to buildings in the Pointed style, supposing that form of arch to have been brought from the East by the Crusaders. But to show what vague notions he held upon the subject, we must add, that he attributes the cathedral of Winchester, and the church of St. Cross, to a period preceding the Norman conquest. Warton's ideas upon this head must have been also very indefinite, for he makes his earliest division of the style to commence about A. D. 1200, which he calls *Gothic Saxon*, as distinguished from the true Gothic, of which he makes tracery in the window-heads the chief characteristic. He even denies the title of Gothic to Salisbury cathedral, which he includes under the term Gothic Saxon. Bishop Warburton gives the name of *Norman* to Pointed architecture, reserving that of *Saxon* for those styles in which the semi-circular arch prevailed.

Captain Grose, a few years later, adverting to the use of the title in question, says, "Most of the writers who mention our ancient buildings, particularly the religious ones, notwithstanding the striking difference in the styles of their construction, class them all under the common denomination of Gothic; a general appellation, by them applied to all buildings not exactly conformable to some one of the five orders of architecture. Our modern antiquaries more accurately divide them into Saxon, Norman, and Saracenic; or that species vulgarly, though improperly, called Gothic."

Mr. Bentham, a cotemporary, remarks upon the same subject as follows:—"The term Gothic, applied to architecture, was much used by our ancestors in the last century, when they were endeavouring to recover the ancient Grecian or Roman manner; whether they had then a retrospect to those particular times when the Goths ruled in the empire, or only used it as a term of reproach to stigmatize the productions of ignorant or barbarous times, is not certain; but I think they meant it of Roman Architecture: not such certainly as had been in the age of Augustus, but such as prevailed in more degenerate times, when the art itself was almost lost, and particularly after the invasion of the Goths: in which state it continued many ages without much alteration. Of this kind was our Saxon and earliest Norman manner of building, with circular arches and strong massive pillars, but really Roman architecture, and so was called by our Saxon ancestors themselves. Some writers call all our ancient architecture, without distinction of round and pointed arches, Gothic; though I find of late the fashion is to apply the term solely to the latter, the reason for which is not very apparent. The word Gothic, no doubt, implies a relation some way or other to the Goths; and if so, then the old Roman way of building with round arches above described, seems to have the clearest title to that appellation; not that I imagine the Goths invented or brought it with them; but that it had its rise in the Gothic age, or about the time the Goths invaded Italy. The style of building with pointed arches is modern, and seems not to have been known in the world till the Goths ceased to make a figure in it. Sir Christopher Wren thought this should rather be called the Saracen way of building; the first appearance of it here was certainly in the time of the Crusades; and that might induce him to think the archetype was brought hither by some who had been engaged in those expeditions, when they returned from the Holy Land."

After these remarks, no one will wonder at Dr. Milner complaining of the confusion and difficulty with which the study of Gothic architecture had been surrounded by the vague and unsettled manner in which terms had been employed by his predecessors and cotemporaries who had written upon the subject.

The employment of the term and its application seems to have arisen from an idea entertained by the Italians, that the style of building to which they applied it was introduced by the Goths after their incursion into Italy; this is evident from the expressions of Vasari, above quoted. Now, if the use of the title were restricted to those buildings with round arches which were prevalent after the fall of the Roman empire, there might be apparently some grounds for its assumption, but this does not seem to be the case even with the Italians, and certainly not with our own countrymen, although some of them doubtless thought that the Pointed arch was an invention of the Goths, in illustration of which we quote a passage on the subject from Sir Henry Wotton. He says:—"As for those arches which our artisans call of the third and fourth point, and the Tuscan writers *de tergo* and *de quarto acuto*; because they always concur in an acute angle, and do spring from a division of the diameter into three, four, or more parts at pleasure. I say, such as these, both for their natural imbecility of the sharp angles themselves, and likewise for their very uncomeliness, ought to be exiled from judicious eyes, and left to their first inventors the Goths or Lombards, amongst other reliques of that barbarous age.

Whether the Pointed style, or that previously existing, be considered as invented by the Goths, the notion in either case is false and without foundation. The Goths had no architecture of their own; and not only are they innocent of introducing any new style into Italy, but more than that, they do not seem to have caused any alteration in the old. What changes did take place arose very naturally from the gradual decline of art. It is not our intention in this place to enter into any discussion on the origin of Gothic Architecture; we defer that for a future paper on POINTED ARCHITECTURE; all we desire to state at present, is that neither the Pointed style nor that preceding, in which the semi-circular arch continued to be employed, were introduced by the Goths; and that, therefore, the term *Gothic* could not justly be applied to them on that score.

By many writers the term is doubtless used as a term of reproach, and is intended as equivalent to the words—uncivilized, barbarous; on which account, many persons of the present day have objected to its continued use. At the time of the revival of classical architecture, or rather of the adaptation of classic orders and details to modern architecture, the excellencies of Pointed architecture were but little understood or appreciated; and hence the desire to stigmatize it as barbarous. Since then, however, the prejudice for the orders has ceased, and Gothic art is viewed with a more favourable, and, we may add, more experienced eye, and men are desirous of rescuing it from any stigma, even though it be but a nominal one.

From this cause, many names have been suggested in lieu of the contemptuous *Gothic*, amongst which we may enumerate the following—*Christian*, *Catholic*, *English*, and *Pointed*—as being the most usual. It is true the word *Gothic* is ill-devised, insignificant, and entirely inapplicable, yet we cannot think that any of the terms proposed are sufficiently expressive to explode a title of so long standing and such universal acceptation. The term was originally, without doubt, employed as a mark of reproach, but now-a-days no such meaning is implied by it, and no one is misled by its use. In applying the term now, no one ever thinks of its original intention, but considers it solely as a phrase descriptive of a certain class of buildings, of which each man forms his opinion, quite independently of its appellation. Even supposing we were to explode this expression, what could be substituted in its place: no one term has been universally agreed upon; and we should have a general scramble, each partisan seeking to adopt his own peculiar title, and probably maintaining it to the utmost of his power; so that instead of one, we should have several titles, each striving for, but none obtaining universal adoption.

We submit, that it is better to have one term well established, even though it be confessedly a very incorrect one, than several exceptionable ones of only partial use.

Sir James Hall speaks to the point when he says: "In the present unsettled state of public opinion, both with respect to the origin and the history of this style, I have judged it best to attempt no innovation in this matter, and have made use of the name of *Gothic Architecture;* which, though certainly no less objectionable than many of those that have been offered to the public, has the advantage of being universally known and understood amongst us."

The two first names which we have mentioned as proposed substitutes for the word *Gothic*, namely, *Christian* and *Catholic*, are objectionable, on the grounds that this is not the only style which is entitled to such designations. Both Lombardic and Byzantine were styles adopted by the Christian church; nay more, in a certain sense they may be said to have been of Christian growth. Mr. Pugin contends, that although other styles have been employed in early ages, they were rather of Pagan origin, or arose from unsuccessful imitations of Pagan buildings; in fact, that they were mere make-shifts, used only for a temporary purpose, until a more perfect system, and one more thoroughly Christian, should arise. We are most willing to admit that Gothic architecture is the perfection of Christian art, but, at the same time, cannot in justice allow its exclusive title to that term. The third term can only be of partial application, and only then correctly employed when applied to the style as practised in our own country: the theory that Gothic architecture originated in this country, has, we believe, been long since exploded. The term *Pointed*, though on many accounts a very correct one, is still open to similar objections to those urged against the two first, inasmuch as it would naturally include other styles besides the one to which it is intended to be applied.

In the quotations which we have above introduced from writers of the last two centuries, we have been necessitated to admit some contemptuous and opprobrious observations on the merits of Gothic buildings, when compared with those of Greece and Rome; but we cannot permit such remarks to pass by unheeded. At the period of what is called the revival of classic art, such unworthy opinions as those we have alluded to were far from uncommon; indeed, it was fashionable in those days to stigmatize everything belonging to the middle ages as dark and barbarous, and no one could give better proof of his admiration of classic antiquity than by reviling and sneering at every other kind of art, more especially at that which threatened a most dangerous rivalry. The quotations which we have already given on this head have been taken from Vasari, Wotton, Evelyn, and Wren; we will now give some more extracts of the same tendency, taken, for the most part, from the writings of the last-named architect. In his *Parentalia*, he says: "It was after the irruptions of swarms of those truculent people from the north, the Moors and Arabs from the south and east, overrunning the civilised world, that wherever they fixed themselves, they began to debauch this noble and useful art, when instead of those beautiful orders so majestical and proper for their stations, becoming variety, and other ornamental accessories, they set up those slender and misshapen pillars—or, rather bundles of staves and other incongruous props—to support incumbent weights and ponderous arched roofs, without entablature; and though not without great industry, not altogether naked of gaudy sculpture, trite and busy carvings; it is such as gluts the eye, rather than gratifies and pleases with any reasonable satisfaction. For proof of this, without travelling far abroad, I dare report myself to any man of judgment, and that has the least taste for order and magnificence, if, after he has looked a while upon King Henry VII.'s chapel at Westminster—gazed upon its sharp angles, jetties, narrow lights, lame statues, lace, and other out-work and crinkle-crankle, and shall then turn his eyes on the Banqueting House, built at Whitehall by Inigo Jones, after the ancient manner; or on what his majesty's surveyor has done at St. Paul's, and consider what a glorious object the cupola, porticoes, colonnades, and other parts present to the beholder; let him well consider and compare them judicially, without partiality and prejudice, and then pronounce which of the two manners strikes the understanding, as well as the eye, with more majestic and solemn greatness, though they, in so much plainer and more simple dress, conform to the respective orders and entablature, and, accordingly, determine to whom the preference is due. Not, as we have said, there is not something solid, and oddly artificial, too, after a sort; but the universal and unreasonable thickness of the walls, clumsy buttresses, towers, sharp-pointed arches, doors, and other apertures, without proportion; nonsensical insertions of various kinds of marbles impertinently placed; turrets and pinnacles, thick set with monkeys and chimeras, and abundance of busy-work and other incongruities, dissipate and break the angles of the sight, and so confound it that one cannot consider it with any steadiness where to begin or end; taking off that noble air and grandeur, bold and graceful manner, which the ancients had so well and judiciously established." "Nothing was thought magnificent that was not high beyond measure, with the flutter of arch-buttresses —so we call the sloping arches that poise the higher vaulting of the nave. The Romans always concealed their butments; whereas the Normans thought them ornamental. These, I have observed, are the first things that occasion the ruin of cathedrals; being so much exposed to the air and weather, the coping, which cannot defend them, first failing, and, if they give way, the vault must spread. Pinnacles are of no use, and of little ornament. The pride of a very high roof raised above a reasonable pitch is not for duration." Elsewhere speaking of their construction, he says: "Few stones were used but what a man might carry up a ladder on his back from scaffold to scaffold, though they had pulleys and spoked wheels upon occasion; but having rejected cornices, they had no need of great engines. Stone upon stone was easily piled up to great heights, therefore the pride of their work was in pinnacles and steeples." "The Gothic way carried all their mouldings perpendicular, so that they had nothing else to do but spire up all they could." "They affected steeples, though the Saracens themselves used cupolas."

We do not feel so much surprised at such expressions escaping men unattached to the profession, or even Vasari, for he was an Italian, and therefore naturally biassed in favour of classic art; but to hear such opinions from a man like Sir Christopher, must ever be a subject for wonder and regret. Wren was, without controversy, a man of great talents and high attainments; of considerable taste, and of unusual scientific knowledge; nor was he ignorant either of the nature of Gothic architecture—for he had made a special professional examination of its finest examples—or of its principles; for, as we believe, he learned much from them, and applied them in his own buildings. That prejudice should have extorted from such a man such unhappy tirades in condemnation of Mediæval art, is, we repeat, at once a matter for wonder and regret. It is pitiable to hear such a man challenging his predecessors with so great self-satisfaction, and inviting a comparison between his own works and theirs; complaining, too, of their faulty construction and useless ornaments, when he himself received no little scientific information at their hands; and as regards the useless ornaments —if, indeed, we do not give him too much credit for constructive skill—was not only aware of their practical utility, but even adopted their principle, though in a less skilful manner, in his own vaunted Cathedral. But we will not rest satisfied with our own authority. Since Wren's time, Mediæval art has met with less prejudiced judges; and many writers of high standing, and architects of well known ability, have given ample testimony in its favour. It is now more fully understood, and its beauties better appreciated; in short, Gothic art is now what Classic was in Wren's days— the "fashion." But ere we proceed to bring forward any more favourable witnesses, let us do Wren justice, and give another extract from his works, which tends in some measure to qualify his previous language.

Even he recognizes, in some few buildings of this style, "a discernment of no contemptible art, ingenuity, and geometrical skill, in their design and execution." Also—"Thus the work required fewer materials, and the workmanship was, for the most part, performed by flat moulds, in which the wardens could easily instruct hundreds of artificers. It must be confessed, this was an ingenious compendium of work suited to these northern climates; and, I must also own, that works of the same height and magnificence in the Roman way, would be very much more expensive than in the other Gothic manner, managed with judgment."

But to pass on to later writers—Rev. J. Milner, alluding to Evelyn and Wren's remarks, says—"Every man who has an eye to see, and a soul to feel, on entering into York Minster and Chapter-House, or into King's College or Windsor Chapel, or into the cathedrals of Lincoln or Winchester, is irresistibly struck with mingled impressions of awe and pleasure which no other buildings are capable of producing; and however he may approve of the Grecian architecture for the purposes of civil and social life, yet he instinctively experiences in the former a frame of mind that fits him for prayer and contemplation, which all the boasted regularity and magnificence of Sir Christopher's and the nation's pride, I mean St. Paul's Cathedral, cannot communicate, at least, in the same degree."

Bishop Warburton says—"Our Gothic ancestors had juster and manlier notions of magnificence on Greek and Roman ideas, than those mimics of taste who profess to study only classic elegance; and because the thing does honour to the genius of those barbarians, I will endeavour to explain it."

Mr. Dallaway says—"Certain it is, that the Gothic churches, whatever be the peculiar manner of their era, present their beauties to every eye. We cannot contemplate them without discovering a majestic air well worthy of their destination, with a knowledge of what is profound in the science and practice of building, and a boldness of construction, of which classic antiquity furnishes no examples."

The following words of Coleridge are remarkable: in comparing the Classic and Gothic modes of architecture, he says,—"The Greek art is beautiful. When I enter a Greek church, my eye is charmed and my mind elated; I feel exalted, and proud that I am a man. But the Gothic art is sublime. On entering a cathedral, I am filled with devotion and with awe; I am lost to the actualities that surround me, and my whole being expands into the infinite; earth and air, nature and art, all sweep up into eternity, and the only sensible impression left is, that I am nothing."

Whewell, referring to the use of the word Gothic as a term of reproach, says—"If we would employ the term barbarous with any significance, it is not to be applied to one style of art merely because it differs from another. A Gothic building is no more barbarous than a Grecian one, if the ideas which govern its forms be fully understood and executed: but those attempts rather are to be called barbarous, which imitate the features of good models, and which, not catching the principle of the art, exhibit such parts incongruously composed and imperfectly developed. In writing Greek, an Anglicism is a barbarism; but we shall not be willing to allow English to be barbarous, because it is not Greek; and a mixture of the two is equally barbarous, whether it pretends to be one or the other."

Mr. Poole, a recent writer on the subject, is very warm in his admiration: he says—"But there arose in the west in the middle ages a style of architecture growing in all its parts and characters out of the wants of the church; and adapting itself to the expression of the very things which she desires to express in all her methods of embodying herself to the eyes of the world, and to the hearts of her sons. And so entirely did this style arise out of the strivings of the church to give a bodily form to her teaching, that it seems to have clothed her spirit, almost as if the invisible things had put forth their unseen, but powerful and plastic energies, and gathered around them on all sides the very forms and figures which might best serve to embody them to the eye of sense. A Gothic church in its perfection is an exposition of the distinctive doctrines of Christianity, clothed upon with a material form; and is, as Coleridge has more forcibly expressed, 'the petrifaction of our religion,' or, as it has been expressed by a mind essentially differing from Coleridge's, which makes the coincidence the more remarkable, 'the divine order and economy of the one seems to be emblematically set forth by the just, plain, and majestic architecture of the other; and as the one consists of a great variety of parts united in the same regular design according to the truest art and most exact proportion, so the other contains a decent subordination, various sacred institutions, sublime doctrines, and solid precepts of morality, digested into the same design, and with an admirable concurrence tending to one view,—the happiness and exaltation of human nature.'

"Much has been said about the proper designation of this style. The term Gothic has use on its side to so great a degree, that it will never be superseded, and though it has no truth in it at all, and was at first given in ignorant derision, one would scarce wish it altered; the style which it designates is exclusively Christian, and it is nothing new or displeasing to that which is distinctively Christian, to take a name from a scorner, and to convert the opprobrium into a glory.

"Such then is Gothic architecture:—theological, ecclesiastical, and mystical, in all its parts and characters. It grew to its perfection both in general design, and in more minute details of ornament and execution, during many successive generations; and although we have few churches entire and unmixed of its earliest forms, we have remains more or less perfect in almost every variation in its style, from the Norman of the twelfth century, to the elaborate perpendicular of the Tudor."

We conclude with the following remonstrance from Mr. Pugin, a gentleman to whom we are pre-eminently indebted for his perseverance in the study and defence of Mediæval art, and to whose "Contrasts," although somewhat overdrawn, we would beg to refer the reader, as apropos to the question before us.

Mr. Pugin says—"Before true taste and Christian feelings can be revived, all the present and popular ideas on the subject must be utterly changed. Men must learn, that the period hitherto called dark and ignorant, far excelled our age in wisdom, that art ceased when it is said to have been revived, that superstition was piety, and bigotry faith. The most celebrated names and characters must give place to others at present scarcely known, and the *famous edifices* of modern Europe sink into masses of deformity by the side of the neglected and mouldering piles of Catholic antiquity. If the renunciation of preconceived opinions on this subject, and the consequent loss of the present enjoyment derived from them, be considered as a great sacrifice, does not the new and glorious field that is opened offer far more than an equivalent? What delight, to trace a race of native artists hitherto unknown, in whose despised and neglected productions the most mystical feeling and chaste execution is to be found, and in whose beautiful compositions the originals of many of the most celebrated pictures of more modern schools are to be traced! what exquisite remains of the sculptor's skill lie buried under the green mounds that mark the site of once noble churches! what originality of conception and masterly execution do not the details of many rural and parochial churches exhibit! There is no need of visiting the distant shores of Greece and Egypt, to make discoveries in art. England alone abounds in hidden and unknown antiquities, of surpassing interest."

Of the peculiar effect produced upon the mind by Gothic edifices, and of the principles upon which its excellencies depend, Milner gives us the following explanation:—"The eye is quickly satiated by any object, however great and magnificent, which it can take in all at once, as the mind is with what it can completely comprehend; but when the former, having wandered through the intricate and interminable length of a pointed vault in an ancient cathedral, discovers two parallel lines of equal length and richness with it; thence proceeding discovers the transepts, the side chapels, the choir, the sanctuary, and the ladye chapel, all equally interesting for their design and execution, and all of them calculated for different purposes; the eye, I say, in these circumstances is certainly much more entertained, and the mind more dilated and gratified, than can possibly be effected by any single view, even though our modern architects should succeed in their attempts to make one entire sweep of the contents of a cathedral, in order to show it all at a single view, and to make one vast empty room of the whole."

Mr. Poole adds—"But surely some part of the effect of a Gothic cathedral resides in that very excess of length over breadth, affording a long perspective, directing the eye towards the altar, through an avenue of oft-repeated similar parts, and creating, as it were, an artificial infinite. The roof as well as the walls of a Gothic building is so composed as to help this effect to the utmost. Groin beyond groin, boss beyond boss, pendant beyond pendant, is seen,—first of all each distinct and clear, but by degrees approaching and touching one another in the perspective, and at last, lost in the complexity—not confusion, but complexity—of the whole. The plain becomes obscure, the defined indefinite, in the long-drawn distance.

"Even irregularity of structure lends its aid to produce this effect, and irregularity is a beauty purely Gothic. The eye that wanders in an oblique direction, travels through the nearer arches to some unexpected aisle or chapel, and seems lost in an undefined distance. It is scarcely possible to exaggerate the effect of this combination of elevation, length, and irregularity, so averse from the Grecian concinnity and uniformity; especially when they are helped by the dim religious light poured through the painted windows.

"Fancy yourself for a moment standing just within the great western entrance of one of our cathedrals, and you will feel what is meant by breadth in architectural effect. The eye is of course directed eastward, and there it has its point of repose; and the great east window limits its view, at a distance, which, with all the accessories before mentioned, seems indefinite. But the aisles at either hand have absolutely no termination to the mind's eye. For a while you see through the intervening arches; but you see less and less at each interval, and long before the actual termination of the aisle, the piers, approaching one another in the perspective, close upon the unfinished view. The mind's eye goes forward, while the eye of sense is arrested. The limit is as effectual as if it had been abrupt; but it is so gradual that you scarce feel where it occurred. There is a perfect consciousness of the length beyond, notwithstanding the absolute impossibility of discerning it."

Thus much for the impugners and apologists of Gothic architecture;—it will appear somewhat incredible that so great a difference of opinion should exist amongst men all eminent for taste and judgment, but such is the case; what in Wren's time was considered barbarous, is now upheld as scientific and beautiful. We follow the taste of our age, which we believe to be correct, and maintain the superiority of Gothic over Classical art, not only as regards its general effect, but also in scientific construction, correct and tasteful ornamentation, accommodation, and general convenience. In our previous extracts we have alluded more especially to the general effect of the two styles, we will now touch upon each of the other qualities seriatim, and, in doing so, we shall give, as before, greater prominence to the opinions of those who have arrived at a high standing in their profession, and principally of those who have devoted their time specially to this subject, than to any observations of our own; as we deem their authority will carry more weight with it than anything we can say. We need only mention the names of Pugin and Bartholomew, Willis, and Whewell, to obtain an attentive perusal, and would refer our readers for more extensive information on the subject than our space will allow of, to the standard works of those gentlemen.

In some of the extracts from the *Parentalia*, previously given, we hear Wren inveighing against the Mediæval builders on account of their rude and unskilful construction; we contrast their remarks with some others on the same subject by the late Mr. Bartholomew, than whom we could scarcely have a more impartial judge, for while on the one hand he is a great admirer of the Mediæval architects, he is no less predisposed in favour of Wren, on whose scientific skill in construction, he is continually pouring forth the most warm—we had almost said the most extravagant—encomiums. Let us hear what are his opinions in this controversy; they are expressed as follows:—

"During the middle ages, geometrical science was applied to architecture in the loveliest manner; the general plan, the columns, the arches, the doors, the windows, the galleries, the vaulting, the flying buttresses, every panel, every compartment, the most minute ornament, exhibited an intimate acquaintance with that profound and masterly science, without which building becomes vicious, cumbrous, expensive, mean, fragile, absurd and disgusting.

"After the decline of Gothic architecture, a foolish notion went abroad in the world, that cumbrousness and extravagance of material were characteristics of Gothic architecture; even that great and talented man, John Evelyn, who possessed a very superior knowledge of architecture, entertained the then current opinion: but of late, mankind have become strangely undeceived on this point; and the plans and sections of ancient and modern buildings, brought together in parallel, now fill the mind with astonishment, that so comparatively small a quantity of materials, and those frequently of minor quality, could have been piled up to exist, with little failure or decay, such a long course of time. It is not that Gothic buildings are always perfect in construction, but in general they are nearly so; in fact, so light are some of them, that they need more substance, as well as harder materials, to resist the mere operation of time upon their surfaces. The Gothic architects always built with the greatest economy: when square stone was easily procurable, they formed their walls very thin; but when, from the length of the carriage of it, it became costly, they used for their walls the most ordinary rubble-stone of the country, and they then gave to their walls thickness sufficient to prevent them from rending and rolling apart from the fluent nature of their materials."

Elsewhere he says—"Now the Mediæval Christian builders arrived to such a delicate and intimate acquaintance with architectural dynamics, that, by the discovery of the way in which all the particles of their materials are affected by gravity, they were enabled, by merely subjecting them to frangibility caused by compression, so to economize them and reduce their quantity, that many members of Gothic edifices after five hundred years' devastation by time, are more sound than corresponding members of our modern buildings which have not subsisted fifty years, and which contain five times their proportion of materials.

"It was this scientific economy which enabled those real magicians to rear up securely their works so high towards heaven in the beauty of architectural holiness; it was this scientific economy which left them money enough to cover their sweet fabrics within and without with the richest intaglio, and the goldsmith's work of heaven, while their patrons grumbled not, nor grudged the rich profusion, but joined heart and soul in the goodly work, and the wise and noble fabricator needed none of that kind of over-persuasion, or cajolery, or intentional misunderstanding, or tasteful out-witting, by which alone the modern architect is frequently enabled to wring from his employer other than bare walls; this scientific economy rendered unnecessary the rabble of cement-makers and sand-concreters—those spendthrift empirics, which suck out the brains of architecture, rifle her pockets, violate her chastity, bruise her face to a mummy, and then cover it with oil-plasters and cosmetics of white-wash and iron oxide.

"So admirable in general is the skill displayed in the dynamic disposition of the material of a Gothic cathedral; so shrewdly are the forces of its gravitation reduced to simple compression, that the whole is like a wonderful piece of shoring, sublimely and permanently imitated in stone. He who compares its flying-buttresses to a piece of wood-scaffolding, at once confesses that it is raised with that art which emanates from the workman's most delicate and anxious caution."

In truth, the erections of this style are but the embodiments of constructive science, not only does the main form and general outline depend thereon, but even those peculiarities which an unpractised eye would be tempted to esteem mere decoration: but those who have made themselves acquainted with the subject, are well aware that the Mediæval architects never constructed decoration, but decorated construction; they made their building perfect, and then applied their ornament with most correct judgment and refined taste. A Gothic building is a practical illustration of the principle of the arch, and of its application in the most perfect form. We had almost termed it the extension and perfection of Roman architecture, for they were the first to apply the principle, but only in a partial and imperfect manner; the idea was new to them, and they did not fully comprehend it, they did not understand its universal applicability, and therefore only partially adopted it. In their buildings many of the forms of Grecian architecture still remained; they were fettered by its rules, by its influence, and thereby prevented from bringing their new theory to perfection. They had been used to the forms, they knew of no others, and hence arises their inconsistency. Roman architecture was, so to speak, a transition, and, so far, imperfect style; in it we see the new and old principles struggling for the mastery, yet each maintaining a certain influence; we have indeed the arch, but there still remains the entablature, which was in this place totally useless and inconsistent, they were each the exponent and characteristic of its own theory, and as the two systems were repugnant the one to the other, so was their introduction into the same building liable to the charge of inconsistency. The entablature in the one case answered the same purpose as the arch in the other, and therefore, where the one prevailed, the other should have disappeared; but this we know was not at first the case, it was left to the Mediæval architects to bring the new system to perfection. Roman architecture is but the germ, Gothic its complete development.

We cannot forbear offering one or two instances of the scientific skill of the Gothic architects, as exemplified in their mode of construction. It is a matter which has been frequently alluded to in other works, but one, we think, without which any treatise on Gothic architecture would be imperfect. It was their custom, as we all know, to cover their large buildings with vaults of masonry, a method of roofing in which they greatly excelled their predecessors. The Romans were acquainted with this method, and applied it in many instances, yet their specimens of vaulting, when compared with the Mediæval, appear but clumsy expedients; they were confined to the use of the common cylindrical and quadripatrite vaulting, or that of which each compartment consisted of four cells only, the latter kind being caused by the intersection of two cylindrical vaults at right angles to each other. But even in this simple kind of groining they found a difficulty, for when the intersecting vaults were of different span, and of the same elevation, their arches being confined to the semi-circular form, they were at a loss how to proceed. In Gothic architecture, the difficulty is entirely obviated by the employment of the Pointed arch, and by its application the Mediæval builders were enabled to construct vaults of so elaborate and varied a character, such as the Romans, with their forms, dared never to have dreamed of. But this is not the only improvement our ancestors effected in vaulting; the Roman vaulting consisted entirely of large stones, and was therefore of very great weight, a circumstance which was very detrimental to its application, for as the wall had to bear the entire burden, it was absolutely requisite that they should be of extraordinary strength. Now, our Gothic builders obviated this difficulty likewise in a most scientific manner; they made their vaults equally secure with a much smaller consumption of material, by which means they not only saved the walls an undue pressure, but also considerably reduced their expenditure throughout the building. This they managed in the following manner. In their large works, such as cathedrals, in which vaulting was more frequently applied, it was their custom to carry up a pier or bearing shaft on the face of the nave-shafts, either springing directly from the ground, or supported on a corbel at some point immediately above the piers. From the top of these shafts, as points of bearing, were extended ribs or arches across the nave from the bearing-shafts on the one side to those on the other, in three or more directions; in the more simple forms, each compartment of the vaulting consisted of six entire arches, enclosing four cells or spaces between the ribs, which were arranged in this manner;—from each of the four bearing-shafts sprang three arches; one, the longitudinal, extending to the next shaft on the same side of the nave, that is, in the direction of the length of the building; another, the transverse, stretching at right angles to the longitudinal to the shaft immediately opposite on the other side of the nave; and a third, the diagonal, extending between the most distant shafts from one angle of the bay to the opposite. These diagonal ribs intersect each other, and at the point of intersection butt against a key-stone, which generally extends below the level of the vault, and is sculptured in the form of foliage or some other ornament; this key-stone locks the system together securely. The ribs formed the constructive portion of the vault; they were the skeleton, as it were, on which the covering or cuticle was stretched: they were the only portions of the vault in which large stones were used, the cells being filled up with much smaller stones, and they of less ponderous material, by which means the whole vaulting was rendered lighter and more secure. In this way did they gain an incalculable advantage over the Romans; nor did their skill cease here; having so far reduced the forces of the enemy, they prepared to carry the remaining thrust of the vault away from the walls of the clere-story, and conduct it safely to the foundations, and this they accomplished with equal or even greater skill. From that point of the clere-story wall, where the thrust of the vaulting was collected, the force was carried over the aisles by means of an arch termed a flying-buttress, which rested at its lower extremity on the pillar buttresses attached to the aisle-walls. But here it is necessary to notice one or two peculiarities which might be likely to escape the observation of a transient observer. Having collected the active force of the vaulting to one spot by means of the ribs, they there spread out the flying-buttress in the same manner as now-a-days we place a board against a wall in cases of temporary shoring, and sometimes placed one arch below another, the two being separated at the wall, but uniting ere they reach the wall-buttress, by which method the force was concentrated at that point, while the whole of the clere-story wall was equally supported. Having conducted the drift to this point, it remained to bring it safely to the ground; and how could this be effected? The method, which would at once naturally have suggested itself, would have been to extend the buttresses from the wall to such an extent as to receive the thrust within its mass until it reached the earth; but this would necessitate a very great projection, and therefore a large consumption of space and materials. This difficulty they met and nullified in the most skilful manner, and by a most simple contrivance. It was by merely superadding a pinnacle to the wall-buttress above the point at which the force was collected. We have now another force in operation, that of the downward pressure or gravity of the materials composing the pinnacle, and this combining with the thrust of the vault, changes the direction of that force so as to make it more nearly perpendicular, and bring it within a buttress of moderate projection, which, be it remembered, served a further purpose of strengthening the aisle-walls and diminishing their thickness, for it is well known, that a wall with buttresses at intervals, is as strong, or stronger, than a mere wall of the combined thickness of the wall and buttress. In this manner did they press everything, whether friendly or inimical, into their active service, and succeeded in rearing edifices of the most skilful construction, most rigid economy, and chaste and delicate decoration.

How Wren could have inveighed against the construction of our Gothic buildings we cannot understand, especially as he seems to have imitated them in several particulars, though not certainly with equal taste or skill. He has used very similar means to those above described, in resisting the thrust of his vaulting, in his vaulted Cathedral; buttresses are carried over the aisle to the outer wall, and are concealed by a screen running round the building, and having the appearance of an additional story, which certainly gives the building a more imposing appearance on the exterior, but at the expense of truth, and, like the dome, creates a feeling of disappointment when you enter the interior. To this circumstance Mr. Pugin alludes in a passage which we shall have occasion hereafter to quote. As regards Wren's objection respecting the size of the stones used in Gothic edifices, we need say nothing, it refutes itself, for surely if a building can be raised with equal security by the use of small stones which a man can carry on his back, it is much superior, at least in point of economy, to one raised with large blocks which require ponderous machinery to move them to their destined positions.

We leave Sir James Hall to answer objections made on the score of false proportions; he deals with them in a way no less summary than it is decisive. After speaking of the principles of Gothic architecture, he says:—"This view furnishes a complete answer to the common objection made to the Gothic style, of wanting proportions, for that accusation has always been the consequence of judging the Gothic by Grecian rules, in which case it could not fail to appear absurd and disproportioned; whereas when tried by its own laws, it will be found completely consistent and harmonious in all its parts;" of course, if persons commence by assuming Grecian proportions to be the acme of perfection, and all that differs from them to be false and barbarous, we may at once yield the argument, for the question is decided ere we commence.

Mr. Pugin alluding to the same subject says:—"Under the head of architectural propriety, we have also to consider the scale and proportions of buildings. Without vastness of dimensions it is impossible to produce a grand and imposing effect in architecture; still, unless these be regulated on true principles, they may destroy their effect by their very size; and here I wish to draw your attention to a point which will prove the great superiority of the Christian architecture of the middle ages, over that of classic antiquity, or of the revived pagan style. In Pointed architecture the different details of the edifice are multiplied with the increased scale of the building; in classic architecture they are only magnified." This principle of multiplying parts with the increased size of the building, is a characteristic of the style, and is one in our opinion in which it greatly excels its rival.

It now only remains to touch upon two subjects of comparison; the first as regards the application of ornament, and the last as to convenience and accommodation. The writers of Wren's time were too apt to consider Gothic architecture as a system of decoration, gaudy and puerile; a system in which useless ornament was the chief aim and object, and in which it was introduced without reason or moderation, and hence they termed it meretricious and barbarous. Investigation has taught us differently; and where they saw naught but confusion and redundancy, we detect order and sound judgment. Ornamentation was seldom introduced by our old church-architects without a cause or without a meaning: we do not mean to go so far as to assert that such was never the case, but we do say that there was, for the most part, a nice adaptation, a propriety, in their decoration; the parts to be enriched were not introduced without a specific object, and their manner of enrichment was made subservient to that object; for instance, look at the projecting string-course, the weather-mouldings of the heads of windows, to conduct the moisture from the enriched and delicate part of their work, so as to preserve it from injury, and the terminating dripstone to throw it off the walls. Each part was decorated so as at once to delight the eye, and answer an useful end; each moulding was beautiful and appropriate to its own peculiar duty; their contours varied, not from any wild fancy or exuberant imagination, but simply to make it efficient to the purpose for which it was employed. Look again at their buttresses, to which we have already alluded, and the gorgeous pinnacles, not a mere decoration, as our forefathers would have it, but a most useful and indispensable addition. But we can almost forgive them for seeing only the beauty, at least where they acknowledge so much, for the graceful finish given to the buttress thereby, is sufficient to justify such an addition, even supposing it served no other purpose than mere ornament, and we need not wonder at their resting satisfied with it as a means of decoration without looking to any further purpose. The buttresses themselves likewise were equally agreeable to the eye, as they were useful and essential to the construction; by them we obtain a bold and pleasing variety in the main outline of the building, and that play of light and shade which adds so greatly to the appearance of a Gothic edifice. Looking once more at the smaller members, we find niches, corbels, bosses, vaulting ribs, each answering two ends, one useful, the other ornamental. What objects can be more beautiful than some of the Gothic niches, especially of the later styles, and yet what more necessary in a climate like ours; on the exterior of buildings, more especially, they serve to protect the higher branches of carving from the inclemency of the weather, and in the interior from accident or injury; but it was probably their unusual elegance rather than their usefulness, which caused their introduction as a means of internal decoration. In short, the Mediæval artists did not construct ornament, but ornamented construction. On this subject we add the following remarks from Pugin's Principles of Pointed Architecture:—

"The two great rules for design are these:—1st. That there should be no features about a building which are not necessary for convenience, construction, or propriety; 2nd. That all ornament should consist of enrichment of the essential construction of the building." "In pure architecture the smallest detail should have a meaning, or serve a purpose; and even the construction itself should vary with the material in which they are executed." "Strange as it may appear at first sight, it is in Pointed architecture alone that these great principles have been carried out; and I shall be able to illustrate them, from the vast cathedral to the simplest erection. Moreover, the architects of the middle ages were the first who turned the natural properties of the various materials to their full account, and made their mechanism a vehicle for their art."

Pointed architecture does not conceal her construction, but beautifies it: classic architecture seeks to conceal, instead of decorating it.

"The clumsy vaults of St. Paul's, London, mere coffered semi-arches without ribs or intersections, have their flying buttresses: but as this style of architecture does not admit of the great principle of decorating utility, these buttresses, instead of being made ornamental, are concealed by an enormous screen, going round the building: so that in fact one-half of the edifice is built to conceal the other. Miserable expedient! worthy only of the debased style in which it has been resorted to."

"An architect should exhibit his skill by turning the difficulties which occur in raising an elevation, from a convenient plan, into so many picturesque beauties; and this constitutes the great difference between the principles of Classic and Pointed domestic architecture. In the former he would be compelled to devise expedients to conceal these irregularities; in the latter he has only to beautify them But I am quite assured that all the irregularities that are so beautiful in ancient architecture, are the result of certain necessary difficulties, and were never purposely designed; for to make a building inconvenient for the sake of obtaining irregularity, would be scarcely less ridiculous, than preparing working-drawings for a new ruin. But all these inconsistencies have arisen from this great error;—the plans of buildings are designed to suit the elevation, instead of the elevation being made subservient to the plan."

The last observation of Mr. Pugin's leads us very naturally to the consideration of the next subject. The Greeks were confined to one plan in their edifices, the parallelogram; and in their application of this form they had but little choice, the main variation consisting in the arrangement of the external colonnade. It was a form well enough adapted to their religious observances, and restricted to buildings of that nature. Their edifices were chaste and grand, but chargeable at the same time with sameness and monotony; the one idea was universally resorted to, and probably because they had no occasion for any other. The Romans, however, did not restrict themselves to this form, their wants were more extensive than those of the Greeks, from whom they borrowed the main idea of their architecture; they wanted something more than temples; in short, they were a more secular people than the Greeks, and thought their secular buildings worthy of as costly magnificence as the temples of their gods. To this circumstance we owe the introduction of the practice of grouping, as it is termed, and the adaptation of the plans of the buildings to the various purposes of life; the Romans broke through the ancient rules of uniformity, and struck out into a wider and bolder path, which led by many directions to a great variety of results. But even the Romans were but tyros in this new system, which they left to after-ages to bring to perfection. The old Greek style was but little adapted to this altered state of things; and as much as the Romans gained in convenience, by so much they lost in appearance; the old principles could but ill brook their forced adaptation to new rules, and in process of time they died, (if we may be allowed the expression,) a natural death. The principles of Gothic architecture took their rise from the wants of the times, and gave completeness to that of which the Romans had originated the idea; and the style has this superiority over every previous one, that it can easily adapt itself to any purpose. No matter what shape you require your plan, nay, it matters not, though it be of no acknowledged or describable shape at all, you may rear upon it an elevation in accordance with the principles of the style, and one which only requires a skilful hand and practised eye to make it at once tasteful and convenient. Sir James Hall has the following trite remarks, which are very much to the point; he says:—

"In order therefore to apply Grecian architecture to our purposes, it has been found necessary very much to alter the old Greek plan; but this having but little variety, could not easily admit of any change. And a Grecian colonnade being of itself a most perfect form, we cannot well conceive how anything should be taken from it or added to it without injury; at least, to do so would require a hand no less dexterous than that by which it was originally designed. It is not, therefore, wonderful, that our artists, employing Grecian architecture for new purposes, and introducing without ceremony forms unknown to the Greeks, should produce works devoid of those beauties for which theirs are so highly distinguished.

"The greatest detriment seems to have been occasioned by the introduction of windows, for which the old Greek masters had made no regular provision, but which are indispensable in most of our buildings. For by thus obtruding a new form upon the old style, its unity of design must be violated. The more so, that a set of windows partake, by their form and arrangement, of the regularity of a colonnade, and consequently occasion more disturbance of the general effect, than if there had been no resemblance between them.

"The necessity among the moderns of forming edifices spacious within, has been a source of great confusion; for the old Greek masters not having need of room, have left us no good examples of the kind, and our own artists, in pursuit of that object, have piled order upon order, and have joined together various parts in the same building, which, though each may be beautiful in itself, have no connection together, and can only deserve the name of more or less elegant pieces of patch-work.

Thus Grecian architecture, though rich in ornamental details, was susceptible of little variety in the general plan.

It has therefore failed when applied to our purposes, though in the hands of the old Greek masters, and employed in the construction of works suited to the wants of that people, it has far surpassed any other style. Gothic architecture, on the other hand, with great variety of ornamental details, admitting of the greatest latitude in the general plan and distribution of the parts, and being susceptible of almost any shape, is applicable to every purpose, and might be suited to the manners of every nation.

"A Gothic edifice receives and accommodates an immense multitude of people, and furnishes an unbounded supply of light in a manner which constitutes one of its principal ornaments. And this advantage seems to belong to the Gothic exclusively; for it does not appear, that in any other style of architecture, a provision has been made for the provision of light in an ornamental manner. It possesses, in the highest degree, several different and seemingly incompatible qualities. When entire in all its parts, everywhere clean and fresh, and enlightened by a bright sunshine, we admire its airy lightness and lively elegance; but when clothed in a majestic veil of obscurity, or reduced to ruins and overgrown with moss and ivy, we are struck with awe by its solemn grandeur.

"It results from this comparison, that the Grecian style excels in all those qualities of elegance and grace which depend upon the nice adjustment and masterly execution of details. Whereas the Gothic style, which with great truth has been compared to the genius of Shakspeare, is lively, picturesque, and sublime, qualities which are derived from the bold variety, and often from the wild irregularity, of its forms."

With this passage we naturally close our comparison; we have stated our own opinions on the subject, and produced authorities on both sides—the reader must form his own decision.

We now proceed to a description and arrangement of the style, but, before doing so, it will be needful to take some notice of those styles which immediately preceded it. Soon after the disruption of the Roman empire, we find architecture, lapsing into barbarism, still retaining strong characteristics of the previous style, but exhibiting only a clumsy imitation. The buildings of this age were but heaps of discordant parts, put together without reference to unity of design or arrangement. Out of this medley arose a style, which, however barbarous it may be deemed, can still boast some title to consistency, for, by this time, architects had broken through the trammels of the old methods which had hitherto fettered them. The style, known by some under the general title of Romanesque, and by others divided according to some marked peculiarity, or to the countries in which it was adopted, into Byzantine, Lombardic, and Norman, was the immediate precursor of the Gothic or Pointed style. It differs essentially from the Roman method in many respects, and presents us with several new principles, amongst which may be enumerated the entire disuse of the entablature, the arches springing directly from the capital of the pier or column; the total disregard of classic proportions, and an unusual variety and license in this respect, some columns being of the average height of the Classic orders, others much stunted, and others again exceedingly extended, more especially those attached to walls or piers, which become little better than vertical mouldings; the practice of including two or more arched openings under one common arch; and some few other particulars, which it is not necessary to mention. We give the following description of the buildings of the period to which we allude, as laid down by one of the writers already quoted. It will be seen to differ, in some respects, from our own account, but this may arise from his more especially alluding to some particular class of buildings, or because he was desirous of making a marked distinction between the erections of this style, and of that which followed it, the Gothic. He gives notice of some particulars which we have omitted.

"The arches," he says, "are round; one supported on pillars retaining traces of the Classical proportions; the pilasters, cornices, and entablatures have a correspondence and similarity with those of Classical architecture; there is a prevalence of rectangular faces and square-edged projections; the openings in walls are small, and subordinate to the surfaces in which they appear, the members of the architecture are massive and heavy; very limited in kind and repetition; the enrichments being introduced rather by sculpturing surfaces, than by multiplying and extending the component parts. There is in this style a predominance of horizontal lines, or at least no predominance and elongation of vertical ones. For instance, the pillars are not prolonged in corresponding mouldings along the arches; the walls have no prominent buttresses, and are generally terminated by a strong horizontal tablet or cornice."

The style, although an approach in that direction, differs in many material points from the later Gothic; but as we have occasion to notice the main features of distinction between the Roman and Gothic modes of building, and have also noticed the differences between the former and the Romanesque styles, we do not deem it necessary to institute a detailed comparison between the intermediate and Gothic systems.

Sir Christopher Wren takes notice of the variations of the two extreme styles, and although his deductions as to questions of merit cannot justly be assented to, his comparison as to principles is, for the most part, correct. He says:

"In this they essentially differed from the Roman way, who laid all their mouldings horizontally, which made the best perspective; the Gothic way, on the contrary, carried all their mouldings perpendicularly; so that the ground-work being settled, they had nothing else to do but to spire all up as they could. Thus they made their pillars a bundle of little tori, which they divided into more when they came to the roof, and these tori split into many small ones, and, traversing one another, gave occasion to the tracery work, as they call it. They used the sharp-headed arch, which would rise with little centering, required lighter key-stones and less butment, and yet would bear another row of doubled arches, rising from the key-stone, by the diversifying of which they erected eminent structures, such as the steeples of Vienna, Strasburg, and many others."

Mr. Rickman, to whom we are so much indebted for his researches on this subject, gives the following more detailed comparison in a tabular form:—

Grecian.	*English.*
The general running lines are horizontal	The general running lines are vertical.
Arches not necessary.	Arches a really fundamental principle, and no pure English building or ornament can be composed without them.
An entablature absolutely necessary, consisting always of two, and mostly of three, distinct parts, having a close relation to, and its character and ornaments determined by, the columns.	No such thing as an entablature composed of parts; and what is called a cornice bears no real relation to the shafts which may be in the same building.

Grecian.	*English.*
The columns can support nothing but an entablature, and no arch can spring directly from a column.	The shafts can only support an arched moulding, and in no case an horizontal line.
A flat column may be called a pilaster, which may be used as a column.	Nothing analogous to a pilaster; every flat ornamented projected surface is either a series of panels or a buttress.
The arch must spring from a horizontal line.	No horizontal line necessary, and never any but the small cap of a shaft.
Columns the supporters of the entablature.	Shaft bears nothing, and is only ornamental, and the round pier still a pier.
No projections like buttresses, and all projections stopped by horizontal lines.	Buttresses essential parts, and stop horizontal lines.
Arrangement of pediment fixed.	Pediment only an ornamented end-wall, and may be of almost any pitch.
Openings limited by the proportions of the column.	Openings almost unlimited.
Regularity of composition on each side of a centre necessary.	Regularity of composition seldom found, and variety of ornament universal.
Cannot form good steeples, because they must resemble unconnected buildings piled on each other.	From its vertical, lines may be carried to any practicable height, with almost increasing beauty.

Mr. Willis, in the annexed table, treats the subject in a somewhat different form, referring rather to rules of principles, than details of practice:—

Classical styles.	*Middle-Age styles.*
Different planes of decoration avoided, and never exceeding two in an entire composition.	Different planes of decoration placed behind each other to any number, and in every possible degree of variety, even in a single member, as in an arch.
Superincumbent weights united as far as possible, by resting on the horizontal cornice, which combines them into one mass.	Superincumbent weights divided into as many parts as possible, and then given to independent props.
Arch, foreign to this style, and when introduced its diagonal pressure excluded from the decoration.	Arch, the essential feature; its diagonal pressures studiously manifested, and the rest of the composition harmonized with them by other inclined lines.
Artifices of construction concealed, as impairing the simplicity of effect.	Every artifice of construction displayed.
Chamfered surfaces inadmissible, and mouldings can only stop against a surface perpendicular to their course.	Chamfered surfaces universal; mouldings are applied to them, and may die against them or any other surface at any angle.
Panels mere superficial ornaments.	Panels are apertures between the parts of the decorative frame of the building.

Elsewhere he adds:—

"These decorative features differ in many respects from the Classical, but the leading principle is to be found in the increased multiplicity of parts, and in a system which affected to support them all independently, arranging them in groups, in opposition to the Classical scheme, in which the parts are simple, and bound together by the dominant cornice."

"It is suggested to me by a friend," says the Rev. W. Whewell, author of Architectural Notes on German Churches, "that this distinctive principle of construction in the Gothic architecture, appears to be the admission of oblique pressures and inclined lines of support; in Greek architecture, the whole edifice consists of horizontal masses reposing on vertical props. In Gothic buildings, on the contrary, the pointed arch is always to be considered as formed by two sides, leaning against each other at the top, and pressing outward at their lower ends. The eye recognizes this statical condition in the leading lines of the edifice, and requires the details to conform to it. We have thus in the Grecian buildings nothing but rectangular forms and spaces, horizontal lines with vertical ones subordinate to them. The pediment is one mass with its horizontal cornice, and does not violate this rule. Arches, when they occur, are either subordinate parts, or mark the transition style, in which the integrity of the principle is no longer preserved. In Gothic works, on the other hand, the arch is an indispensable and governing feature; it has pillars to support its vertical, and buttresses to resist its lateral pressure; its summit may be carried upwards indefinitely, by the joint thrust of its two sides. All the parts agree in this character of infinite upward extension, with an inclination or flexure to allow of their meeting at top; and they obviously require, and depend on pressures acting obliquely."

He adds the following particulars in a more tangible and systematic form.

"1. The arch is essential, the entablature is not, and the columns support arches instead of entablatures.

"2. There are any number of planes of decoration one behind the other. When we have in this way several arches under one, we are led, as Mr. Willis has shown, to tracery; when we have arches of different forms one under another, we are led to foliation.

"3. The weights are divided into as many parts as possible, and these are given to independent props; whence we have, among other results, clustered piers and pillars.

"4. The diagonal pressures of the arch are displayed, whence we have buttresses and pinnacles.

"5. And, generally, the running and dominant lines are vertical in this style, as they were horizontal in the ancient styles: the characteristic forms of the one being horizontal, reposing, definite; of the other, vertical, aspiring, indefinite."

We do not feel it incumbent upon us to add anything to the above, the subject having been fully treated of by each writer, the difference of treatment which may have been noticed, arising from the fact, that some of the writers have looked at the grand principles of the two styles, while the others have confined themselves to a comparison of the results of such principles, as applied in practice.

Having thus given a general description of the Gothic style, and its main characteristics, as distinguished from the Classical and succeeding modes of building, we will now proceed, in order to give a more detailed account of it as a distinct style, without any reference to other systems. In order to do this, it will be requisite to adopt some systematic arrangement in connecting and subdividing the various examples, so as to arrive at some clear notion of the rules which guided the Mediæval architects in the erection of their buildings; and in doing this we shall confine ourselves to the methods usually employed, not only because they are well established, but further, because they have been determined upon with great judgment.

Amongst the earlier writers, there does not seem to have been much attention given to this part of the subject; Warton, however, in his tract, attempts a classification, in which he thus distributes the different varieties:—In the first division, which he denominates *Gothic Saxon*, as not fully entitled to the name of Gothic, but having a decided tendency to that style, he places Salisbury Cathedral, and gives the thirteenth century as the epoch of that division. The next division, which he terms *Absolute Gothic*, he extends over the fourteenth and first half of the fifteenth century; he lays down as the characteristic feature, the ramification of the decoration in the window-heads, and gives as an example, the body of Winchester Cathedral. To the third division he gives a duration of only forty years, from A. D. 1441, to 1480, at which latter period he places the commencement of the *Florid Gothic*, the third division having the title of *Ornamental Gothic*; of the latter he gives King's College Chapel, as a specimen; and of the former, the chapels of St. George, Windsor, and of Henry VII., Westminster.

Mr. Dallaway arranges the styles as follows:—

	A. D.	During the reigns of
Semi or Mixed Norman..	1170—1220..	Henry II., Richard I., & John
Lancet-arch Gothic.....	1220—1300..	Henry III., & Edward I.
Transition or Pure Gothic	1300—1400..	Edward I., II., & III., & Richard II.
Decorated Gothic......	1400—1460..	Henry IV., V., & VI.
Tudor or Florid Gothic.	1460—1540..	Edward IV., to Henry VIII.

But the arrangement which most modern writers have followed, is that of Rickman, which is more simple, consisting of only three divisions, viz.:—

	A. D.
Early English............	1189—1307
Decorated English........	1307—1377
Perpendicular English.....	1377—1630

Mr. Bloxam subdivides the Early English into two distinct styles, and in this he agrees with Mr. Dallaway, but he names the earliest division Semi- or Mixed Norman, and the later Early English. He also subdivides the period allotted by Rickman to the Perpendicular style, restricting that title to those examples erected before A. D. 1540, and to the later buildings applying the term Debased.

Others again have retained the tripartite division of Rickman, but have used other titles, denominating the first division First Pointed, the second Middle Pointed, and the last Third Pointed.

The difficulty in classifying the examples of this style arises mainly from the gradual development of each particular division, the one merging into the other by such imperceptible degrees, that it is difficult to determine where the one commences and the other ends, although when each style is seen in its matured and perfect form, it is readily distinguishable from its neighbour. The most prominent characteristics of each style are to be seen in the windows, where the distinction is usually very manifest; the shape of the arches also, forms another principal feature by which the date of a building may be to a certain degree determined, although not very accurately, for the same shaped arches are used in different styles. Perhaps the most certain distinctive marks are to be observed in the mouldings and matters of detail; and these, taken together with the more prominent features, will in general lead to a tolerably accurate decision. We shall consider the peculiarities of each style in a systematic and detailed form, dividing a building into its several component parts, and comparing them, as it were, analytically. Before entering on this task, however, we deem it advisable to refer to the nomenclature and system of classification in the description of particular buildings, recommended by Mr. Willis; so that should any of his terms occur in the following pages, they may be correctly understood. We must recommend them for adoption, as affording, for the most part, a simple, intelligible, and systematic mode of arrangement.

In the description of a building, he advises that one bay of the interior should be taken as an example; divided into its several parts, and each of these treated fully and systematically. This, with a specification of the number of bays, will form a description, generally speaking, of the main portion of the building, unless any differences occur in the other bays, and in such case it will be requisite of course to note the variation. The same course is to be pursued on the exterior of the building, but here it will be requisite to note, in a more especial manner, the arrangement and decoration of the principal façades, as also of the towers and spires, if there be any, and of any other similar addition.

The following are some of the principal terms employed by him in his nomenclature.

Impost, the line or surface of common section between the arch and the support upon which it rests; not, as heretofore explained, the mouldings or capital from which the arch springs, but the plane upon which the arch and pier meet.

Continuous imposts, those in which the mouldings of the arch are continued, without interruption, to the ground.

Discontinuous imposts, where the mouldings of the arch die into the pier without any band of mouldings.

Corbelled imposts, where the mouldings of the arch spring from a corbel without being continued to the ground.

Arches he divides into *simple* and *compound*, the latter term being applied to such as consist of several different surfaces projecting one beyond another, or such as may be resolved into a number of concentric archways successively placed within and behind each other.

Shafted archways are those in which the horizontal section of the shaft differs from that of the arch.

Banded archways, those in which the horizontal sections of the pier and those of the arch coincide, but which have impost mouldings or capitals.

Shafts are divided as follows:—

Vaulting shafts, those which sustain the ribs of vaulting.

Bearing shafts, those which sustain the whole superincumbent weight.

Sub shafts, such as sustain arches of which the upper side is united to the soffit of the next arch or wall.

Face shafts, such as sustain arches of which the back only is united to the wall, and which appear as though placed upon the face of the wall.

Edge shafts, those which support arches united by their sides and back to the nearest wall or arch, so as to appear to support the edge only.

Nook shafts, are similar in plan to edge shafts, but the rib differs from an edge-rib in not being united to the contiguous wall, but, like the shaft, nestled into the re-entering angle formed by the side and face of the contiguous arches.

The same terms are applied to the arches which are sustained respectively by the above-named piers; thus we have *sub-arches*, *face arches*, &c. Shafts which sustain vaulting ribs are termed by Mr. Whewell *Building pillars;* and compound piers, *pilaster masses*.

When an arch is indented with foils or cusps, it is said to be *foiled*, but when it has another foiled arch below the simple one, it is said to be *foliated*.

Thus, in describing an archway, it is first designated as simple or compound, and, if compound, it is described as consisting of so many orders, according to the number of arches it consists of, or, in other words, according to the number of the different soffits or projections, and thereupon each order is described separately in reference to the nature of the impost, whether continuous or discontinuous, as to the position of the shafts and arches, as sub-shafts, face shafts, &c., and so on, in accordance with the nomenclature above given.

Mr. Whewell describes the arches of a vault as *longitudinal*, *transverse*, and *diagonal*, the first term being applied to those running in the direction of the length of the building; the second, those carried at right angles to the longitudinal; and the last, to those carried diagonally, intersecting each other at the centre, and connecting the extreme angles of the severy.

Vaulting is also described as *quadripartite*, *sexpartite*, *octopartite*, &c., according to the number of cells contained in each bay.

Mr. Willis divides the intersections of vaults into *groins* and *ridges*, the former term being applied to those forming an external angle or *edge*, and the latter to those forming an internal angle or *nook*. Hence we have *groin ribs*, *ridge ribs*, and *surface ribs*, the last expression applying to those spread over the surfaces of the vaulting cells.

It will be further necessary ere proceeding to the particular description of the styles, to give some account of the various kinds of arches employed in Gothic buildings. This is especially necessary, as the arch forms a very strong characteristic of the style, and is of very great assistance in deciding, by its shape and formation, the period to which any particular example may belong.

The arches in use in Mediæval buildings, are the triangular, circular, and pointed. Of these, the first, composed of two straight lines inclined towards each other, and forming two sides of a triangle, are almost peculiar to the Saxon style, but are occasionally, though rarely, found at a later period; the second, the outline of which consists of a curve of constant curvature, or some portion of a circle, may be divided into three different kinds, according to the proportion of the circle which it includes.

The most simple of these three kinds, and that which is the more frequently used, is the semi-circular, comprising one half of the circle, the centre of which is in the springing line of the arch. This form was in general use from the time of its introduction by the Romans, until the establishment of the Gothic style, from which it was almost discarded; some few instances are, however, still to be found, in examples posterior to that period.

The horse-shoe arch, as it is called, containing a larger portion than the half of the circumference, and having the centre of the circle above the spring-line, is of very rare occurrence at any period. The segmental, on the contrary, which contains a portion of a circle only, and which springs above its centre, is of occasional employment at every period, more especially as an arch of construction, but also in apertures, as doors and windows. There is yet another method of using the semi-circular arch, by stilting it on uprights, so that the curve of the arch is continued downwards in a straight line below the springing of the course; this is found more especially in the pre-Gothic styles.

Of the Pointed arch, which is characteristic of the style, there are many varieties. In the first place, they divide themselves into two-centred and four-centred arches, of the former of which there are at least three descriptions; the Lancet, the Equilateral, and the Obtuse.

The Lancet consists of two segments, the centres of which fall outside the arch, the radius being of greater length than the span: it may be described about an acute-angled triangle. The equilateral has the centres of the segments on the opposite extremities of the span, the radii of the circles therefore being equal to the span of the arch; it may be described about an equilateral triangle. In the obtuse arch, the centres of the segments fall within the arch, and has therefore the radii less than the span of the arch; it may be described about an obtuse-angled triangle.

The four-centred arch, which is also named the Tudor arch, from the dynasty during which it was in use, is described from two centres on either side, the one being on a level with the springing, and the other at a considerable distance below it, the curves of lesser curvature, or those described with the longer radius, meeting at a point, and thus leaving the arch still pointed.

There is another kind of arch termed the ogee, each side of which consists of a curve of double curvature, the lower curve being concave on its under side, and having its centre on a level with the spring, and the upper convex, with the centre on a level with the apex.

There yet remains to be noticed a more ornamental kind of arch, which is by no means uncommon, and is what is termed a foiled—or, to designate it still more closely—a trefoiled arch. The appellation arises from the shape or outline, which is that of a trefoil, or rather of a semi-quatrefoil. There are two kinds of these; the round-headed trefoil, in which the curve between the cusps is a semi-circle, and the pointed trefoil, in which the same curve is composed of segments less than a semi-circle. There are also what are termed square-headed trefoil arches, in which the centre compartment, instead of being circular, is square or rectangular, leaving the side-ones still circular.

Such are the arches most frequently applied in Gothic buildings; there are some few other varieties, but they are of so rare occurrence, that it is scarcely worth while taking notice of them.

But to return to the classification and description of the various styles; the first of which, the Early English, dates from A. D. 1180 to 1300, including the reigns of Henry II., Richard I., John, Henry III., and Edward I., may be called, in general terms, the style of the thirteenth century. The architecture of this period is exceedingly beautiful and chaste, simple and elegant in design, and excellent and delicate in execution, equally applicable to the modest village church, and the noble abbey or cathedral, remarkable in the one for its unobtrusive simplicity, and, in the other, for its solemn and majestic grandeur.

In describing this and the succeeding styles, we shall follow the method commenced by Rickman, and adopted by most of the later writers, of considering them in detail; that is to say, we shall select the most important of the component parts of a building, and describe them separately as to their character and treatment in each style. We shall arrange these parts and their descriptions in the following manner: *Arches;* next their supports, *Piers*, which we subdivide into *Shaft Capital*, and *Base;* then *Windows*, *Doorways*, *Buttresses*, *Parapets*, *Roofs*, and so forth, including *Towers*, *Spires*, and decorative features, such as *mouldings*, *pateræ*, *foliage*, and other sculpture.

Arches. The arches principally in vogue at this period, were acutely pointed, either lancet or equilateral, the former being most prevalent in the larger structures; in which, however, the latter was not unfrequent, as may be seen at Salisbury cathedral, where it is more frequent than any other shape. It is, however, a rule that the arches are comparatively more acutely pointed in larger churches and cathedrals, and accordingly we find the obtuse-pointed arch most extensively used in small parish churches. The semi-circular arch was not entirely out of use at this period, as we find it frequently combined with the pointed, two or more of which are sometimes included under one of the former shape, as at Whitby Abbey, and in other examples. There are also not a few instances in which the semi-circular form is used alone, and sometimes treated in a similar manner as regards decoration, to those of a later date. Segmental arches were likewise in use, not only as constructive arches, but also as coverings for apertures, and more especially doorways.

The soffits of the arches were, in the more magnificent examples, richly moulded with a series of projecting rolls with deep hollows intervening, but in smaller churches they were for the most part merely cut in recession, so as to present two or more surfaces, having the angles of each projection plainly and broadly chamfered.

Piers. In large edifices the *shafts* of the piers were often composed of a series of pillars clustered together in various forms, to the number of four and upwards. Sometimes these shafts were attached to each other, but they were frequently detached, consisting of a massive central pier, usually circular, but sometimes octagonal or square, and surrounded by four or more slender pillars, entirely detached from each other and the central shaft, except at the base and capital, and occasionally at one or two points in the height of the shaft, where they were connected by narrow bands or annulets of moulding. These annulets are used also in the other kinds of shafts, and are characteristic of the style. The smaller pillars, when detached, are often constructed of a more costly material than the other parts of the shaft, being sometimes of Purbeck marble and polished. The same arrangement of central shaft, with four surrounding pillars, is to be found with the pillars attached to the main pier; specimens of both kind exist at Westminster Abbey. The pillars are usually simple rounds, but sometimes they have a narrow vertical fillet.

In smaller churches the shafts were a simple circle or octagon in plan; more frequently the former, and are distinguishable from those of a later date only by the details of base and capital. It frequently happens that the shafts of piers in the same edifice differ in form, and they are frequently so arranged as to have circular and octagonal forms alternately in the same arcade.

The *capitals* of this period are usually bell-shaped, and are often, especially in the smaller examples, quite plain, with the exception of a necking, and one or two mouldings beneath the abacus. In such cases, they are distinguished from the capitals of later styles only by their mouldings, which consist of rounds and deep hollows; the bell is generally very deeply undercut, which is a strong characteristic of the style. The mouldings are generally plain and few, but sometimes the nail-head or dog-tooth ornament is inserted between them. In the larger and richer specimens, the bell is covered with foliage, which springing from the necking, is curled over with a graceful curve beneath the upper mouldings. The foliage is somewhat stiff in appearance, but of a bold and striking character, and is sometimes undercut to such an extent as to be partially detached from the bell; it consists for the most part of a variety of adaptations of the trefoil leaf, and we rarely meet figures of any kind. In clustered piers, the capitals follow the form of the pier; as also in the single shaft they adopt the same form, with the exception that the multangular shaft has not unfrequently a circular capital. The abacus is either circular or octagonal, and sometimes square in plan, and consists of mouldings varying in number, and made up of deep hollows with overhanging rounds, which are either plain or filleted.

The base consists of a series of mouldings, frequently of a deep hollow and fillet between two rounds, of which the lower one projects beyond the other; it is also often similar to the Attic base, with the exception that the proportions differ, the upper torus being greatly reduced, and the concave mouldings deeply undercut. The base most frequently stands upon a single or double plinth, which in the earlier examples is square, having the angle covered with a leaf which springs from the mouldings of the base, and falls over the plinth. In later specimens, the plinth assumes the form of the base, and is either circular or polygonal; it is sometimes of great height, having a second series of mouldings below the base.

The *windows* of this style are for the most part long and narrow, with acutely-pointed heads. The earliest and simplest form is that of a long narrow single light, with arched head, and without moulding of any kind either internally or externally, the exterior angle being merely chamfered, and the interior widely splayed. Such windows were sometimes without any weather-moulding, but occasionally a string-course was carried from one window to another, at a level with the springing of the head, and then lifted over it, adopting its form, and carried on to the next aperture. In later times such windows appear in groups of two, three, or more, the first being commonly found in the side-walls of churches, and the latter being almost confined to the east end, except in very large buildings, where it is found in all positions. The separate lights of these groups are generally placed at some distance apart on the exterior, so as scarcely to appear as belonging to the same window; but in the interior, owing to the great splay given to each light, the distance between them appears inconsiderable, giving them the appearance of a single compound window. This idea is sometimes manifested on the outside by the two or more lights being contained under one drip-stone. The glass is inserted near the outer face of the wall, which circumstance, taken in connection with the great thickness of the walls, accounts for the difference of the size of the aperture on the two faces of the wall. This arrangement was in all probability adopted for the purpose of obtaining a larger proportion of light, or rather spreading what they obtained over a larger portion of the interior.

The arches of the splay on the interior, seldom follow the form of the window heads on the exterior, but spring from a lower level, and are almost always chamfered or moulded at their angles or edges; the mouldings projecting below the soffit, and either dying into the jamb, or resting upon corbels at the spring of the arch.

In windows of three lights, the centre one is almost always of a greater length than those at the side, its head rising considerably above theirs, so as to preserve the arched form in the entire window. We occasionally meet with windows of four lights, the two centre ones rising above the others, but more frequently with others of five or seven lights rising in gradation to the centre one, which is higher than the rest. These large windows have a very beautiful effect, occupying as they do nearly the whole of the east wall. In all the above cases the jambs are sometimes plain, being merely chamfered and splayed as before described; but at other times we find them decorated with small detached pillars, with moulded arches. This is most frequent in the interior, where the shafts are not unusually of polished marble, but such decoration is also to be met with on the exterior, especially in large buildings. In windows of a late date, the arched heads are sometimes foiled.

Before the termination of this style, windows of a somewhat different appearance were introduced, which originated thus:—In cases where windows of more than one light were employed, it was, as has been mentioned, a not unusual practice to include them under one arch, the head of which was left plain; but in the course of time this space began to be pierced with another small light in the form of a circle or trefoil, which at once relieved the blank space beneath the arch, and admitted a greater amount of light. At Brownsover church, Warwickshire, there is a very simple arrangement of this kind, in which the third light is somewhat in the shape of a diamond placed between the arched heads of the principal lights, to which two sides of the figure are parallel, the two remaining sides being parallel to the curved sides of the larger connecting arch. In the earlier specimens of this class, the openings are still chamfered only, with shafts sometimes on the inside; but at a later period the lights were brought closer together, and were divided by slender shafts, and the arches and ornamental lights in the head moulded and foliated. We have many beautiful examples of windows of three lights, with three foliated circles in the head, and sometimes of five or more lights similarly decorated. The windows of the Chapter-house, York, are most beautiful specimens of five lights, which are arranged in two pairs of two lights each, connected under one arched head containing a foliated circle: the central light being also surmounted by an arch containing a trefoil. The whole of these are enclosed under the principal arch, which contains above the lights, three large foliated circles. The effect of this design is grand in the extreme. The east window of Lincoln Cathedral is another magnificent example: it contains eight lights in all, which are divided into two compartments containing four lights each, with arched heads filled with foliated circles, whilst the principal head is filled with one large circle containing seven of a smaller size. This is probably the largest window of the kind we possess.

Circular or rose-windows are not unfrequent in this style, and are divided into compartments by slender shafts with capitals, &c., radiating from the centre, and sustaining at the circumference small arches, which are usually trefoiled. Smaller windows of this form are either left plain, foiled, or filled with quatrefoils, &c. Windows of triangular shape are also found, as well as a peculiar sort of window in the form of what is called the Vesica Piscis; but these are always small, and placed in subordinate situations, such as the gables or the clere-stories of parish churches. Small square-headed windows are sometimes employed, but only in towers and similar situations.

The *dripstones* follow the form of the arch, and usually terminate on a projecting head or knob of foliage, but are sometimes returned horizontally along the wall; the moulding has a deep hollow on the under side to prevent the rain running over it. A string-course is generally carried along the external and internal walls, immediately below the windows.

The *doorways* of this period are most frequently furnished with nook-shafts in the jambs, which are, for the most part, detached from the walls, except at the capitals and bases. The more simple doorways have only one shaft on either side, supporting an archivolt of a few bold mouldings, the whole surmounted by a simple hood-moulding conforming to the shape of an arch, and terminating in a head or bunch of foliage, or returned in a horizontal direction along the walls. More elaborate specimens have two or more shafts on either side, and a greater number of mouldings in the arch. The jamb is cut in recession to receive the shafts, and the spaces between the mouldings or shafts are frequently filled up with the dog-tooth ornament or a running pattern of foliage. The arched heads of doorways are most frequently pointed, but not rarely round-pointed or square-headed trefoil.

The doorways of the larger structures are mostly divided into two arched apertures by a simple or clustered shaft, which is often of polished marble, and furnished with a richly moulded or foliaged capital. The arches are also foiled or foliated, and enclosed under one main arch, the space between being perforated in circles, trefoils, &c., and sometimes filled with groups of sculpture.

The *doors* are either plain or covered with iron scroll-work, sometimes proceeding from the hinges, which are often of a very ornamental character, but at other times nearly plain. In some cases this scroll-work is very elegant, and completely covers the door.

The *buttresses* of this period are, for the most part, of a simple character, consisting, in smaller churches, of two or more stages, the lowermost projecting beyond the other, each set-off being sloped at the top so as to carry off the rain. The buttress finishes at the top under the parapet, or eaves, with a simple slope similar to that of the other projections. In larger buildings, the buttress is frequently finished with a triangular head or gablet, but is seldom carried above the parapet, except where stone vaulting is employed, and, in such cases, it is covered with a pinnacle which is either plain or enriched with blank arcades. Sometimes each set-off is finished with a triangular head, and, at others, the water-table is continued round three sides of the buttress. The edges of such buttresses are often chamfered, or the angles ornamented with slender shafts; occasionally, too, the face is formed into a niche to contain a statue.

There is a peculiarity about the position of buttresses of this period, which is often the only means of distinguishing them from those of later date; at the angles of buildings they are not placed diagonally, but at right angles to the wall, so that whereas in this style we require two buttresses at each angle, placed at right angles to each other and to the adjoining walls, in the following styles we need but one.

Flying-buttresses, which are arches springing from the wall-buttresses over the roof to the clere-story, were now first introduced, and are common in all large buildings with vaulted roofs. They are of simple design, with a plain capping and archivolt.

Parapets are not frequent in small buildings, the roof being carried over the walls with dripping eaves; but when they occur, they are of a simple character, finished at the top with a moulded capping, and supported underneath by a corbel-table, which consists of a series of blocks moulded or sculptured in the form of heads or masks, and sometimes of foliage; these are often connected together by trefoiled, or other arches. The projection of the parapet above the corbel-table is often merely chamfered, but in the richer specimens moulded, and sometimes decorated with the dog-tooth ornament. In cathedrals, we occasionally see the parapet relieved by panelling, as at Salisbury, where the panels are of the form of trefoiled arches, and sometimes pierced with trefoils, &c. Battlements are not often found in this style.

Pinnacles, which rise above the general level of the buildings, are often mere continuations of the rectangular buttress capped with simple pyramids of square or polygonal bases, without any ornamentation, but in more costly examples the latter form is chiefly employed for the entire pinnacle, and is enriched with one or more series of blank arcades, which give them a light and elegant appearance; in some instances, the arcades are perforated.

The *Roofs* are of a high pitch, the angle at the apex coinciding mostly with that of an equialateral triangle, but sometimes they are more depressed. In small buildings, as we have above stated, they not unfrequently overhang the walls, but in larger ones they are stopped by the parapet. In the interior of large churches and cathedrals the roof is generally vaulted, the vaulting being of the simplest kind, or that which has been described as quadripartite, that is, consisting of four cells in each bay, and being divided only by transverse and diagonal ribs, not having a longitudinal one along the apex, as in later examples. The mouldings of the ribs consist generally of rounds plain or filleted, and deep hollows, and are covered at their intersection by bosses of sculptured foliage.

The wooden roofs of the period were like all Gothic roofs, except those of a very late date, open to the ridge, and unceiled, so as to afford a view of the timbers from the body of the building. In recent times, however, most of these open roofs have been excluded from view by the intervention of a modern ceiling, and it is seldom they are brought to light, except on the occasion of an extensive repair or restoration of the entire fabric. This fact will account for the paucity of information respecting this portion of a building, a want which is more particularly felt in respect of the early styles; so much so, indeed, that we scarcely know for certainty how to distinguish the early English from the Decorated examples, and it is probable that there is no very marked difference between them, although it is usual to make a distinction in treatises of this nature.

The most simple roofs, which we may attribute as more particularly belonging to this period, consist only of common rafters placed at short distances apart, without the intervention of trussed principles, and have a very good effect, owing to the lengthened perspective produced by the frequent repetition of the same parts. The rafters are very often secured by means of collar beams and braces, or by intersecting braces springing from purlins about half-way up the rafters, and rising to a higher purlin on the opposite side of the roof. These two systems are very common and simple, but not unfrequently the two were united, so as to have a collar beam with cross braces intersecting a point usually above it; and sometimes, in addition to these, we have a strut below, all resting upon the wall-plate, so that the entire outline of the under side presents the appearance of a polygonal arch. In some instances, the braces are curved in the form of a pointed arch. Where the roof is carried over both nave and aisles, the portion over the nave is of a similar description to those above mentioned, and in that over the aisles, the side next the nave is supported by short beams or struts abutting against the nave walls; this is also common in lean-to roofs. Although the practice of adopting only common rafters may be more usual, the introduction of principals is not unfrequently resorted to, which, in such instances, follow the same constructive form as the common rafters before referred to, the common rafters, however, are of a more simple character than the principals.

Tie-beams do not seem to have been of frequent occurrence, and king-posts are still less usual, their absence being very readily accounted for by their necessary weight in roofs of a high pitch; when tie-beams are employed, they are sometimes supported underneath by sloping braces abutting against the wall, and this method removes, in a great degree, the objection made against ties, of destroying the vertical tendency of the general design.

The timbers of the roof are often plain or chamfered on the edges, but in the richer specimens they are moulded, or at least the main beams, such as principals, purlins, wall plates, and such like, but the common rafters are mostly plain.

The *Towers* of the period are of various proportions, but generally bear a substantial, massive appearance; they are almost always square on plan, but sometimes octagonal, and in a few instances square below and octagonal above. They are strengthened at the angles by buttresses, two at each corner, projecting at right angles to the walls, which generally terminate a stage or more below the top; projecting stair-turrets are not uncommon, but are sometimes concealed by the buttresses.

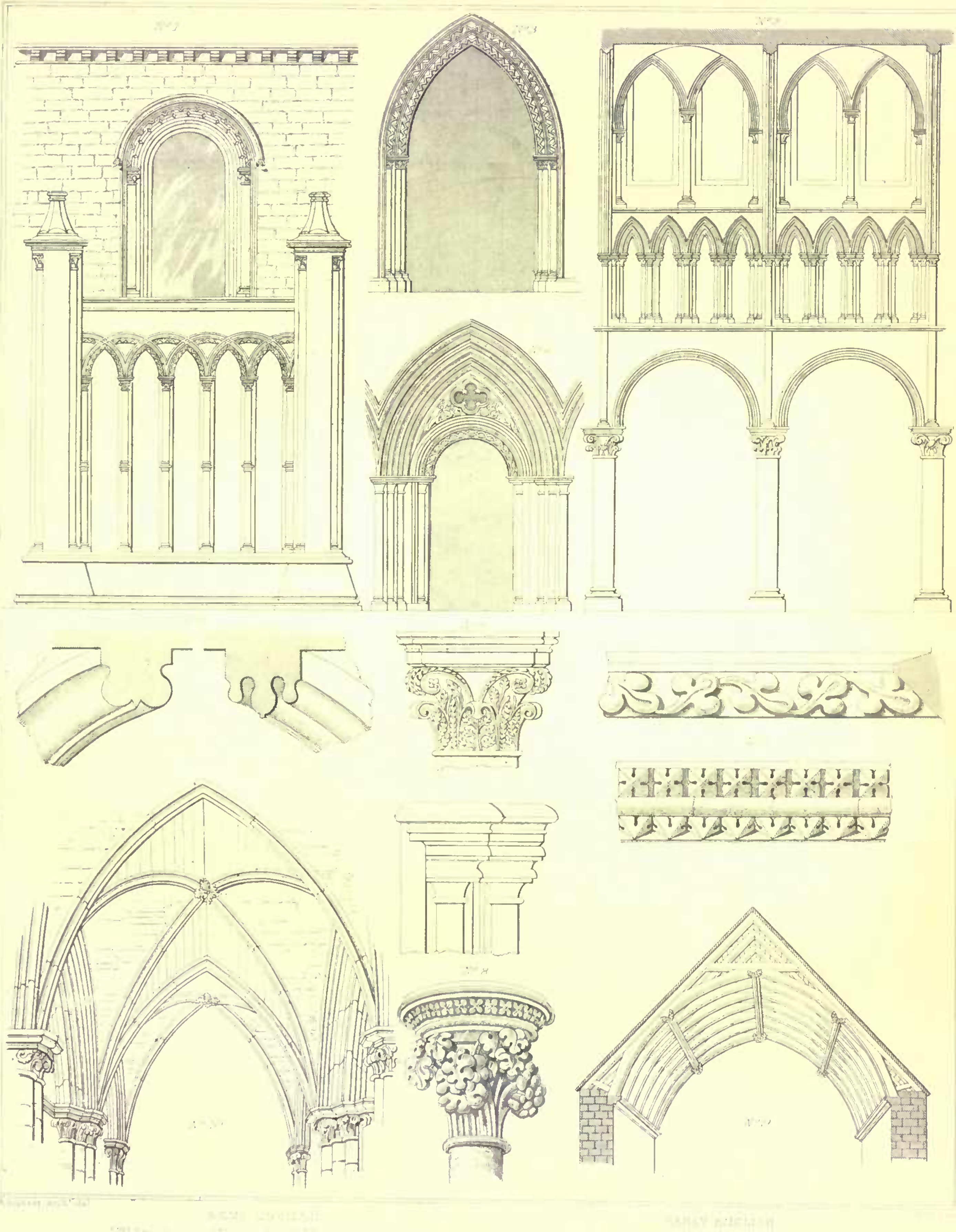
The tower is divided into stages by set-offs or otherwise, of which the upper ones are frequently decorated with blank arcades, a few being perforated, to serve as windows; sometimes the faces are perfectly plain, with the exception of the apertures for windows, which consist of one or more light, the most important being placed in the upper stories. Here, in smaller churches, we generally have a window of two lights divided by a shaft, and having a foiled aperture under the arched head, but in larger churches we find windows of three lights, or triplets, but of equal height; in the lower stories we usually find single lancets.

These towers are occasionally covered by a low pyramidal or a gable roof, but more frequently by a lofty spire of stone or wood, although for the most part less acutely pointed than those of a later style. The spires are almost invariably broach-spires, that is to say, such as spring directly from the roof, without the intervention of a parapet; their plan is almost always octagonal, four of the sides sloping down to the eaves, but the four corner ones leaving a triangular space at each angle of the tower uncovered, which is occupied either by a pinnacle, or more frequently by a triangular pyramid, which connects the angles of the tower with the angular faces of the spire. Towards the lower part of the spire, the cardinal sides are furnished with windows, which rise perpendicularly, so as to give a projection at the top which is covered with a gable-head, and sometimes we have two or more tiers of such windows placed often on alternate sides of the spire. The whole is surmounted by a finial and vane. The cornice below the eaves is frequently ornamented with the dog-tooth moulding, or a running pattern, and is often supported upon a bold corbel-table.

A very elegant substitute for tower and spire, is employed in small churches, in the shape of a bell-gable, with one or more openings to contain the bells.

The *Mouldings* of the style have no great variety of form, but consist almost universally of bold rounds with deep undercut hollows intervening, so as to produce a great amount of shadow. The rounds are sometimes filleted with one or more fillets, but this is not usually the case with the smaller mouldings. Where several mouldings are connected together, there is considerable difference of size, the entire series being generally divided into a few distinct portions by mouldings of a large size, which are often filleted, and the intermediate spaces filled up by smaller plain mouldings. In such cases, it will be generally found that the mouldings are so arranged,

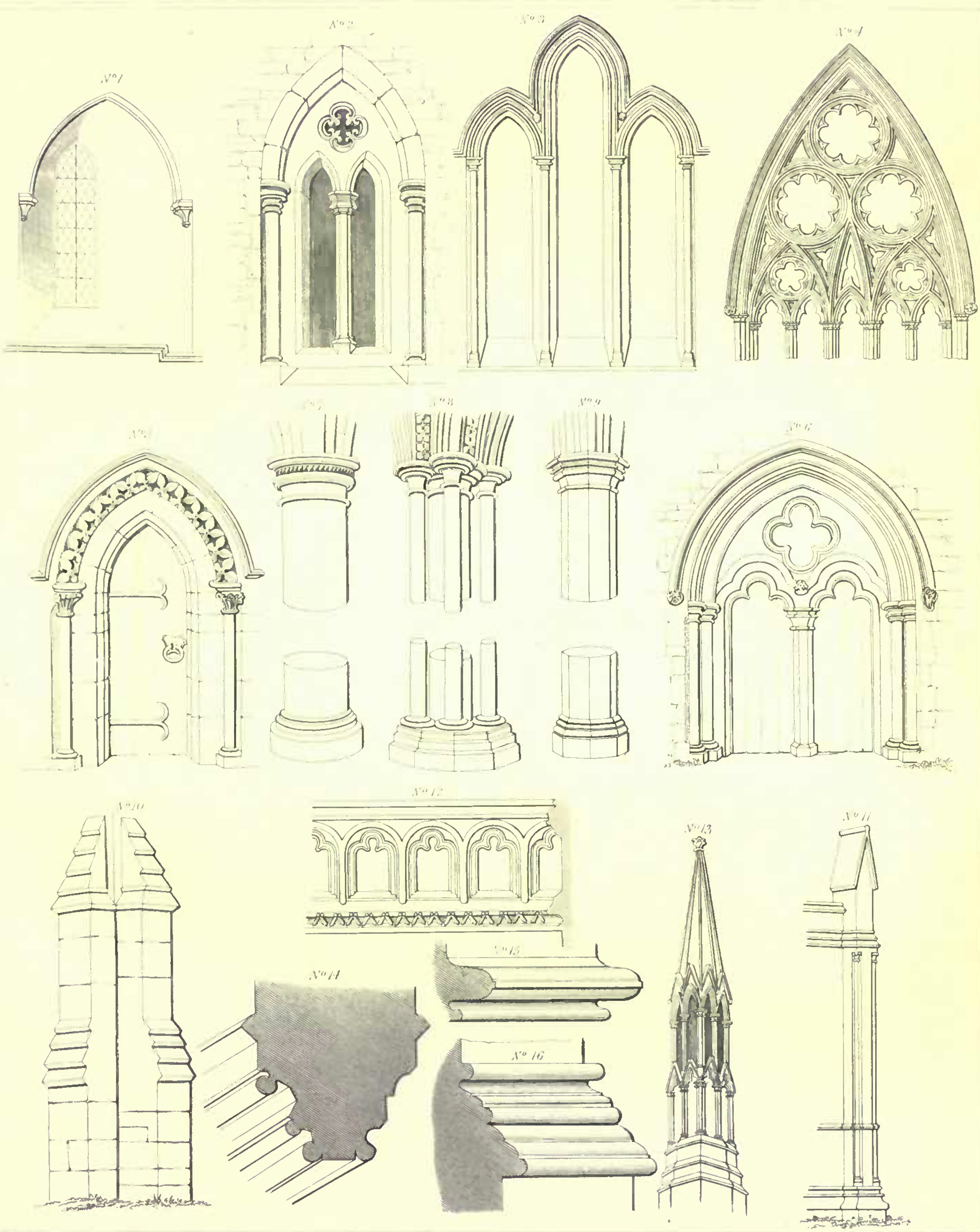
SEMI-NORMAN AND EARLY ENGLISH EXAMPLES.



SEMI-NORMAN.

EARLY ENGLISH.

GOTHIC ARCHITECTURE — EARLY ENGLISH EXAMPLES.



J. Gilbert, Archt. del. | R. Thew, Sc.

No. 1 Window, Single light	No. 5 Doorway, Single	No. 9 Pillar, Octagonal,	No. 13 Pinnacle
No. 2 Window, Two light	No. 6 Doorway, Double	No. 10 Buttress, Angular	No. 14 Moulding, Archivolt
No. 3 Window, Three light	No. 7 Pillar, Circular	No. 11 Buttress	No. 15 Moulding, String Course
No. 4 Window, Five light	No. 8 Pillar, Clustered	No. 12 Parapet	No. 16 Moulding, Basement

that if a line be drawn to touch the most prominent points, it will form a succession of rectangular recesses. The large rounds are sometimes brought to a pointed edge in the middle, and the smaller ones very deeply undercut on one side: in some cases, a fillet intervenes at the junction of the round and hollows, but they mostly unite in a continuous line without any interruption. String-courses often consist of a plain round-moulding, or of a roll-moulding of two different curves, so as to cause the upper half to overlap the lower; sometimes they are mere slopes with hollow underneath. Hood-mouldings consist for the most part of an overlapping round with deep hollow underneath. The base-mouldings are composed of a series of slopes, with sometimes a string-course moulding along the top, but in more elaborate works they comprise a series of mouldings consisting of projecting and overhanging rounds deeply undercut.

The hollows of the mouldings are often filled with ornaments peculiar to the style, of which the most usual and characteristic is that termed the *dog-tooth* ornament. It is a kind of pyramidal flower of four leaves, the division between the leaves being placed in the centre of each side of the pyramid; the flower is placed in an inverted position, the base of the pyramid being placed against the hollow, with the apex projecting. This ornament varies to some extent in different examples, but always preserves the same general appearance; it is very effective on account of the deep shadow produced at the division of the leaves. They are placed in a hollow moulding, or in the edge of a jamb, either singly, with a space intervening between each two, but more frequently in close proximity to each other. Single leaves and flowers of a different character are sometimes inserted in a similar way, and sometimes a running pattern of leaves or foliage.

Sculptured foliage is much used in the more costly buildings, forming capitals, corbels, crockets, and bosses, and is usually of a stiff character, that is to say, the leaves have a crisp appearance not observable in other styles. It is very beautiful, however, and worked with much taste and freedom; although it does not present an appearance so natural or flowing as that employed during the next period. Amongst other varieties of foliage, the trefoil is predominant, the two lower lobes of which, and sometimes all three, are worked with a bulb or swelling in the centre, the middle lobe being frequently of larger size than the others.

The crockets likewise are usually in the form of a trefoil-leaf, curled back like the head of a pastoral staff.

The *walls* of large buildings are frequently ornamented by a series of blank arches supported on pillars. These are common, running round the base of the walls on the interior, and are employed in many other situations, both externally and internally, so much so as to become a characteristic of the style. Another method of ornamenting blank walls is by diapering, or carving them in low recession after some small and recurring pattern, frequently in the form of square leaves, as in the triforia, Westminster Abbey.

Niches were in use at this period, but of a less elaborate character than those of succeeding styles. The figures were frequently set on small pedestals, and surmounted by a canopy consisting oftentimes of a three or five-foiled arch with plain pedimental head; in many cases, the canopies project or bow forwards. Niches are often placed in ranges of two or more, under one common arch, and in such cases are generally separated by single shafts.

Mr. Bloxam has subdivided this style into two, the earliest of which he names the *Semi-Norman* style. It is the same as that styled by others the *Transition* style, and embraces that class of buildings in which the round and pointed arches seem to be struggling for pre-eminence, and which bear evident marks of their near affinity to both systems: remarkable examples of the kind are the Church of S. Cross, and Malmesbury Abbey.

The general characteristics of this division consist in the use and combination of round and pointed arches in the same building; in some instances, pointed arches are surmounted by others of the semi-circular form, in others semi-circular arches are made to intersect, and thus form pointed arches. Another characteristic is the existence of pointed arches on massive piers of Norman design. The piers are mostly Norman in character and proportion, but have their capitals often ornamented with a simple description of foliage. In other respects, the details of such buildings are for the most part Norman.

Sometimes the piers are of more slender proportions, and attached to a large central pier, which is either square or round; and a still closer approximation to the Early English examples is shown in the horizontal bands surrounding the piers about midway.

The soffits of arches are frequently recessed, which shows an advance upon previous examples, but the chamfer common to Early English buildings is omitted, the edges being left square.

The Decorated style.

Otherwise termed, in architecture, the *Middle-pointed*, stands next in respect of time and decoration. It had its commencement in the reign of Edward the First, and arrived at maturity during the reigns of the two succeeding Edwards, from which circumstance the name of *Edwardian* has sometimes been applied to it. It dates from 1307 to 1377, or a little later, and may be named generally the style of the fourteenth century. This period of architecture is of all others the most beautiful; it rivals the preceding in chasteness, while it surpasses it in richness; and at the same time is free from the extravagant and redundant ornamentation of the succeeding styles.

The *arches* of this period are described from equilateral or obtuse-angled triangles, and in many instances are not easily distinguishable by their shape from those of the previous style; and in smaller buildings, where the soffits are merely recessed and chamfered without mouldings, it is a difficult matter to distinguish them at all; the date, however, may usually be determined by the mouldings of the caps and bases of the piers. In larger or more costly buildings, the arches are moulded, and the distinction marked by their contour. The mouldings consist of rounds projecting to the extent of from one to three-quarters of the circumference, and are frequently filleted, alternating with plain soffits and faces. As arches of decoration, the trefoiled was not uncommon. Hood-moulds frequently occur, and are terminated on heads or foliage.

The *shafts* of *piers* in small parish-churches are mostly of a simple circular or octagonal plan, similar to those of the preceding period, and, like the arches, are only distinguished by their capitals and bases. The alternate arrangement of the circular and octagonal piers is still adhered to. In larger buildings the piers are clustered, and consist of four or more shafts, which are in contour, either half or three-quarter cylinders. They differ from Early English examples in being attached to each other, whereas the latter are detached from each other, and frequently from the central shaft. The plan of these clustered piers is often that of a lozenge, or of a square placed diagonally; another shape is that of a quatrefoil, but many other forms are found which we cannot stop to mention. In many instances, we see four or more main shafts with smaller shafts introduced between them, and sometimes mere mouldings in the place of the secondary shafts; in late examples, small shafts occur, separated by a deep hollow and two fillets, a form which prevails in the succeeding style, but in perpendicular examples the hollow is very shallow in comparison. In all the above cases vertical fillets are employed to a very large extent both upon the shafts and mouldings. In very large structures the piers are made up of a very great number of shafts.

The *capitals* are either bell-shaped or octagonal, and in clustered pillars usually follow the general form of the pier, but sometimes are continued in one sweep all round without any regard to the contour of the shafts. They are frequently only moulded, the prevailing mouldings being rounds, plain or filleted, ogees and hollows, in which some ornament, such as the ball-flower, is often introduced. The mouldings are not so deeply cut as in the Early English examples. In most of the clustered, and many of the single pillars, the vase is covered with rich and beautiful foliage placed horizontally, and consisting of very perfect and natural imitations of the oak, ivy, vine, &c., very freely and delicately executed. Some capitals are ornamented with sculptures of heads, figures, and such like. The *abacus* is either circular or polygonal in plan, and its mouldings are composed of rounds, frequently with an overlap, of ogees, and hollows. We have instances of continuous imposts in this style, where the mouldings of the pier are carried round the arch without the intervention of a capital.

There is great variety in the *bases* of this period. In plan they usually agree with the shaft, but are sometimes octagonal where the piers are circular, the mouldings following the contour of the pier, and overhanging the plinth; in some few instances the mouldings are raised on a square plinth. The plinths are frequently double, and of considerable height, the lower one projecting beyond the upper with a simple splay, reversed ogee, or hollow, with sometimes one or two small mouldings above. The base mouldings vary, but consist, for the most part, of reversed ogees or quarter-rounds, with the occasional insertion of one or two small rounds. In clustered columns the bases follow the general outline of the pier.

The *doorways* have one or more shafts in the jambs, which differ from the Early English examples in being constantly engaged. These have moulded or sculptured capitals, but the jambs are filled up with mouldings, which are continued round the arch without interruption. Many doorways are without pillars, being entirely composed of mouldings, which are continuous with those of the architrave, and are composed of a series of quarter-round and semi-cylindrical mouldings, the former being often filleted up the face. The hollows are frequently filled up with sculptured foliage, such as the ball-flower, or a square ornament placed at intervals, and sometimes with a running pattern of ivy or vine leaves, &c.; occasionally we find a series of niches carried up the jamb. The doorways are not usually so much recessed as those of the previous style, and the shafts are more slender, approximating more nearly to mouldings. In large buildings the arch is mostly pointed, but in smaller examples the ogee arch is not unfrequent, and the square-headed trefoil occasional: the architrave is usually moulded. The hood-moulds are seldom returned, but terminate in a head or knop of foliage. The arches are frequently surmounted by a triangular, or ogee canopy, which is finished with crockets and finials, and the spandrels filled with sculpture of various kinds. The doors themselves are often hung with ornamental hinges, as in the previous style, but the iron-work is of somewhat different design. In other respects the doors are mostly plain, though sometimes panelled and with tracery in the heads. The nails are often of an ornamental description, being of an hexagonal form, or made in the shape of a leaf or flower.

The *windows* of this period are usually of a large size, and of several lights, but there are also windows of a single light which are of a less elongated form than the Early English, and their heads are frequently trefoiled. Larger windows are divided into two or more lights by vertical mullions, but are seldom divided horizontally except in tall spire-lights, or in domestic edifices. These vertical mullions are carried up as far as the springing of the arch, and from that point branch out in various directions, interlacing and forming patterns of varied and beautiful design, known under the name of tracery. The variation from Early English practice is here distinctly marked, first in the employment of mullions in the place of shafts with capitals and bases, but more prominently in the method of filling the head or arch, of the origin of which we have taken notice above. In the earlier specimens the tracery is composed of circles, trefoils, quatrefoils, triangles, and other simple and complicated geometrical forms, arranged in various patterns, and is hence termed, geometrical tracery; but at a later period the lines assumed a more wavy or flowing appearance, and were disposed with greater freedom, such description of work being distinguished as flowing tracery. A very simple kind of window is that in which the mullions merely cross in the heads; and another of two lights with a simple trefoil in the head. This last approximates very closely to some Early English examples, but there is another kind which bears a close resemblance to the earlier specimens or triplets, and consists merely of three lights comprised under one arch, the centre one of which is higher than the two side ones, and separated from them by mullions. The subordinate arches formed by the intersections of the mullions, are generally foiled, as are also the principal compartments of the tracery; but there are some few exceptions.

The heads of the windows are principally two-centred pointed arches of various proportions; but segmental arches both simple and pointed, not unfrequently occur, as also does the ogee. Square-headed windows are by no means uncommon, especially in subordinate parts of the building, and have their heads filled with tracery, as in the other cases; some few, however, are entirely devoid of tracery. Common hood-mouldings resting on masks, heads, &c., are most frequent, but sometimes in rich examples we find pedimental and ogee canopies introduced, and ornamented with crockets and finials.

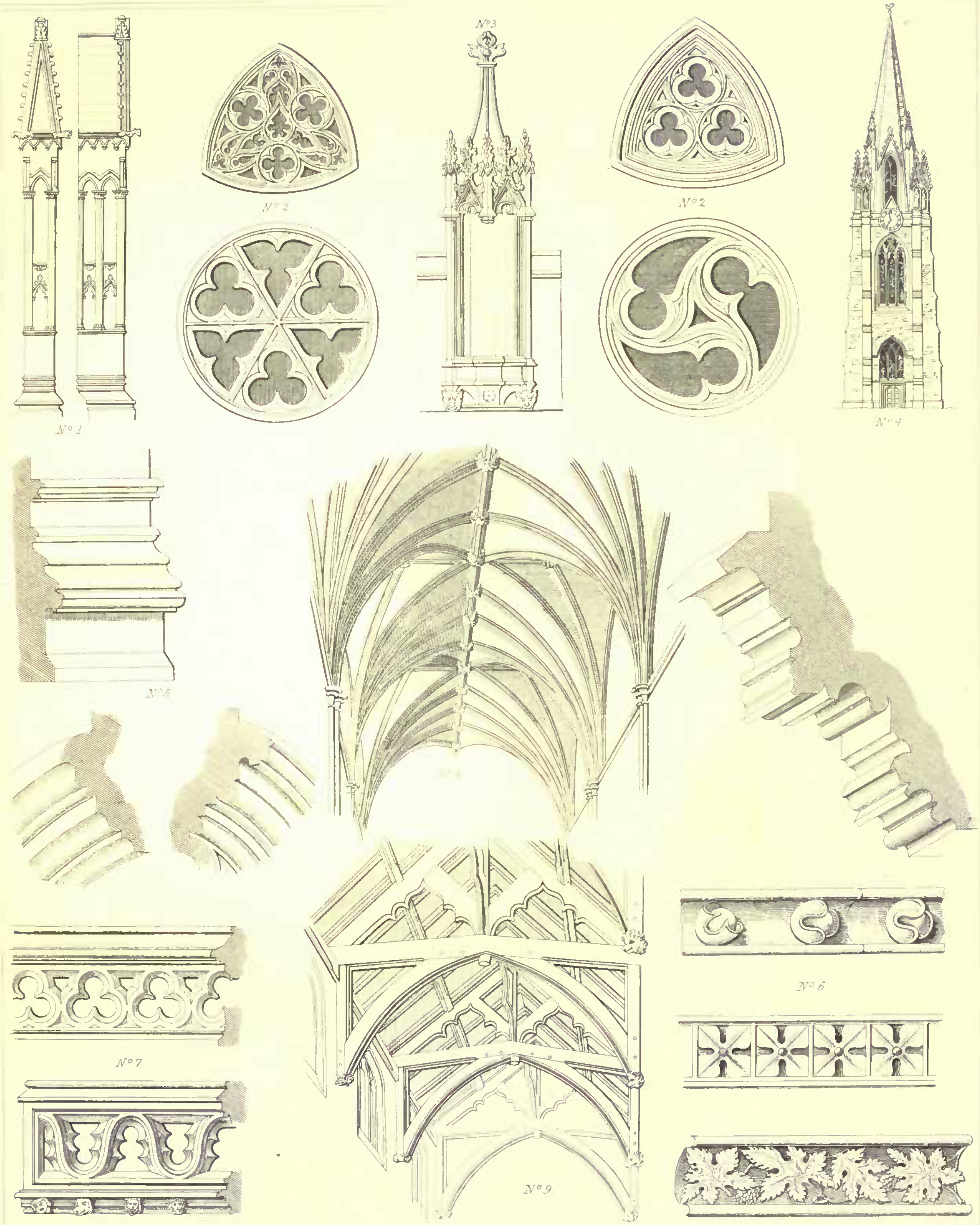
The mullions are most frequently simply chamfered, or in later examples slightly hollowed, but in more costly buildings each mullion is composed of a series of mouldings, set diamond-wise, and sometimes the hollows are filled up at intervals with some ornament peculiar to the style. In some cases we find shafts with capitals and bases still introduced, more especially against the jambs. String-courses are seldom omitted on the exterior beneath the windows. The windows are splayed on the interior, and the inner arch is frequently of a different form to that on the exterior, its edge being moulded or chamfered, similar to the practice followed in Early English examples.

Very beautiful windows of this style are to be seen at Exeter cathedral, almost every one of them being of a different pattern; the most elaborate, however, and the largest, is over the west entrance.

Circular windows filled with tracery are not uncommon in large structures, and are sometimes of excellent design. Windows in the shape of squares, trefoils, quatrefoils, spherical triangles, and sex-foiled circles, are common, but are of small size, and are usually seen in subordinate situations, such as clere-stories, gables, &c.

GOTHIC ARCHITECTURE — DECORATED EXAMPLES.

GOTHIC ARCHITECTURE — DECORATED EXAMPLES



R. Thew.

The more simple *buttresses* are not easily to be distinguished from those of other styles, consisting, as they do, of plain piers, with one or more slopes or set-offs without any further decoration; but in some cases they may be known from those of the Early English, by their position at the angles of buildings, where they are set diagonally. This, however, is not a very sure criterion, for some Decorated buttresses stand in the same position as those of the preceding style. In many instances the set-offs are finished with a pedimental head or gablet, which is sometimes plain, but more frequently foliated, and decorated with crockets and finials. In rich examples, the faces are often recessed for niches, which are surmounted by rich canopies, small buttresses, pinnacles, &c. The buttress seldom reaches above the parapet unless surmounted by a *pinnacle*, which is mostly of an elaborate description, being finished on all sides by a pedimental head similar to that above described, and the whole surmounted by an acute pyramidal top with crockets and finials.

The *parapet* is frequently embattled with plain or moulded capping, but very often consists of a plain horizontal cap. Some horizontale xamples are pierced or sunk in trefoils, &c., and very often with trefoils inserted in the spaces left on either side of an undulating moulding. *Corbel-tables* are of rare occurrence, but the parapet is usually finished on the under side by a cornice consisting of a roll-moulding, overlapping a deep hollow, in which are sometimes inserted ball-flowers, masks, and other ornaments.

The *roof* still continues of a lofty pitch, but somewhat more depressed than in the previous style. The larger churches are vaulted as before, but there is some difference in the arrangement of the ribs, which are greatly increased in number. Each bay or compartment of the vaulting is intersected, not only by longitudinal, transverse, and diagonal ribs, but these again are intersected by others in a variety of ways, so as to divide the vault into a greater number of cells, a practice which gives the roof a more complicated and richer appearance. Bosses of elegant design, and excellent workmanship, cover the intersections of the ribs, which are moulded, and the hollows frequently filled with the ball-flower ornament.

The same remarks apply to the wooden roofs of this period as to those of the preceding: we have but few examples now remaining, roofs of a later period having frequently been substituted in buildings of this style. The early roofs are doubtless of much the same character as the Early English, but in later examples there are some distinctions, although it is a somewhat difficult task to decide the exact date of any. In some examples the beams are merely chamfered as before, but in many they are moulded or have their edges foiled or cusped in such a manner that the spaces between the timbers present the appearance of some description of polyfoil. Tie-beams seem to have been of frequent occurrence in this style, and are often suspended by king-posts, which are sometimes but plain timbers, but at others assume the form of an octagonal shaft with moulded base and capital. Polygonal roofs having the timbers so disposed as to present to view a number of canted surfaces, are not unusual, they are mostly of six sides, but sometimes in later examples heptagonal. The principles of high-pitched roofs are frequently disposed in the form of an arch, and where tie-beams are employed, the same outline is preserved, by supporting them on curved braces, fixed to a wall-piece and resting on corbels. Longitudinal braces are frequently carried from the king-post of one principal to that of the next, and are often of an arched form resting at each end on tie-beams, and reaching to the ridge-piece at the apex, such arches being frequently foiled. A somewhat similar arrangement is adopted on the sloping sides of the roof, the purlins resting on arched purlin-braces, which stand upon the wall-plates, and are carried up under the common rafters. In some instances both king-posts and collars are employed, in others, king-posts with struts on either side, and occasionally queen-posts and straining pieces are introduced.

A curious roof of this date is thus described by Mr. Bloxam :—" In the little desecrated church of Horton, near Canterbury, is an open wooden roof, of a construction different to those which have been described. It is divided into bays by horizontal tie-beams, with the under parts moulded, resting on the wall-plates and on vertical wall-pieces supported on corbels, with a curved brace between each wall-piece and the tie-beam. From the centre of each tie-beam rises an antagonal-shaped king-post up to about two-thirds in height of the valley of the roof, where it supports a longitudinal rib or beam. From the principals of the roof, at about two-fifths in height, spring plain braces, which cross diagonally just above the longitudinal rib, and rest on the opposite principal. Above these there is neither collar-beam nor apparent ridge-piece. From four sides of the king-post spring curved braces, both longitudinal and lateral; the former support the longitudinal rib, the latter the braces which cross above it. The roof is high-pitched." Other examples of this or a similar description occur, and the arrangement of curved braces springing from the four sides of the king-post are not uncommon.

In the richer class of roofs the spandrels formed by the intersection of the timbers are frequently filled with tracery.

The general arrangement of the *towers* is similar to that of the previous style, the greatest differences appearing in the apertures and decorations. The windows of the lower stories are many of them of small dimensions, and of single lights with ogee or foliated heads, and label or square hood-mould. The belfry-windows are the most important features, and are arranged singly or in pairs; they are of a large size, frequently filling up the entire story. The largest window, however, frequently occurs on the west face of the lower story, or that above the entrance, and forms one of the general range in the interior of the church; it is often of very large dimensions and elaborate design, standing in this respect next to that in the east wall of the chancel. Blank arcades are not so much in vogue as in Early English examples, and when used are of a form and decoration common to the period.

The *spires* are very acutely pointed, but in some cases are very low, forming merely a low pyramidal roof to the tower: the latter is mostly constructed of wood, a material frequently employed in the construction of the loftier kinds, which in larger structures, however, are almost universally of stone. The large spires boast a larger number of spire-lights than those of earlier date; and not only so, but they are of a more elaborate description, being capped by lofty pediments enriched with crockets and finials. They are also sometimes divided into a number of compartments by horizontal bands of panelling, and the angles of the spire enriched with crockets running all the way up, and terminating in a large finial. The tower is mostly finished with a parapet, which is either plain or embattled, and sometimes pierced in quatrefoils, &c., and is supported on a moulded cornice, the hollows of which are often filled with the ball-flower or some other ornament. At the angles we frequently find projecting gurgoyles in the form of animals, &c. Pinnacles of a prominent and elaborate character are of constant occurrence, and sometimes behind them rise ornamented flying-buttresses to support the lower portion of the spire. Parapets and gutters, however, are not universal, for we not unfrequently meet with broach-spires of this period.

The *mouldings* consist for the most part of a greater number and variety of members than those of the Early English style. Rounds and hollows still prevail, but the latter are not so much undercut as before; in the earlier examples they are still deep, but grow more shallow towards the termination of the style. Quarter, half, and three-quarter rounds are most prevalent, and are often filleted and separated by small hollows; ogees, too, are of frequent occurrence, as are also ovolos and cavettos. Another undulating moulding, similar to that in use in the next period, but of somewhat different projection, is also used, and is in appearance somewhat like a double cyma, consisting of a convexity in the centre between two hollows. The roll-moulding, in which the upper half overlaps the lower, is in constant use. Rounds and hollows are sometimes separated by fillets, but frequently run into each other without any interruption.

For string-courses, the overlapping roll-moulding is very common, but sometimes a simple roll or a roll filleted, or what is termed keeled, is used in its place; the latter term being applied when the roll comes to a sharp edge in the centre. These mouldings are used either separately, or with other subordinate ones; a hollow is not unfrequently carried underneath. Hood-moulds are formed of quarter-rounds or ogees with a hollow or plain chamfer beneath, and are seldom returned. The base-moulds consist of one or more slopes with or without a projecting edge, the whole being surmounted by a filleted or keeled round. In all the above cases the ball-flower and other ornaments are often inserted in the hollows and carettos.

The leaves selected for imitation in the *foliage* of this period, are those of the oak, vine, ivy, fern, white-thorn, &c., which are copied with a boldness and freedom not common in previous examples. They are also more naturally disposed, and have a less stiff and formal appearance than those of any other style; there are not so many sudden projections, and the outline is of a more gently undulating form than in the Early English specimens: in capitals, the stems are twined about in various directions, instead of rising vertically from the neck.

The most usual and characteristic of the ornaments is the ball-flower, which consists of a round ball enclosed within a flower of three or four petals, the ball appearing beneath the slight opening of the petals; it is supposed by some to represent a rose-bud. It is used in almost every situation, but more especially in the hollow mouldings of jambs, arches, cornices, &c., in which it is inserted at intervals. Another ornament consists of an open square flower of four leaves, with a small ornament in the centre, which is employed in the same manner as the preceding; but a series of them is sometimes used, the flowers being placed in contact with each other, in which manner it is frequently applied as a diaper. They are sometimes introduced alternately with the ball-flower. A representation of a very beautiful ornament which occurs at Adderbury, is given by Mr. Bloxam in his manual. It bears some affinity in form to the dog-tooth moulding, and consists of four ivy leaves placed in the angles of a square, with their upper sides to the wall, the stems projecting outwards, and meeting in one point, which gives the ornament a pyramidal form. Leaves, masks, heads, &c., are often used in similar positions.

The crockets of finials are of various descriptions, but are readily distinguished from the Early English by their natural and flowing outline, and by the crumpled leaves, so different from the crisp appearance of the latter.

The *niches* are of a very elaborate description, and are usually of a considerable depth, having the roof covered with minute ribs and bosses. They are almost always surmounted by pedimental or ogee canopies, which are sometimes bowed forward in the form of an ogee, and are almost always decorated with crockets and finials. The arches are foliated, as are also frequently the spandrels above them. Some niches have conical coverings like spires crocketed at the angles, and surrounded with a series of canopies one on each face of the spire. The sides, too, are often enriched with small ornamental buttresses. Some again have flat tops.

The *Perpendicular* style dates its rise towards the close of the fourteenth century, at the latter portion of the reign of Edward III., and prevailed until the disuse of Gothic architecture. It is characterized by the exuberance and redundancy of its ornaments, and is wanting in the simplicity of the Decorated style. In the earlier examples, this enrichment is not carried beyond bounds, but in later times it becomes excessive, and the chief aim of the architects seems to have been to employ as much labour as possible on decoration. This practice proved injurious, and at last fatal, and Gothic architecture may date its decline from the commencement of the fifteenth century.

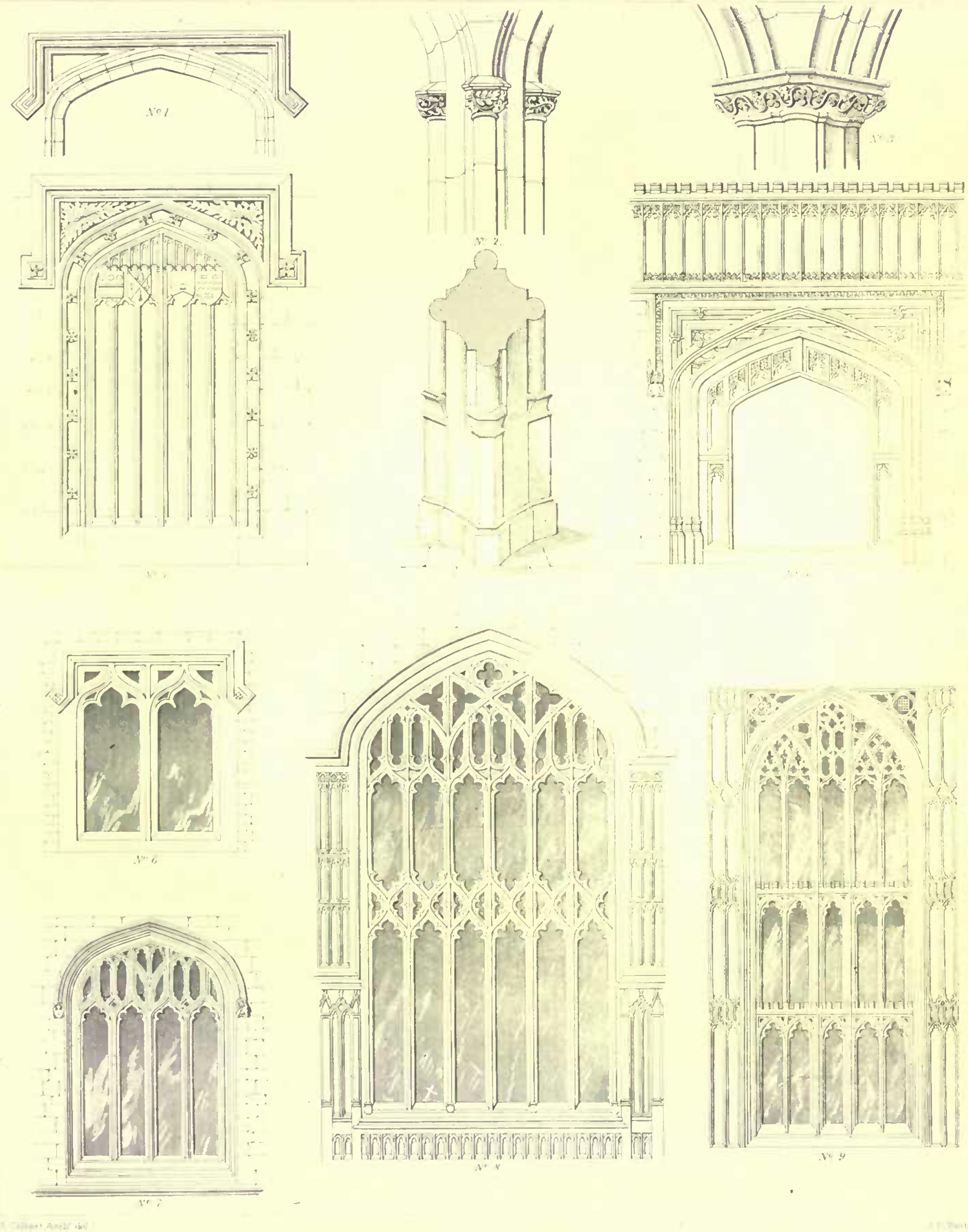
This style is called by some *Third-pointed*, and by others *Florid*. The term *Perpendicular* was given to it on account of the peculiar arrangement of the tracery in window-heads, which forms a very marked characteristic of the style; but some have objected to the name, as of only partial application, and suggest the term *Horizontal*, as being much more appropriate and significant of the general tendency of the style; and in this they are certainly correct, as witness the depressed arch, low-pitched roof, square-headed windows and door-ways, square hood-moulds, and the horizontal transoms. But on this subject we shall not here enter; the term is well established, and could not readily be laid aside, supposing such a course to be desirable.

Pointed *arches* of all descriptions are to be met with in this style, nor do they differ materially from those of the preceding period, but drop arches are perhaps more prevalent. An arch of a peculiar kind, however, began to be used some time ere the close of the style, which is not to be found in any other; it is described from four centres, two of which are on the springing line, and describe arcs of very small radii, and the other two at some distance below it. Such arches have a very depressed appearance, the rise above the springing line being inconsiderable when compared with that of the two-centred arches; the rise, however, varies to some extent in different examples. This arch is termed the Tudor arch, and was introduced about the middle of the fifteenth century. Ogee arches are of constant and universal occurrence, and foiled arches are very frequent in decorative work.

Arches are very frequently moulded, but in the plainer examples are only recessed and chamfered. The mouldings consist of much the same members as before, but they are of a less prominent character; the hollows are more shallow, and the projecting mouldings less prominent: the contour is of an undulating appearance, the junctions of the different members being but indistinctly marked. A large but shallow cavetto is of frequent occurrence, and is sometimes ornamented by the insertion of a square flower at intervals. The soffits of some arches are ornamented with panelled work.

The *shafts of piers* are sometimes simple octagons in plain, as in the preceding styles, but are not of such frequent occurrence as before, and sometimes differ in contour, having the sides of the octagon slightly concave; they may be distinguished from earlier examples by their capitals and bases. Clustered piers are very frequent, and their general

GOTHIC ARCHITECTURE.—PERPENDICULAR EXAMPLES.



A. Gilbert Archt. del.

Nº 1. Arch	Nº 4. Doorway	Nº 7 Window
Nº 2. Shaft and base	Nº 5. ditto	Nº 8. ditto
Nº 3. Capital	Nº 6 Window	Nº 9. ditto

plan is that of a square set diagonally, but the breadth of the pier between the aisles is frequently greater than the depth between the arches. They are composed of four or more slender shafts, engaged, with hollows, ogees, and fillets intervening. A very common arrangement presents a section of the form of a square, having its angles cut in a broad but shallow concavity, and the four sides or flat faces ornamented with a half or three-quarter round shaft attached, and projecting beyond the face. This shaft does not occupy the entire face, but leaves a flat surface on either side ; it is finished with distinct cap and base, but the surface and concave angles of the parallelogram are frequently continued round the arch without interruption. When piers are placed diagonally, the angles are often ornamented with slender pillars with caps and bases, while the intermediate spaces, which constitute the main body of the pier, are moulded and continued uninterruptedly to the apex of the arch. The sub-shafts are sometimes the only ones furnished with capitals, the face-shafts being carried up to the whole height of the building to the wall-plate without caps, but sometimes the shaft is continued above the capital. Three or more shafts clustered together are not unfrequently found at the angles in the place of the single one above alluded to.

The plan of such small shafts is commonly circular and plain, but they are sometimes filleted, and occasionally polygonal, with concave sides. The piers are not unfrequently composed of mouldings only, and these carried up continuously, without capital or any other projection, to the apex of the arch; and where arches are neither moulded or recessed, the sides of the pier and soffits of the arch are usually enriched with panel-work.

Capitals are either circular or octagonal, but the necking is usually of the former, and the upper members of the abacus almost invariably of the latter form, whether the capital and its mouldings be circular or octagonal. The vases are mostly plain, but sometimes enriched with foliage, which is of a more conventional form than in the previous style. The mouldings consist of ogees, rounds, beads, and hollows, the second and fourth of which are frequently combined without forming edges, and have a bead underneath. The top of the abacus is often splayed, and sometimes ornamented with a crest of small battlements : the sides are occasionally hollowed out. In clustered piers, the capital is sometimes carried all round without interruption, and the vase covered with foliage, but more frequently the capital of each shaft forms a separate and distinct member.

The *base* mouldings are usually set upon a lofty polygonal plinth, which is sometimes double ; the lower one projecting, and the projection moulded with a hollow or reversed ogee. The upper members of the base-mouldings follow the form of the shaft, but the lower ones are often polygonal, like the plinth which they overhang. In clustered piers, the bases are mostly treated separately, as is the case with the capitals, but sometimes the mouldings are continued all round, as are the plinths almost invariably.

The earlier *doorways* of this style have two-centered pointed arches, but the most common and characteristic form is the four-centered : for smaller doorways, the ogee is sometimes used. The two centered arch is often surmounted by an ogee-shaped hood-mould, enriched with crockets and finials, but some of them, and nearly all the four-centered, are enclosed within a square head formed by the outer mouldings, with hood-mould of the same form, the spandrels being filled with quatrefoils, flambeaux, roses, shields, &c. Sometimes, however, the hood-mould follows the form of the arch, even in the four-centered examples. The hood-mouldings are often returned horizontally, and when not so, terminate at the springing of the arch, on heads, shields, &c., or have the mouldings twisted round in the form of a lozenge, or circle, with some little ornament in the centre. The hood is usually placed immediately above the apex of the arch, but in some specimens it is considerably elevated, the intermediate space above the spandrels being filled with quatrefoils, or other panelled work ; the upper members of the hood sometimes coincide with the lower portion of a string course. Double doorways are of very rare occurrence.

The jambs are not unfrequently ornamented with shafts with caps and bases, but they are mostly small, and often not well defined, except by the capitals and bases ; in many instances all the mouldings are continued round the arch, without apparent impost. Large hollows are very frequent amongst the mouldings of doorways, and are occasionally filled with foliage or other decoration.

The doors themselves are often covered with panel-work of a rich description, and sometimes with tracery in the head. The smaller doors are often weather-boarded, without any ornament; the iron scroll-work being rarely employed at this period.

The *windows* of this style are easily distinguished from all others, by the vertical disposition of the tracery in the heads ; the mullions of the lights, instead of branching out at the springing into flowing lines, are continued vertically to the intrados, and secondary mouldings are continued in the same direction from the centre of each light, and converge once or twice ere they reach the arch. The principal and subordinate lights are all arched and foliated, the principal being frequently divided horizontally by transoms, which are a further characteristic of the style. Windows which consist of several lights are divided into two or more compartments, containing each two or more lights, and these are frequently arched over in the heads. The transoms are often finished at top with a small ornamental battlement ; and the mullions present a concave outline. The heads of windows offer a great variety of form, some being two-centre-pointed of various degrees of acuteness, others four-centred, others again segmental, triangular, and square-headed. Windows of the last class are very common, having perpendicular tracery in the heads ; they are frequent in clere-stories, where we also find circles and quatrefoils used for the same purpose.

The plainer *buttresses*, are similar to those of the preceding styles, consisting of one or more projections, with plain faces and set-offs, frequently terminating in a slope under the parapet, but sometimes finished with a crocketed pinnacle. In the richer examples the faces are covered with panel-work, and are finished with square pinnacles, sometimes set diagonally and terminated with a crocketed spire, or finished with an animal or such like ornament.

The *parapets* are often embattled, and have usually the coping carried all round the embrasures ; the plain surface down as far as the cornice, is not unfrequently panelled or pierced in quatrefoils, foiled-arches, &c. The top of the parapet is as often horizontal, and either plain or covered with sunk or pierced ornaments, consisting of trefoils and other polyfoils inserted within square, circular, or triangular compartments. The cornice consists of a few mouldings, the most prominent of which is frequently a large shallow cavetto, which is often enriched with flowers placed at intervals.

The early *roofs* of this style are of a moderate height, but later examples are of very low pitch. The vaulting is still more complicated than in the preceding style ; the number of ribs is increased, and they are frequently disposed so as to form geometrical patterns, as in the choir of Oxford cathedral, and in many other examples. A kind of vaulting peculiar to the later period of this style, is termed fan-tracery vaulting. In it several ribs diverge at equal angles, and in all directions, from one bearing-post, and spread on the roof in the form of a circle, the entire figure having somewhat the appearance of a semi-cone: all the ribs preserve the same curvature. These spring from either side of the roof, and often meet in the centre, or the space left between, as also the spandrels are filled with ribs, forming geometrical tracery; when, however, a large space intervenes, it is frequently occupied with pendent figures of the same description, forming a kind of inverted cones suspended from the roof, the surface of which, like those at the sides, is covered with divergent ribs, and richly panelled. Roofs of this kind are more frequent in small structures, such as chantries and the like, but we have magnificent specimens of a grander description in Henry VII.'s chapel, Westminster, St. George's, Windsor, Peterborough cathedral, and some few other churches.

The wooden roofs of this period are more numerous, and more readily defined, than those of any previous era. Their increased number arises probably from a practice common at the time, of substituting more enriched roofs in the place of plainer examples of earlier date, a practice which is often evinced by the form of a more highly-pitched roof than that existing, being still visible on the tower, against which it abutted. The majority of examples of this style are of a very low pitch, so much so as sometimes to be entirely hid on the exterior of the building by the parapet; but roofs of a lofty pitch are by no means uncommon.

In the loftier examples tie beams are not used, but the principals are usually connected by a collar beam immediately below the ridge, or by a block-collar completely filling up the angle of the ridge; where the collars are in a lower position, a king-post is sometimes carried from them to the ridge-beam. The collars are often ornamented with mouldings or small battlements, which have a very good effect. A simple form of roof consists of principals of stout planking resting on corbels, and cut in the form of an arch, with block collars underneath the ridge, as at Stourbridge church. Sometimes arched planking of this kind is supported on projecting hammer-beams, with curved braces underneath resting on corbels, which method gives the outline of the entire roof the form of a trefoiled arch either round or pointed. A similar form is often constructed of the usual timbers, and springs from the level of the wall-plate, without curved braces, as at Athelhampton Hall, Dorset.

Tie-beams are sometimes used in roofs of this kind, supported by braces resting against wall-pieces, and these again, on corbels or shafts, the spandrels being often filled with tracery. The principal rafters above the tie-beam frequently consist of planking of arched outline, pierced with quatrefoils, &c., as at Malvern Abbey. Some roofs again are constructed without principals, the common rafters being tied at the top with a collar-beam resting upon timbers disposed so as to form a circular arch, the lower extremities of which rest upon hammer-beams.

The hammer-beam is peculiar to this style, and is found employed to a very great extent in the large hall-roofs of the period. A very common form for these roofs consists of two principal rafters tied at the upper part with a collar-beam, under the extremities of which are two queen-posts resting on hammer-beams, and these again on curved braces. The latter are fixed to wall-pieces, which stand on corbels at some distance down the walls. Arched braces are frequently carried from the end of the hammer-beam to the centre of the collar, which is sometimes suspended by a king-post. Some examples have two sets of hammer-beams, one above the other, as at Hampton Court, where the roof is a sort of curb; it is very strong, but composed of many timbers, which are somewhat complicated in their disposition. We must not pass over unnoticed, the roof of Westminster Hall, which is one of the most magnificent in existence. Its principal feature is an arched rib composed of three thicknesses of timber, which completely spans the building, and is carried down below the top of the walls to the corbels. Immediately above the apex of this arch is a collar-beam, having in the centre a king-post reaching to the ridge, and at the sides two queen-posts with a straining piece. The hammer-beams are carried out beyond the line of the arch, and are supported at the extremities on curved braces resting on the corbels, a similar curve being also carried upwards to touch the large arch so as to form by their combined outline a trefoiled arch. Above the ends of the hammer-beams rises an upright or queen-post, which is carried up to the end of the collar, and supports the principal rafters at about midway. This, as also most roofs of the kind, is moulded and enriched with perforated panel-work, and other ornaments; the hammer-beams are often carved into representations of angels bearing shields, musical instruments, &c.

The obtuse low-pitched roofs peculiar to this period, are often framed with tie-beams and king-posts, with curved bracing-ribs underneath, resting against an upright wall-piece supported on a corbel; the braces being mostly curved in the form of an obtuse arch. The spandrels are often filled with open tracery, as are also the spaces above the tie-beams. Sometimes roofs of an exceedingly low pitch, or even perfectly flat, are formed without any truss whatever, consisting only of principal and common rafters, and purlins, without either tie or collar beams. In such cases the principals are often supported at the end by upright wall-pieces resting upon corbels at a considerable distance below the wall-plates, and from the foot of the wall-pieces curved braces are carried up to the centre of the principals. These braces are often solid, constructed out of a piece of stout planking and entirely filling up the spandrels.

The sloping bays of low-pitched roofs are often divided into square compartments by purlins and common rafters, the former being increased in number, and the latter placed at a greater distance apart than usual. The intersections of the timbers are almost always covered with ornamental bosses, and the timbers themselves richly moulded. Sometimes these compartments are subdivided by other secondary mouldings, with bosses likewise at the intersections. The larger beams in almost all these examples are moulded, and the horizontal timbers, such as wall-plates, ties, and collars, are often enriched with small battlements, or have the mouldings ornamented with some decoration peculiar to the period.

The *towers* are frequently constructed on a very grand scale, and are very often devoid of spires, being occasionally surmounted by octagonal lanterns, as at Boston, Lincolnshire, where the tower is of great height and magnificence. Another very beautiful and lofty example occurs at Dundry, near Bristol, but in this case it is finished at the top by four little square turrets, placed one at each angle; the turrets, as also the lofty battlemented parapet, being pierced in panel-work, a practice very common in parapets of this period. At Magdalen College, Oxford, is another very beautiful example, the corners of which are finished above the battlements with octagonal turrets or pinnacles, carried up from the ground in the shape of buttresses; another buttress is carried up the centre of each face, and is finished above the parapet with a pinnacle of smaller dimensions. Another ornament in this example is of common occurrence, and consists of bands of sunk quatrefoils or other ornaments. In smaller churches the tower is often finished with a plain parapet or simple battlement, but it is a very prevalent practice of the period to carry up a polygonal stair-turret at one angle, which rises some feet above the general level of the tower, and forms a very picturesque object. The windows and general arrangement of the towers are much the same as in the last style, differing only in matter of detail; square-headed windows are of frequent occurrence, and often appear in the belfries, especially in that class of towers just alluded to.

Spires are not so frequent as in other styles, and are never what are termed broach-spires, the tower being invariably crowned by a parapet. Where spires occur, they are of the same form and general description as before. They are often supported at their angles by flying-buttresses, springing from the corners of the tower. The angles are also frequently crocketed.

The *mouldings* of this period are in general flatter, or of less projection, and therefore less effectiveness, than those of previous styles. There is also a greater prevalence of angles or corners. Round and hollow mouldings are often connected without any apparent line of separation; but members of a different description are separated by either quirks or fillets. A large shallow concave moulding is very prevalent, and forms a characteristic mark of the style. It appears very often in archivolts and cornices, and is often enriched by the insertion of flowers, leaves, and other ornaments. Ogees are perhaps more frequently used than any other kind of mouldings, but rounds, beads, and cavettos are of very common occurrence. An arrangement of ogees in close contact, with the convex sides next each other, is of constant occurrence, and is characteristic of the style. A moulding of an undulating contour, being convex in the middle, and concave on either side, is common in abaci and dripstones, as is also the reverse of this, the hollow being in the middle, and the convexity on either side. Fillets are used, but are not often applied to larger mouldings. In general, it may be observed, that in all cases the mouldings of this style are more flat, the hollows and projections approaching more nearly to a straight line.

The *ornaments* used, consist mainly of detached flowers or leaves usually of a square outline, of running patterns and bunches of foliage, of grotesque heads and figures of animals; of shields, and various kinds of heraldic devices. The rose, the badge of the houses of York and Lancaster, is a characteristic ornament, as is also a lozenge-shaped leaf, supposed to represent the strawberry-leaf, and generally known under the name of the Tudor flower. The foliage is very elaborately and delicately carved, but does not exhibit the same amount of freedom of design or execution, which is manifest in the earlier styles.

The *walls* are often covered internally, and sometimes externally, with panel-work tracery, which is a characteristic feature of the style.

The *niches* of the period are somewhat similar to those of the Decorated style, but sometimes consist of mere recessed panels. They are usually, however, either octagonal or sexagonal in plan, with vaulted covering. Of canopies, some are flat, and others projecting; the latter being either semi-circular, or polygonal in plan, and either finished horizontally, or capped with a small spire or bell-shaped roof. The angles are occupied with buttresses and pinnacles, the latter being sometimes suspended from the overhanging covering, which is enriched with crockets and finials, and other ornaments in profusion.

With the commencement of the Reformation, the practice of Gothic architecture may almost be said to have ceased, as did all ecclesiastical building to a very great extent. The sacrilegious plunder of Henry VIII., his destruction of the monasteries and religious houses, and the wholesale spoliation and destruction of the works of antiquity which was carried on under his orders, tended to discourage persons from the erection of churches or religious edifices, and the art was soon entirely lost. The introduction of the Italian style assisted greatly in the overthrow of a mode of building which had been in vogue some three or four hundred years. Pure Gothic architecture may be said to have ceased about the middle of the sixteenth century, but it still retained some influence for a few years later. The method of building adopted during this interval, has been fitly denominated the *Debased.*

The characteristics of this style, if it may be so termed, may be briefly enumerated as follows:—The windows are square-headed, divided into bays by perpendicular mullions, the heads of each bay being frequently left square, but sometimes obtusely-arched, and occasionally foiled. The mullions are plain and unfinished, without mouldings of any kind, and all the workmanship is of a very inferior kind. Hood-moulds are often, but not always, used.

The *doorways* are either obtusely-pointed, or round-headed with prominent key-stones. In late specimens, many of the features of Italian architecture are introduced in details and construction. Examples of the Debased style exhibit a poverty of design and clumsiness of execution, in comparison with those of previous styles, which will at once decide their date and position.

In the above sketch, we have made no allusion to Continental Gothic; our remarks and descriptions having been entirely confined to the style as developed in our own country; nor have we space here to treat of the former separately. We can only refer to those writers who have treated this subject specifically, amongst whom the following names stand pre-eminent. Whewell's Architectural Notes on German Churches; Willis on the Architecture of the Middle Ages in Italy; and Moller's Memorials of German Gothic Architecture.

From this article, we refer to the words Church, Cathedral, Ecclesiastical Architecture, and to various articles of the same nature.

GOUFING FOUNDATIONS, a term used in Scotland, and particularly at Glasgow, for the under-pinning of a wall when found insecure.

GOUGE, a concave and convex chisel, the section of which is the frustum of the sector of a circle, serving to cut a concave excavation in wood or stone. The basil is made from either the concave or convex side.

GOWT, or Go-out, in engineering, a sluice used in embankments against the sea, for letting out the land-waters when the tide is out, and preventing the ingress of salt water.

GRACES, Gratiæ, or Charities, in the heathen mythology, were fabulous deities, and represented as three young and handsome sisters, attendant on Venus.

Their names are Aglaïa or Ægle, Thalia, and Euphrosyne; *i. e. shining*, *flourishing*, and *gay*. They were supposed by some to be the daughters of Jupiter and Eurynome, the daughter of Oceanus, and by others to be the daughters of Bacchus and Venus. Vossius *de Idol.* lib. xiii. cap. 15. Homer (*Iliad*, lib. xiv.,) changes the name of one of the Graces, and calls her Pasithea; and he is followed by Statius. (*Theb.* lib. ii.) Some will have the Graces to have been four, and make them the same with the *Horæ*, *Hours*, or rather with the four seasons of the year.

The Lacedæmonians admitted only two of them, whom they worshipped under the names of Klyta, Kleta, or Clita, and Phænne. The Athenians allowed the same number, but denominated them Auxo and Hegemone.

A marble in the king of Prussia's cabinet represents the three Graces in the usual manner, with a fourth seated, and covered with a large veil, with the words underneath, AD SORORES IIII. Yet Mons. Beger will by no means allow the Graces to have been four: the company there present, he understands to be the three Graces, and Venus, who was their sister, as being daughter of Jupiter and Dione.

They are always supposed to have hold of each other's hands, and never parted. Thus Horace, (lib. iii. od. 21.) describes them:

"Segnesque nodum solvere gratiæ."

They were also represented in the attitude of persons dancing; whence Horace says (lib. i. od. 4):

"Alterno terram quatiunt pede."

They were commonly thought to be young virgins. In the earlier ages they were represented only by mere stones, that were not cut; but they were then represented under human figures, at first clad in gauze. The custom of giving them drapery was afterwards laid aside; and they were painted naked, to show that the Graces borrow nothing from art, and that they have no other beauties than what are natural.

Yet, in the first ages, they were not represented naked, as appears from Pausanias, lib. vi. and ix., who describes their temple and statues. They were of wood, all but their head, feet, and hands, which were white marble. Their robes or gowns were gilt; one of them held in her hand a rose, another a die, and the third a sprig of myrtle.

They had temples, as we learn from Pausanias, at Elis, Delphos, Perga, Perinthus, Byzantium, and in several other places of Greece and Thrace. The temples consecrated to Cupid were likewise consecrated to the Graces: and it was also customary to give them a place in those of Mercury, in order to teach men, that even the god of eloquence needed their assistance. Indeed, some authors reckoned the goddess of Persuasion in the number of the Graces, thus intimating, that the great secret of persuasion is to please. The Muses and the Graces had commonly but one temple; and Pindar invokes the Graces almost as often as he does the Muses. Festivals were appropriated to their honour through the whole course of the year, but the spring was chiefly consecrated to them as well as to Venus. Greece abounded with monuments sacred to these goddesses; and their figures were to be seen in most cities, done by the greatest masters. They were also represented on many medals. The favours which these goddesses were thought to dispense to mankind, were not only a good grace, gaiety, and equality of temper, but also liberality, eloquence, and wisdom, as Pindar informs us; but the most noble of all the prerogatives of the Graces was, that they presided over all kindnesses and gratitude; insomuch that, in almost all languages, their names are used to express both gratitude and favours.

GRADATION, (from the Latin, *gradus*, a degree,) in architecture, an artful disposition of parts, rising as it were by steps or degrees, after the manner of an amphitheatre; so that those placed before do not obstruct the view from those behind.

The painters also use the word *gradation* for an insensible change of colour by the diminution of the tints and shades.

GRADATION, in painting, relates both to chiaro-oscuro and to colour: that is, all the different degrees in which light and dark, and colour, may be modified, are comprehended in it.

An object receding from the light, and gradually losing it, becomes at its farthest extremity obscurely defined. A coloured body, pure or bright in tint, under the same circumstances, gradually diminishes in clearness of hue throughout its receding parts, and becomes dull and dark. By fixing the scale of gradation in both these particulars, effects of great force or great simplicity may be produced. The scale of descent being made rapid, great force will ensue, from the strong oppositions it promotes; and the reverse will take place when the degrees of descent are prolonged, and less contrast thereby effected. The nature of the subject, and the situation of the figures with regard to light, must be the artist's guide in this matter.

The gradation of colour includes not only the different degrees of purity, or brilliancy of the same colour, but also the approximations of each colour to its neighbour, necessary to produce harmony; and also the art of gradually losing the local colour in obscurity, and yet maintaining its character in the object; which is extremely difficult, and of great importance, in the art of painting.

GRADETTO, GRADETTI, or ANNULI. *See* ANNULETS.

GRADIENT, in engineering, a term indicative of the proportionate ascent or descent of the several planes upon a railway, thus: an inclined plane four miles long, with a total fall of 36 feet, is described as having a fall of 1 in 586⅔, or 9 feet per mile. Mr. Macneill suggested the word CLIVITY, as a more appropriate term than gradient; and its compounds, *acclivity* and *declivity*, are very comprehensive and significant.

GRAFTING TOOL, in engineering, a kind of spade, used by *navigators* in railway and canal works; it is made very strong and curving; often called only a *tool*.

GRAIN, the plates of wood or stone, in the direction of which it may be split into various thicknesses.

GRAIN, in mining, is applied by quarry-men and masons to the minute figures in most blocks of stone, by which they are disposed to split more easily in some certain direction, than in any other, as wood is disposed to split in the direction of its grain. *Beat*, *sheet*, *lamella*, and *stratula*, are other terms of almost similar import. Experienced masons can generally discover the grain of the most homogeneous or perfect freestone blocks, or such as will cut with equal ease in any direction. This they often do, by observing the directions of the very minute plates of mica, or silver, as they call it, which are frequently found arranged in the stone, in the direction of the grain, or beat of the stone; which, it must be observed, is not always that of the beds or stratification, many rocks having stratula which cross their beds obliquely, often at an angle of from 30 to 45 degrees with the bed or plane of the stratum; and such stratula not uncommonly dispose the stone to split into flags, or paviers, or even tile-stones, or slates for houses, and into the most thin and perfect lamina. Sometimes these oblique stratula cross stone beds of very great thickness, and have been frequently mistaken, by inattentive observers, for the stratification itself.

GRANARY, a building contrived for laying up and storing corn, in order to preserve it for a length of time.

The construction of this class of buildings has not, we believe, received that attention which the importance of it deserves, and we consider therefore that some account of the proper mode of designing and erecting granaries on scientific principles will be both interesting and useful.

It must be evident to all, that, owing to the uncertainty of harvests, the produce of a year may be either abundance or dearth, the frequent recurrence of the latter, in the earlier ages, obliged most of the ancient nations to seek means of preserving the superabundant produce of plentiful years, in order to be prepared against the privations of less fortunate ones. This necessity was more imperative, when the means of conveyance by land and water were less perfect than at present. In modern times a higher state of civilization has taught mankind to feel the advantages of a free circulation of produce, famine is not now therefore so fearful an evil as formerly. The improvements in the mode of culture have also much increased the produce of the earth; but the probabilities of famine, though decreased, still remain to a certain extent, and the construction of proper repositories for storing up grain must be always important, as a means of lessening its evils.

In some countries public granaries are established upon a very large scale, and in them is preserved the grain collected from the whole of the surrounding districts. The French have given great attention to the subject, and the following plan for a public granary, by an eminent French engineer, is well worth imitation. M. Bruyere observes, that in the calculations necessary to fix the dimensions of a granary destined to contain a determinate quantity of grain, the following considerations must be attended to.

A granary of reserve, as it is termed in France, contains wheat of different ages, and the duration of their preservation is three years, the grain being supplied by thirds every year. The disposition to ferment being caused by the degree of moisture, and by the quantity, and the oldest corn being the dryest, it follows that the mean depth of the heap should vary with the age of the corn. From these data, and by the help of experience, the depths of the heaps of corn may be fixed as follows:—

Corn of one year	19½	inches.
" " two years	24	"
" " three years	27	"

A distance of about a yard should be left between the foot of the heaps and the wall, and an empty space of thirteen to sixteen feet between the heaps, for the operation of turning. To these spaces must be added also those occupied by the staircases, rollers, trap-doors, working-rooms, &c., and the whole must be deducted from the superficial content of each floor. The remainder, multiplied by the number of stages, and the mean height of the heaps, will give the solid content of wheat that the granary can contain.

The situation of a public granary is important; if possible it should be placed near a canal or navigable river, in order to receive or send out the grain by water, or by any other easy method of transport, as the expense is thereby much diminished.

For the same reason, granaries should be near a sufficient quantity of mills, whose motive power can, in certain cases, be applied to the different machines used in the manipulation of the corn. These mills should not, however, be placed in the same building with the granaries, or be too near to them on account of the danger of fire, and because the two operations are hurtful to each other; the dust of the wheat injuring the flour, and the motion of the water rendering the grain too moist.

The aspect of granaries should be south, as the change of temperature will then be sufficient to keep a current of air between the opposite openings, and it is most important to use the driest winds for ventilating and drying the grain.

In order to diminish the extent of granaries, it is necessary to add to their height, by multiplying the number of floors; and, as it is easy to raise the grain by the help of machines, we thus gain the advantage of being able to make it descend from sieve to sieve, which cleans and sorts them in the least expensive manner.

The lowest floor, should be sufficiently elevated above the earth to prevent damp, and to facilitate carting. Experience has proved that a height of 8 feet is sufficient for the curve that is described by the wheat when thrown up by a shovel. Each floor should therefore have a height of 10 feet.

The walls of the granary should be thick, not only on account of strength, but also to keep out damp and heat. The windows should descend to the level of the floor, so that the air may circulate through the lowest part, and strike the foot of the heap of grain. The entrance of the air is facilitated by widening the openings from the interior to the exterior. They should be grated with iron wire to prevent the entrance of birds, and furnished with shutters which, when open, fall back on the thickness of the wall.

When the granary is of considerable size, it appears natural to place the entrance in the middle of its length. This entrance should be large enough to permit vehicles to cross the building, so as to load or unload under cover. To prevent the division of the lowest floor, this passage is sometimes made by a projecting porch, under which the vehicles can be ranged, though in a less convenient manner. The staircases should be placed, near the passage, for the carts, but, to prevent interruption of the heaps of corn, some place them in a projection opposite the porch, or in one of the angles of the building.

It is desirable that granaries should not be of too great an extent, in order that the grain may more readily dry by the currents of air. On the other hand, as it is always necessary to reserve the passages along the walls, the size of the interior should not be less than 40 feet, or exceed 65 feet. In all cases, they are divided by pillars of stone, wood, or cast iron. (*Bruyère Etudes Relatives à l'árt des Constructions.*)

The following may be taken as a guide for the erection of a granary in this country. The building should be rectangular in plan, the height about twice the distance between the opposite walls, that is, 20 feet high by 10 feet in width on each side, and provided with numerous air-holes, declining outwards, to prevent the entrance of rain or snow. From each air-hole to a corresponding one on the opposite side, should be fixed an inverted angular spout or gutter, to permit the air to pass through unimpeded by the corn lying about; as many of these gutters should be fixed, as there are holes to receive the ends after crossing the building; and the extremities of the holes should be covered with wire gauze, to defend them from vermin.

The first floor of the granary should be divided into a series of hoppers, these hoppers to empty themselves into one large hopper underneath, provided with a sliding door to regulate the passage of the grain into a sack or other receptacle. At the top of the building a loft should be erected, to which the corn may be first hoisted by a tackle or crane, and be discharged over a cross-bar into the body of the building, which operation may be continued until it is filled to the top. Upon drawing off any corn at the bottom, the whole of it will be put in motion, and the airing of every part promoted; the process of airing should, however, be continually going forward through the numerous passages under the inverted gutters, the angles of which do not fill up by the lateral pressure of the grain.

GRAND STAIRCASE, the principal staircase of a large edifice, for the use of the family and visitors. *See Staircase.*

GRANGE, the ancient name of a barn; sometimes applied to the farmhouse itself. The term grange was also used in former times to designate the farming establishments attached to religious institutions.

GRANITE, an aggregate rock, the essential ingredients of which are feldspar, quartz, and mica, being the same as those of gneiss, from which granite differs chiefly in the arrangement of the three component parts. In granite these are mingled without order or regularity, which produces a granular structure, while that of gneiss is generally slaty.

"GRANITE is one of the most abundant rocks at or near the surface of the earth, it is likewise considered as the foundation rock of the globe, or that upon which all secondary rocks repose. In alpine situations it presents the appearance of having broken through the more superficial strata of the earth; the beds of other rocks in the vicinity rising towards it, at increasing angles of elevation as they approach it. It forms some of the most lofty of the mountain-chains of the eastern continent; and the central parts of the principal mountain-ranges of Scandinavia, the Alps, the Pyrenees, and the Carpathian mountains, are of this rock. No organic fossil remains have ever been found in granite, although it is sometimes found overlying strata containing such remains." (*Imperial Dictionary.*)

Of all materials for building, granite is the most durable, as shown by many of the ancient Egyptian monuments. By the Egyptians and other very ancient nations it was more particularly applied, together with sienite, for the purposes of architecture and statuary, and many very interesting monuments of their skill and patience are still existing in the collections of antiquities. As instances of the extreme durability of granite, we may mention, that the obelisk in the place of Saint Jean de Lateran at Rome, which was quarried at Syene, under the reign of Zetus, king of Thebes, 1300 years before the Christian era; and the one in the place of Saint Pierre, also at Rome, consecrated to the sun by a son of Sesostris, have resisted the weather for full 3000 years.

The use of granite for architectural and economical purposes is perhaps nowhere more amply displayed than at St. Petersburg, where not only the imperial and other palaces, but even ordinary dwelling-houses, have their lower parts lined with slabs of granite. The left bank of the great Neva, from the Foundry to the Gulf of Cronstadt, and both banks of the Fontanka and of the Catharine canal, are lined by high walls constructed of such slabs of granite; as are many bridges over the Neva, balustrades, &c. The pillars, stairs, balconies, &c. in the palace of Cronstadt, are almost all of the finest kinds of granite. Those employed for ornamental architecture are cut and polished by lapidaries; but those intended for less delicate purposes, such as common slabs, steps, cylinders, troughs, &c. are worked by peasants, particularly by those of Olonesk. The government-towns, however, Moscow not excepted, are too distant from the chief granite mountains, to be enabled to make frequent use of that rock for the above purposes.

Mr. Brand has divided the different granites used in the arts after their predominant colours; the following are the principal varieties, in which, however, the black-and-white kind is not included, one of its ingredients being hornblende, which assigns it a place among the sienites.

GRANITE, *Gray, of Chessi*, in the department of the Rhine, consists of white quartz and black mica, with large crystals of rose-coloured feldspar. The columns of the Eglise d'Enée (ancient temple of Augustus) at Lyons, are of this kind of granite, which has also been worked by the Romans.

GRANITE, *Gray, of Thain*, consists of gray quartz, black mica, and white feldspar crystals, which are sometimes from two to three inches long. The quarries of this granite are on the road from Lyons to Valence, on the right bank of the Rhône. It is very well adapted for the construction of large monuments. The granite of St. Peray, not far from Thain, is exactly like this, except that its feldspar crystals are of a rose-colour.

GRANITE, *Gray, of Lavezzi*, a small island near Bonifacio, south of Corsica, in the straits which separate that island from Sardinia, is composed chiefly of small irregular crystals of feldspar, mixed with a little black mica, besides which it contains also feldspar crystals, of a milk-white colour. In the quarry of that island a large unfinished column is to be seen, which had been relinquished by the Roman workmen.

GRANITE, *Gray, of Elba.*—Its grain is pretty uniform; its colour sometimes approaches to light violet. There are four columns of this variety to be seen in the Musée Napoleon: they were taken out of the church which contained the tomb of Charlemagne, at Aix-la-Chapelle.

They gray granites are much more common than the green or greenish, of which the following deserve to be mentioned.

GRANITE, *Antique green.*—Its predominant ingredient is white quartz, with here and there some light green feldspar. There is a column of it in the Villa Pamfili, near Rome.

GRANITE, *fine-grained antique.*—(Basalte verd oriental.) The component parts of this sort are so minute and intimately blended, that they can scarcely be distinguished by the naked eye. Its colour approaches to deep olive. It is very hard and takes a fine polish. The Egyptians have much employed it for the construction of monuments; and several statues of it may be seen in the Capitol and the Villa Albani. There is another variety with white spots, known at Rome under the name of *Basalto Orientale pidochioso;* but it is very rare, for there are but two columns of it in existence, namely, in the church of St. Pudentiana at Rome. Some varieties bearing that name are silenite.

GRANITE *of St. Christophe:* composed of violet quartz, white feldspar, and green mica. This magnificent rock is found at Oisans, in the department of the Isère.

GRANITE, *Corsican, orbicular.*—This beautiful rock (which probably belongs to the sienite formation) was discovered by M. Barral, in the island from which it derives its name. Its composition is very extraordinary; it has a basis of ordinary gray granite, which, however, in most parts exhibits a considerable portion of hornblende. But what more particularly characterizes it, is a number of balls, of from one to two inches in diameter, each composed of several concentric and perfectly parallel layers, the outermost of which, generally white, opaque, and two or three lines thick, is composed of quartz and feldspar, blended in various proportions, and exhibiting a radiated appearance, rather converging towards the centre of the ball. The second layer, which is of a greenish black colour, and about one line thick, is composed of fine laminar hornblende; and this is succeeded by a white and usually translucid quartz layer, of about four or five lines in thickness, inclusive of two or three very thin layers of hornblende, that are commonly seen within the substance of this third principal layer. Each of these layers is generally of equal thickness in the whole of its circumference. These three parts may be considered as the coating: the interior of each ball is less defined than the surrounding layers, and consists of a blackish and a whitish substance, the former surrounded by, and passing into the latter, the centre of which is usually a dark gray spot.

The quarry of this rock is unknown, a single block only having been found in the gulf of Valinco, in Corsica: its weight was about 80lb., but it was soon broken into small fragments, which are now distributed among collectors. There is a beautiful vase of it, one foot six inches high, in the cabinet of M. Dedrée. The granite of Corsica is figured by M. Faujas de St. Fond, in his *Essai de Géologie*, and in Mr. Sowerby's *Exotic Mineralogy.*

Among the red granites, we have what is called *red oriental granite*, which usually contains hornblende, often in large separate patches.

Granite, *Red, of Ingria.*—"This granite," says M. Patrin, "is distinguished from others in this, that the feldspar, instead of being in grains, or parallelopiped crystals, as in most other granites, constantly appears in the shape of round or oval pieces, of from half an inch to two inches in diameter. This granite takes a very fine polish, and in this state exhibits the feldspar in the shape of white, round, or oval (*chatoyant*) spots, in a reddish ground. The rock which serves as a pedestal of the equestrian statue of Peter the Great, at St. Petersburg, is of this granite: the block was originally 32 feet long, 21 feet thick, and 17 feet wide; but, in order to give it its present shape, imitative of a picturesque natural rock, it has been much diminished in size. This block was disengaged from a swamp, about forty versts from Petersburg: its weight was calculated to be above three millions of pounds." We have seen several fragments that were detached from the very block forming the pedestal of the statue; but in none of them did we observe the form ascribed by Patrin to the feldspar.

The public summer promenade-garden at Petersburg is decorated with a superb colonnade of this granite: the columns, which are sixty in number, are of the Tuscan order; their shafts, made of one piece, are about 20 feet high, and three feet in diameter. The island, called Kotlin-Ostrow, on which is the fortress of Cronstadt, is covered with blocks of this granite, the feldspar of which is sometimes of the kind called Labrador-stone.

Granite, *Red, of the Vosges Mountains.*—This granite is composed of large laminæ of rose-coloured feldspar, gray grains of quartz, and small scales of mica. It has so strong a resemblance to the Egyptian red granite, that it is difficult to distinguish them. Its quarries are on the heights of Montaujeu, near the Papean mountains, in the Vosges.

Granite, *Violet, of Elba.*—The feldspar of this variety is in large violet crystals. The pedestal of the equestrian statue, in the Piazza della Santissima Annonziata at Florence, is made of it, as are also the *sodes* in the chapel of St. Laurence in the same town.

Granite, *Rose-coloured of Beveno.*—This beautiful granite consists of flesh-coloured feldspar, white quartz, and some grains of black mica. Considerable quarries of it are found on the borders of the Lago Maggiore, which are worked without intermission, for supplying Milan, and the whole of the neighbouring country, with this granite. It takes a very fine polish: here and there it exhibits ribands, or zones, of a gray colour, which are composed of the same ingredients as the rest of the mass, but reduced into very minute particles. Many columns, porticos, &c. are seen of it at Milan.

The name of *Graphic granite* is given to those kinds in which the feldspar forms large concretions, intermixed with gray quartz crystals, exhibiting, when cut transversely, angular figures, mostly shaped like a 7; while others are less regular, and bear a distant resemblance to rude alphabetical writing. They are not considered to be genuine granite by some mineralogists.

Granite, *Graphic, of Portsoy.*—The feldspar is of various tints of pale flesh-red; the quartz dark, but transparent, with now and then some small particles of mica. This rock is minutely described by Dr. Hutton.

Granite, *Graphic, of Siberia.*—Its feldspar is of a yellowish white, or reddish colour; the quartz, exhibiting figures similar to those of the quartz in the preceding sort, is of the variety called *smoky topaz.* Mica occurs in it in small nests, and black shorl in acicular crystals.

Granite, *Graphic, of Autun.*—Of a pale rose-colour; quartz crystals gray, very numerous; found in the neighbourhood of Autun, department of Saône and Loire, particularly at Marmagne. This, in Mr. Brand's opinion, is the most beautiful of all granites. Another variety of this stone is found at the same place: its feldspar is white; the quartz gray, in small crystals; it is susceptible of a very fine polish.

Granite, *Graphic, of Corsica.*—Likewise of a rose-colour; but generally paler than that of Autun, from which it is also distinguishable by its quartz crystals being larger, and at greater distance from each other. It contains some thinly disseminated bronze-coloured mica, and takes a fine polish.

GRATICULATION, a term used by some writers for dividing a drawing into compartments of squares, in order to be reduced.

GRAVITY, *Table of Specific, See* Specific Gravity.

GREAT CIRCLE OF A SPHERE, a circle passing through the centre, which is one of the greatest.

GREAT STAIRCASE, *See* Grand Staircase.

GREEK ARCHITECTURE, such as was practised by the Greeks. For information on this general subject we must refer to the description of each order given under their several titles, where will also be found some account of their origin and progress. *See* below, Greek Orders; also Architecture, Roman Architecture, &c.

Greek Cross. *See* Cross.

Greek Masonry, the manner of bonding walls, as used by the Greeks. *See* Masonry.

Greek Mouldings, *See* Mouldings.

Greek Œcus. *See* Œcus.

Greek Orders, are the Doric, Ionic, and Corinthian orders. *See* Doric, Ionic, and Corinthian; also Orders, and Architecture.

Greek Ornaments. *See* Ornaments.

GREENING, in plumbery, the rubbing of a new sheet of lead with any green vegetable, where it is to be soldered, in order to prevent the solder from adhering except at the places where it is scraped off.

GREENHOUSE, a house of shelter in a garden, contrived for preserving the more tender and curious exotic plants.

Structures of this kind were formerly erected with slated roofs, like dwelling-houses, and with large upright windows in front, divided and supported by pillars; examples of which may yet be seen in several of the royal gardens about London, and also in different parts of the country. It was soon found that handsome specimens of plants could not be grown in houses of this description; and the only purpose to which they are now applied, is the growing of orange or lemon-trees, and protecting other plants in winter.

Greenhouses, as now built, serve not only as conservatories, but likewise as ornaments of gardens; being usually large and beautiful structures, sometimes in the form of galleries, wherein the plants are handsomely ranged in cases. *See* Conservatory.

The greenhouse is a sort of building designed for the purpose of preserving various kinds of exotic shrubs, &c., through the winter season, and for growing and protecting those kinds of plants which are too tender to live in the open air. It is fronted and covered with glazed frames, but the aid of artificial heat is not necessary except in intensely cold weather. It is advisable, however, in constructing such houses, to erect flues to use occasionally, which may prove serviceable, not only in severe frosts, but also in moist, foggy weather, when a moderate fire will now and then dry up the damps, which would otherwise prove pernicious to many of the tender kinds of plants.

It differs from the conservatory chiefly in this circumstance, that the plants, trees, or shrubs, are in pots or tubs, and placed upon stands, frames, or stages, during the winter, to be removed to proper situations in the open air, during the hot summer season; while in that, there are beds, borders, and clumps, laid out in the ground-plan, and made up with the best earthy materials, to the depth of three or four feet, in which the shrubs, trees, &c. are regularly planted; the whole of the roof being removed during the summer to admit fresh air, and replaced on the approach of the autumn, to remain until the following summer.

Greenhouses should stand in the pleasure-ground, near the house, if possible, upon a somewhat elevated spot, full to the south, and where the sun has access from its rising to its setting. These buildings are generally of brick or stone, having the fronts and tops almost wholly of glass-work; and ranging lengthwise east and west. They are generally constructed upon some ornamental plan. As to the general dimensions, in respect to length, width, and height, they may be from 10 to 50 feet, or more, in length, according to the number of plants to be contained; and in width, from 10 or 15 feet to 20 feet; but, for middling houses, 15 or 18 feet is a sufficient width; and in height in the clear, nearly in proportion to the width.

The walls on the backs and ends, particularly the former, should be carried up two bricks thick; and if more than 15 feet high, two bricks and a half thick; at one end of the back wall, on the outside, a furnace may be erected for burning fires occasionally, communicating with flues within, ranging in two or three returns along the back wall, having one flue running along the front and end walls, raised wholly above the floor of the house.

The fronts of the buildings should have as much glass as possible, and wide glass doors should be made in the middle, both for ornament and entrance, and for moving in and out the plants. It would also be convenient to have a smaller entrance door at one end; the width of the windows for the glass sashes may be five or six feet: and the piers between the sashes may be either of timber, six, eight, or ten inches wide, according to their height, or if of brick or stone work, two feet wide at least, sloping both sides of each pier inward, that by taking off the angles, a free admission may be given to the rays of the sun. For the same reason, the bottoms of the sashes should reach within a foot of the floor of the house, and their tops almost as high as the roof; and if brick or stone piers two feet wide, shutters may be hung on the inside, to fall back against each pier. The roof may be either wholly or only half glass-work, next the front; the other half slated, especially if the upright or front piers are of timber; and the shutters to cover the top glasses may be so contrived as to slide under the slated roof: where the piers are of brick or stone, it is common to have the roof entirely slated or tiled; but slating is the most ornamental for a half or whole roof; and the ceiling within should be white; which, as well as the whole inside wall, must be well plastered and white-washed, so as to render it clean and neat.

But in greenhouses of modern construction, in order to have as much glass as possible in front, the piers between the sashes are commonly of timber only, from six to eight or ten inches thick, according to the height, so as to admit as great a portion of light and heat of the sun as possible, and the roofs are wholly of glazed frame-work.

The greenhouses for large collections of plants have sometimes two wings of smaller dimensions, added to the main building, at each end, in a right line, separated sometimes from it by a glass partition, with sliding sashes for communication, and the front almost wholly of glass-work, and half or whole glass roofs. Thus, by these additional wings, the houses consist of three divisions, whereby the different qualities and temperatures of the various plants can be more eligibly suited. The middle, or main division, may be for all the principal and more hardy, woody, or shrubby kinds, which require protection only from frost; one of the wings appropriated for the succulent tribe, and the other to the more tender kinds, that require occasionally heat in winter, but which can live without the heat of a stove or hot-house.

On whatever plans greenhouses are constructed, the whole of the inside walls should be neatly finished off with plaster and whitewash, and the wood-work painted white; the bottom being paved with large square paving tiles, or some similar material.

In the greenhouse there should be stands, frames, or tressels, which may be moved in and out, upon which rows of planks may be fixed, so as to place the pots or tubs of plants in regular rows, one above another; by which their heads may be so situated as not to interfere with each other. The lowest rows of plants next the windows should be placed about four feet from them, that there may be a convenient breadth left to walk in front; and the rows of plants should rise gradually from the first, in such a manner, that the heads of the second row may be entirely advanced above the first, the stems only being hid; and at the back of the house a space allowed of at least five feet, for the conveniency of watering the plants, and to admit a current of air round them, that the damps occasioned by their perspiration may be the better dissipated; when this is not done, the damps, pent in too closely, often occasion a mouldiness upon the tender shoots and leaves, and, when the house is close shut up, this stagnating rancid vapour is often very destructive; for which reason the plants should never be crowded too close to each other, nor should succulent plants ever be placed among them.

GRIFFIN, or Griffon, (from the Greek γρυψ,) a fabulous creature, usually supposed to have the head and wings of an eagle, with the body, legs, and tail of a lion; but sometimes with the head of the latter, and the horns and beard of a goat, as in the Ionian antiquities. The ancients adorned the statues and temples of their gods with symbols of their supposed influence. The griffin, which was particularly sacred to Apollo, and in fabulous antiquity believed to be ever watching the golden mines on the Scythian and Hyperborean mountains, is introduced as a guardian of the lyre, which belonged to him, as inventor of music. It has a lion's head, because Apollo, or the sun, is most powerful when in that sign of the zodiac. The Persians also had a statue of him, with the head of that animal.

GRILLAGE, in engineering, a term applied to a kind of frame-work, made something like a grating, of heavy pieces of timber laid lengthwise, and crossed by other pieces, notched down upon them. It is used to sustain foundations, and prevent their irregular settling, in soils of unequal firmness or solidity. This frame-work is firmly bedded, and the earth packed into the interstices between the timbers; a flooring of thick planks, termed a platform, is then laid on it, and on this the foundation-courses rest.

GRINDSTONE, a cylindrical stone, mounted on a spindle through the axis, and turned by a winch-handle, for grinding edge-tools.

GRINDING, the act of wearing off the redundant parts of a body, and forming it according to its destined surface.

GRIT-STONE, a stone consisting of particles of sand agglutinated together. Of this kind of stone there are many varieties, differing in the size of the particles of sand that compose them, the several properties of these sands, and their various degrees of compactness and agglutination.

Some of them are used for building, others for grinding, others for whetting sharp steel instruments, and others for filtering water. *See* Stone, and Whetstone.

Grit-Stone, in mining, a hard granular or gritty stone, composed of grains of silex or quartz, cemented together, generally either by a silicious, an argillaceous, or a ferruginous cement. The first of these, or the silicious grit-stones, are alone fit to be used in repairing roads. The other sorts, in wet weather, soon become a heavy sandy mire upon the road; when the argillaceous parts are dissolved and washed away by the winter rains, this mire changes in summer to loose sand, rendering the roads almost intolerable. Most travellers will have observed this in the argillaceous grit-stone district about Ashby de la Zouch, in Leicestershire, and numerous other coal countries, and the ferruginous grit-stone district about Woburn, in Bedfordshire, and other places. The greater part of the numerous grit-stone rocks and beds of such stone in the coal-mines, are argillaceous, of a fine grit, with minute plates of mica, and are unfit for roads, until hardened by the action of fire; being still, however, very weak and improper materials for road-making, if better can be produced.

A large portion of the argillaceous grit-stones have but a slight disposition to perish or moulder when exposed, and can be used in walls and ordinary buildings; others will perish in a few years; and a large portion of what appears, when first dug, at proper distances below the surface, to be very hard grit-stone, will, after a very short time of exposure, fall to a loamy or clayey sand; such very perishable grit-stone strata are called, by the colliers, *stone-binds*, *gray-beds*, &c., except about Newcastle, where they are denominated *sand-stones.*

In some places, crystallized granular lime-stones occur, as in the yellow or magnesian lime-stone range, near Mansfield in Nottinghamshire, and such are sometimes, though improperly, called *grit-stones*, or *gritty lime-stones. See* Sand-stone.

GROIN, in architecture, the hollow formed by the intersection of two or more simple vaults, crossing each other at the same height.

In the geometrical point of view, the centre of a groin is formed by the entire meeting of the surfaces of two or more cylindrits; that is, such, that every straight line around the whole circumference, on the surface of the one cylindrit, will meet every straight line around the circumference of the one adjoining.

Hence the sections parallel to the axes of all the cylindrits which form the groin are in the plane of their springing; otherwise the surfaces could not meet each other entirely.

Hence, also, the axes of all the cylindrits are also in the same plane, and cut each other in the same point.

In the above definition of a groin, it must, however, be observed, that its surface is no portion of that of the solid which would be contained by the surfaces of the cylindrits and a plane passing through their axes, but only that part of the whole which is formed on the outside of the space which would be thus enclosed in the centre of the groin and form a polygonal dome. The surface of the groin is therefore equal to the whole of the cylindritic surfaces, deducting that of the dome.

The surface of any cylindrit is either that of a cylinder or cylindroid.

When the cylindrits which form the groin are all cylinders, the two vaults are of equal breadth.

In any simple vault of a groin, the planes which are tangents to the surfaces at the springing, have equal inclinations with each respective wall. When all the openings of a groin are equal, the groin is termed an *equilateral.*

The branches of a groin are each of the two opposite parts of each simple vault.

The invention of groins must have been subsequent to that of simple vaulting, and probably originated from arched passages, when it was necessary to occupy the whole height. At what time they were first introduced in architecture, is uncertain; the remains of antiquity show that they are of very remote date, which, however, cannot be traced beyond the times of Roman power and grandeur. Use or necessity was, without doubt, the occasion of their invention, but in process of time they were used as ornaments, and became fashionable at the decline of the Roman empire; they are to be found in the amphitheatre at Rome, formed at the intersections of the radiating and elliptic passages. In the temple of Peace, and baths of Diolcetian, at the same place, instead of massive piers, they are supported upon columns, the most feeble of all supports, and which would be incapable of resisting the lateral pressure of the arches, were it not for the auxiliary support of the walls immediately behind them, at the sides and angles of the building, which act as buttresses.

Groins continued to be used after the dissolution of the Roman empire, in ecclesiastical structures; and wherever grandeur or decoration was required, they were never omitted; they became the most principal ornament of the time, and formed the most conspicuous features in the edifices in which they were employed: at first they were used in the same manner as by the Romans, but in after-times the groins were supported upon ribs, which sprung from cylindrical or polygonal pillars, with capitals of the same form; this produced a necessary change in the figure of the vaulting, as the bottoms of the ribs rose from the circumference of a circle, instead of the angles of a square, with its sides parallel to the walls; and as the spaces between and over the ribs were vaulted in a twisted or winding surface, so as to coincide in every part with a straight line level between the ribs, the angles of the groined surface were thus very obtuse at the bottom, but diminished continually upwards, and ended in a right angle at the summit of the ceiling. Afterwards, when the pillars were formed upon a square plan, the sides of which were obliquely disposed with regard to the sides of the building, and decorated with vertical mouldings, or small attached columns, and the number of ribs increased, the first idea of fan-work would be presented at the springing of the ribs; but in this the architects would soon perceive an incongruity of form in the surface, as it approached the summit of the vaulting; the ribs would be formed all of equal radii, and disposed around, to support a concavity, which might be generated by revolving a curve round an axis which was in the centre of the pillars; and being accustomed to groins meeting in lines crossing each other, it was natural to suppose they would at first permit the ribs to run out and meet each other, which would then be of unequal lengths. If the difference between the openings was not very great, the intersection thus formed by the meeting of the opposite sides of the vaulting would not differ materially from straight lines, but would not be parallel to the horizon, as they would run upwards towards the centre of the groin; but this would depend on the angle formed by two opposite ribs in the same plane. Thus, if the tangents formed at the vertex of the opposite curves contained an angle of 120 degrees, the apex line on the ceiling would form a curve in receding from the vertical angle of the said ribs, of a very decided convexity; but in going progressively forward, the curvature would change into a concavity, and then would begin again to descend. The idea of intersecting the ribs thus disposed in vertical planes around a common axis, by circular horizontal ribs, was natural; and thus again would generate another idea of supporting the upper ends of the ribs, by a circular ring concentric with the axis of the pillar, and this being done from four pillars, would leave a space enclosed by four convex arcs of circles: nothing farther was required to complete this system of vaulting than to fill up the space, and the whole would be keyed together. In this manner, by slow and imperceptible changes, a species of vaulting was invented, very different from that of the Greeks and Romans. Instead of closing the space, if we suppose another ring, forming a complete circumference, to be built interiorly to touch the former arcs, and the four triangular curved spaces closed and wedged together with masonry, the whole will stand equally firm as if the middle had been solid, and thus an aperture for light will be formed the same as in dome-vaulting. This species of vaulting has also another property, that it can be carried up from a square plan with less hazard than the common mode of groining.

In warehouses which are loaded with the greatest weights, and where the walls are placed at a remote distance, it becomes necessary to introduce many supports to the floors: these, if constructed of timber, being liable to accidents from fire, and to rot, are consequently exposed to sudden danger; to prevent which, every precaution should be taken, at least as far as may appear to be warrantable from the profits to arise from the articles to be deposited. This will be fully accomplished by the introduction of groins, which not only answer the same purpose as the flooring of timber-work with its wooden supporters, but are more durable, and proof against fire and rot. Though groins are only employed in the lower stories of buildings, on account of the great expense and loss of space which would be occasioned by the requisite thickness of the walling; yet they may at all times be used in cellars and ground stories, without much additional labour or expenditure of materials.

It having been found that brick groins, rising from rectangular piers, are inadequate to the weight they have to support, and are incommodious to the turning of goods round the corners of the piers, it will be found convenient to employ octagonal piers, and to cut off the square angles of the groin, equal to the breadth of the side of the piers. This mode of construction is decidedly preferable to that in which square piers are used; for the angles of the groins, built in the common way, as they form a right angle, are hardly capable of sustaining themselves, much less the load required to be supported, owing to the bricks being so much cut away at the angles, in order to fit them thereto and to each other, so that they have little or no lap. This scheme should certainly be carried into practice, wherever groins are applied to such uses.

In the construction of edifices for dwelling, they ought always to be employed in cellars, and other damp situations, particularly where there are paved apartments above.

Groins for use only, may be indifferently constructed of brick or stone, as one or other material may be most easily procured.

If employed by way of proportion or decoration, their beauty depends on the generating figures of the sides, the regularity of the surface, and the acuteness or sharpness of the angles, which should not therefore be obtunded. In the best buildings, where durability and elegance are equally required, they may be constructed of wrought stone; and where elegance is wanted at a small expense, of plaster, supported by timber-work.

Groins are consequently constructed in two different ways, according as they are built of stone or brick, or formed of timber-work, lathed and plastered. In the former case, a timber centering is made to form the concavity, and to support the groin during its erection. The centering consists of several ribs, disposed at three or four feet distance, made to the size of the vault which has the greatest opening: The extremities of these ribs rest on beams supported by standards, and are boarded over without any regard to the transverse openings, which are afterwards formed by another set of ribs adapted thereto, and then boarded so as to meet the boarding of the first vault, which if of considerable breadth, must have short ribs fixed upon its surface, in order to shorten the bearing of the boarding of the transverse openings; and thus the centering will be completed. It is obvious, that in forming the ribs for each vault, the outer curve must be the arc of a circle or ellipsis within the curve of the vault, and distanced from it towards the axis equal to the thickness of the boarding. In making the groined centre, it will be necessary to find the place of the angles on the boarding of the large vault, in order to ascertain the place of the ribs and boarding of the transverse vault; this may be done by three different methods. First, let two straight edges be placed vertically at the angles, and a third straight edge, or an extended line, be made to touch the surface of the boarding, and marked at all the points of contact, keeping the latter straight edge or line always upon the edges of the two vertical straight edges.

The defect of this method is, that the place of the angles at the bottom can never be found, since it would require the cross straight edge or line to be of infinite length, and the vertical ones of infinite height. A more eligible method, therefore, where there is room, is, secondly, to fix two ribs in the transverse part, and direct a level straight edge upon their edges, so that the end may come in contact with the boards, and mark the boarding in this place; find a sufficient number of points for the purpose, in the same manner, and draw curves through the points, which will give the curves for fixing the end of the filling-in ribs, otherwise called *jack ribs.*

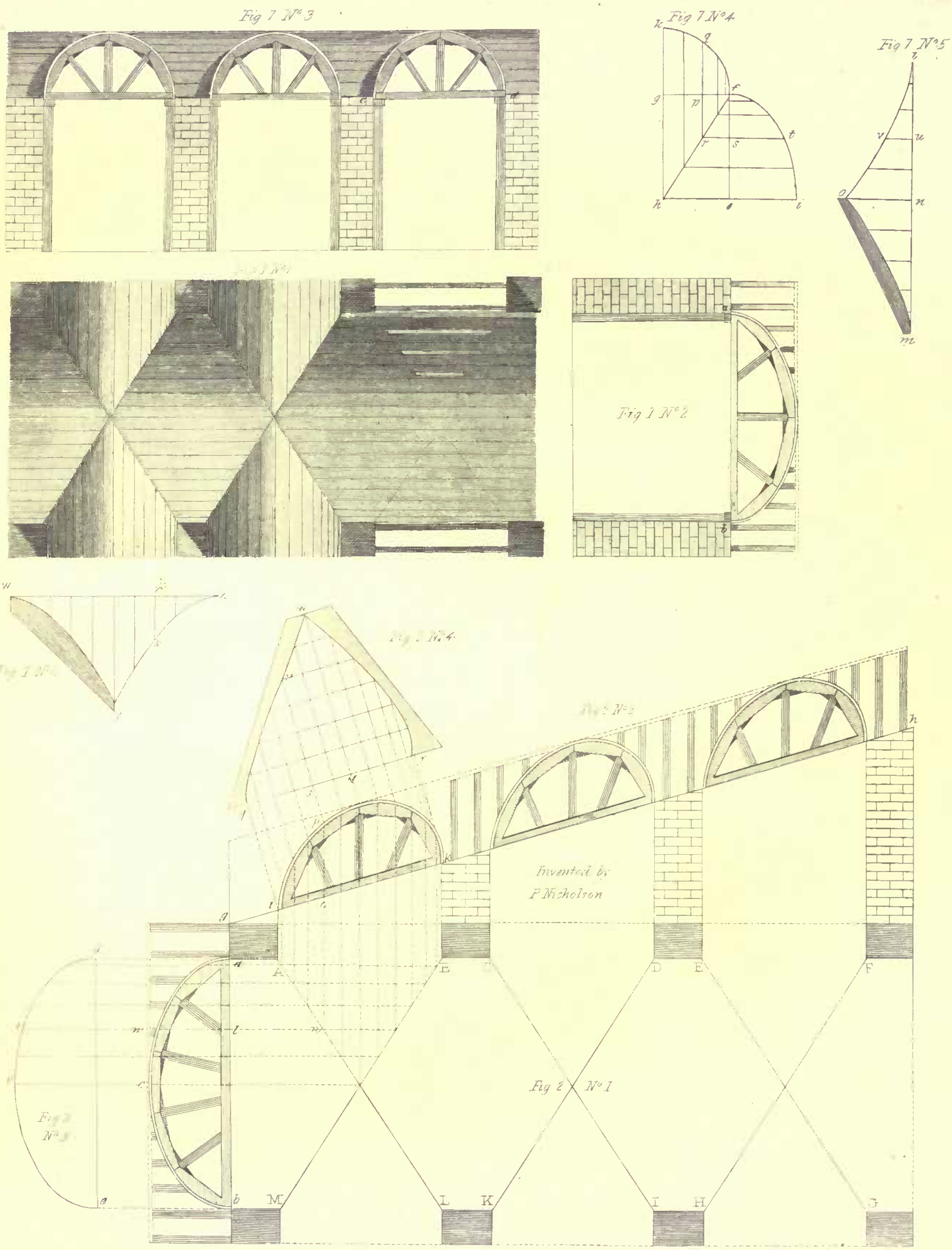
In constructing groins to be finished with plaster, the angle-ribs must be first fixed, then straight longitudinal pieces parallel to the axis of the groin fixed, either flush with the under sides of the angle-ribs, or their under sides a little below those of the angle-ribs, so as to admit of their being nailed together; this is the most eligible method of constructing plaster groins.

There is another mode, by forming curved ribs, in planes perpendicular to the axis of each simple vault: but here, as the curve of these ribs must be the same as that of the cylindrit of each simple vault, the waste of timber will be very great; though not if the ribs are constructed in straight pieces. Whatever mode is adopted in the formation of plaster groins, the under sides of the ribs must always range in the intended surface of each simple vault. These constructions will be more clearly understood in the following explanations.

Plate 1. (Centering for Groins,) *Figure* 1, No. 1. A plan of the widest opening of the groin, first boarded the whole length without interruption; then the cross vaults are boarded; the two cross openings upon the left hand appear as finished, ready to receive the masonry or brickwork, while that on the right exhibits the ribs without the boarding.

No. 2. The elevation of the widest aperture, showing the edges of the ribs of the transverse openings fixed upon the surface of the boarding of the longitudinal opening; this also shows the height of the jack-ribs, which will give their length also.

No. 3. Shows the elevation of the transverse apertures, as completely finished.



Drawn by P Nicholson.

Eng.d by R. Thew

Problem I.—*Given one of the ribs of the transverse ranges, to find the body-range.*

Suppose the given rib to be a semi-circle, or a semi-ellipsis, describe a semi-ellipsis, the length of which is that of the body-range, and the semi-conjugate axis the height of the given rib, which is that of the groin; and the semi-ellipsis thus described will be the contour of the ribs which are to form the body-range.

In the same manner, if a rib of the body-range be given, that of the transverse openings may be found.

But if the given rib be any other curve than that of a semi-circle or semi-ellipsis, lay down the curve of half the given rib upon any straight line, as a base; from the point where the curve intersects the base, draw another straight line at a right angle therewith: upon this line set the extent of half the width of the range from the angular point: complete the rectangle, of which these two straight lines are adjoining sides; draw that diagonal of the rectangle which meets the curve given; take any number of points in the given curve, draw ordinates perpendicular to the base to intersect them; from these points draw lines parallel to the other two sides of the rectangle, to meet the diagonal; from the points of division, draw straight lines parallel to the base of the given rib, to meet the side of the rectangle, which joins the curve of the given rib; from these points raise perpendiculars; transfer the ordinates of the given rib upon the perpendiculars; and the curve drawn through the extremities of these perpendiculars will be that of the rib required.

Figure 1, No. 4, *f q k g f* is the given rib, *g f* its base, equal to half the width, *c d*, No. 3, of the transverse openings; *f t i e f* is the rib found from the given rib *f q k g f*, and *f e* its base, equal to half the width, *a b*, of the body-range.

Figure 1, No. 5. Shows the method of finding the mould for drawing the angles for placing the jack-ribs. The operation is thus performed:

Figure 1, No. 5. Upon any straight line, *m l*, transfer the arc *f t i*, No. 4, stretched out with all its parts from *l* to *m*; from the points thus transferred, erect perpendiculars, and transfer *e h*, No. 4, to the middle perpendicular, *n o*, No. 5; then the remaining parallels of *e h* of the triangle *e h f*, No. 4, respectively to the parallels of *n o*, No. 5, on each side of it; and through the remote extremities of these perpendiculars, draw a curve each way from the point *o*; and thus two equal curves will be formed. But lest the reader should not be able to follow a general description, the following shows not only how any particular point may be found in the required rib, but also how any point may be found in the covering.

First: *To find a point in the required rib.*

Figure 1, No. 4. Take any point, *q*, in the given rib; draw *q p* perpendicular to *g f* the base; draw *p r* parallel to *f e*, cutting *f h* at *r*; draw *r s* parallel to *g f*, cutting *f e* at *s*; draw *s t* perpendicular to *f e*; make *s t* equal to *p q*, and *t* is a point in the curve. In like manner, as many points may be found as required.

Now let it be required to find the point *u*, No. 5. Transfer the arc *i t*, No. 4, upon the straight line *m l*, No. 5, from *n* to *u*; draw *u v* perpendicular to *m l*; make *u v* equal to *s r*, and *v* is a point in the curve. The trilinear area *m o l* is the envelope of the portion of the groined surface represented by either of the two triangles of the plan of the groin, which have the width of the body-range for the base; *m o* is the edge of a mould by which the angle of the groin, or the cylindritic lines, are found; the point *m* is laid to the bottom, and the mould bent upon the surface, so that the point *o* may be in the summit, and the convex side of the mould towards a vertical section passing through the point from which the bottom of the mould rises.

Figure 1, No. 6. Shows the envelope corresponding to either of the two triangular parts of the plan of the transverse parts, and is found in the same manner as No. 5. This shows the mould for cutting the boarding, by laying it out to the full breadth upon a plane, and drawing the ends of the boards by the curved edge of the mould, so as to fit against the boarding of the body-range.

Figure 2. Shows the construction of a groin upon an inclined plane, the widest opening, or body-range, having its ascent or descent in the direction of the inclination of the plane; the transverse ranges are therefore level. The ribs in both directions are set in vertical planes. The rib for the body-range is a semi-ellipsis; those of the sides will also be semi-ellipses, but will not have their axes in a vertical and horizontal position. The elevation of the transverse openings is shown at No. 2, and that of the body-range at the lower end. Each elevation exhibits the construction of the centre, a section of the boarding, and the manner of placing the jack-ribs.

No. 3. Is a section of the body-range at right angles to the plane of its inclination.

No. 4. Shows the form of the moulds for drawing the angles, in order to place the jack-ribs. The construction is thus: Divide the half, *d f*, of the curve *d e*, No. 3, into any number of equal parts; from the points of division draw lines parallel to the axis of the body-range, cutting the diagonal A L; from the points of intersection draw lines parallel to the sides of the transverse opening, and continue them on the other side of the inclination, *g h*, of the elevation of the said openings; from *g h*, as a base, make the heights of the several lines thus continued equal to the corresponding heights of the elevation of the body-range, and a curve drawn through all the extremities will give the form of the ribs, *i p k*, for the transverse openings. From the summit of the centre thus constructed, draw the line *v w* at right angles to the inclination *g h*; extend the arc *d f*, No. 3, with its divisions, to *v w*, No. 4; through all the points of division in *v w* draw lines at right angles thereto; from all the points found in the curve of the rib *i p k*, No. 2, draw lines parallel to *i h*, cutting the respective lines perpendicular to *v w*; and a curve drawn on each side of *v w* will give the angle of the groin.

Groin Ceiling, a cradling constructed of ribs, lathed and plastered. It differs in its construction from groin centering, as the former requires angle-ribs. There are two different methods of constructing groin-ceilings; one by ribs fixed vertically and perpendicularly to the sides of each branch; the other by angle-ribs and ceiling-joists, or straight pieces of timber, running parallel to the axis of each branch, fixed to the angle-ribs, and to other intermediate ribs, in vertical planes, at right angles to the sides of each of the branches, and placed upon opposite piers, to shorten the bearing, in order to make less scantlings for the ceiling-joists, and thereby save timber. But in whatever mode the groined-ceiling is constructed, the surface must finish in the same manner. It is evident, however, that the latter method by ceiling-joists will require much less timber and workmanship than the former, where so much stuff is cut to waste, and so much time employed in making the angle-ribs.

Figure 1. The cradling of a groin ceiling, constructed with ceiling-joists. Stout ribs are thrown across the angles and between the opposite piers; the ceiling-joist being put on below and spiked upwards. In this, the rib, *a l b c*, of a transverse range is given, to find the others. Take any number of points in the half arc *a l b*; draw lines parallel to *g i*, the base of the rib of the body-range, to cut the diagonal *d f*; from the points thus obtained in *d f*, draw lines at right angles to *d f*, and make the corresponding perpendiculars equal to those of the given arc *a l b*; then construct the other half by reversion, and it will form the whole angle-rib.

To obtain the rib of the body-range from the points of section in the base line *d f*, draw lines parallel to *a c*, to cut *g i*, and produce them on the other side of *g i;* from the points thus obtained in *g i*, transfer the corresponding heights of the ordinates of the given rib upon the perpendiculars as ordinates, then construct the ordinates of the other half by reversion, which will give the curve of the ribs of the larger branch.

Figure 2. The cradling of a groin-ceiling, constructed entirely of ribs. The section of the ceiling of the transverse ranges is that of a semi-circle; consequently, the angle-ribs, and those of the body-range, are semi-ellipses, the width of the body-range being greater than those of the transverse branches. The description of the curves of the ribs will be found under the article Ellipsis, *Method* III. *Figure* 3.

The ribs must be bevelled each way, so as to range with either branch of the groin. This is best done by getting them in two thicknesses, then each half of each thickness must range the contrary way, one half with the ceiling of the largest branch, and the other half with the ceiling of the lesser branch, in the same groin; the branches being supposed on the same side of the diagonal: so that when the two parts are put together to form the rib completely, the bevelling of the one half of one thickness and that of half of the other, will range with the surface of the ceiling of one branch, and the contrary edges with the surface of the ceiling of the other branch. In ranging the ribs, each thickness is cut out by the mould: then, in order to range the half of each thickness, the mould must be shifted, so that the upper point of the curved edge will slide in a line parallel to the base, while its lower point will slide upon the base line to the distance required at the bottom: this is represented on the lower end of the principal branch.

Figure 3. A groin in which the principal branch is inclined: *i k l* is the given curve of the rib; *a b* the line of elevation of the spring of the arches. Draw the diagonal *p o*, and *o s* perpendicular to it; join *o n*, which produce to cut *a b* at *r;* make *o s* equal *q r;* produce *o p* to meet *i l* at *a*, and join *s a* (*the reader must however observe, that the engraver has joined* s p *instead of* s a, *and has not produced* o p, *as here stated, and as it was in the drawing*). Bisect *i l* at *y*; through *y* draw *k v* parallel to *m o* or *p n*, meeting the curve in *k*, and *op* at *v;* draw *v u* perpendicular to *o p*, cutting *s a* at *t;* make *t u* equal to *y k;* draw *v* x parallel to *i l*, cutting *a b* at *w;* make *w* x equal to *y k;* then *p s* will be a diameter, and *t u* the semi-conjugate of the ellipsis, which forms the curve of the angle-rib: also *w r* and *w* x are the semi-conjugate diameters of the curve of the ribs for the transverse branches, and the curves may be described as in *Method* V. *Problem* I. of the article Ellipsis. Or, the two axes may be found as in *Problem* II. of the same article, and the curves described according to *Method* III. *Problem* I.; or the curve may be drawn by ordinates as here exhibited. The cradling is shown at the lower end.

Figure 4. Shows the construction of ribs for the arches of apertures cut under the pitch of a large vault at right angles to the wall. Apertures of this description are called *lunettes.*

Let A *z e m p* D be the curve of the section of the principal vault; it is required to construct the ribs of a lunette of a given height.

Produce the base A D to *k*, and the side *g* D to *l;* let *f g* be the breadth of the aperture; bisect *f g* in *i;* draw *i h* perpendicular to *f g*, which assume equal to the intended height of the lunette; draw *h k* parallel to *g* D, cutting D *k* at *k;* make D *l* equal to D *k;* draw *l m* parallel to D A, cutting the curve of the principal vault in *m;* draw M *o* parallel to D *g*, cutting *h i* produced to *o;* join *o f* and *o g;* assume any number of points in the part *m d* of the curve D *m e* A; from the assumed points draw lines parallel to *m o*, cutting *o g;* from the points of division draw lines perpendicular to *o g;* make the lengths of the several perpendiculars from the base equal to the corresponding ordinates contained between the base *n* D and the arc *m* D; then a curve being drawn through the remote extremities of the perpendiculars not in *o g*, will give the curve of the angle-rib. Again, from the intersections in *o f* and *o g*, draw lines perpendicular to *f g*, and produce them on the other side of *f g;* make the heights of the perpendiculars equal to the corresponding heights of the ordinates belonging to the curve D *m*, of the given rib on each side of the middle line *i h;* then a curve being drawn through all the extremities of the perpendiculars not in *f g*, will give the curve of the ribs of the lunette.

On the left-hand side is shown another metnod of tracing the curves of the angular rib, and of ribs forming the sides of the lunette. The cradling is shown below the lower end of the plan.

Groin, sometimes spelt Groyne, a kind of jetty built across the beach at right angles to the line of the shore from high to low-water mark. Groins are used particularly on the southern and south-western coast of England, to retain the shingle already accumulated, to recover it when lost, or to accumulate more at any particular point; also to break and check the action of the waves. The following description of a groin is taken from Mr. Weale's very useful little work, 'A Dictionary of Terms of Art:'—

"The component parts of a groin are piles, planking, land-ties, land-tie bars, blocks, tail-piles, and keys and screw-bolts. The length of a groin depends on the extent, and the requisite strength of its component parts on the nature of the beach on which it is to be constructed.

"Those at Eastbourne, on the coast of Sussex, of which the following is more particularly a description, are from 150 to 250 feet in length, and the beach at that place being very rough, consisting of coarse heavy shingle and large boulders, they require to be composed of proportionably strong materials to resist its force.

"The piles are from 12 to 25 feet long, and 8 by 6½ inches scantling, shod with iron. The planking is in length of 8, 12, and 16 feet, 2½ inches thick, and with parallel edges. The land-ties are of rough timber from 20 to 25 feet long, and large enough at the butt-end to receive the bars. The land-tie bars are 13 feet 6 inches long, and 12 by 5 inches scantling. The land-tie-bar blocks are about 2 feet long, and of the same scantling as the piles. The land-tie tail-keys are about 2 feet 6 inches long, and 6 by 2½ inches scantling. The above materials are of oak or beech. The screw-bolts are of inch round iron, 2 feet 9½ inches, and 2 feet 1½ inch long, in equal proportions.

"The relative proportions of the component parts are, four piles, one land-tie with tail-piles and keys, one land-tie bar with two blocks, two long and two short bolts, about 180 square feet of planking, and about 140 six-inch spikes for every 16 feet in length; and the expense of a groin, constructed with materials of the above dimensions, may be calculated at about £30 for the same length.

"General rules observed in the construction.

"When the object, in constructing a groin, is to recover shingle, or accumulate more, the first pile is driven at the high-water mark of neap-tides, leaving its top level with that of spring-tides. The next is driven at the point on the sands, beyond the bottom of the shingle, to which the groin is to

RIBBING FOR GROINS, CEILINGS &c.

Fig. 1.

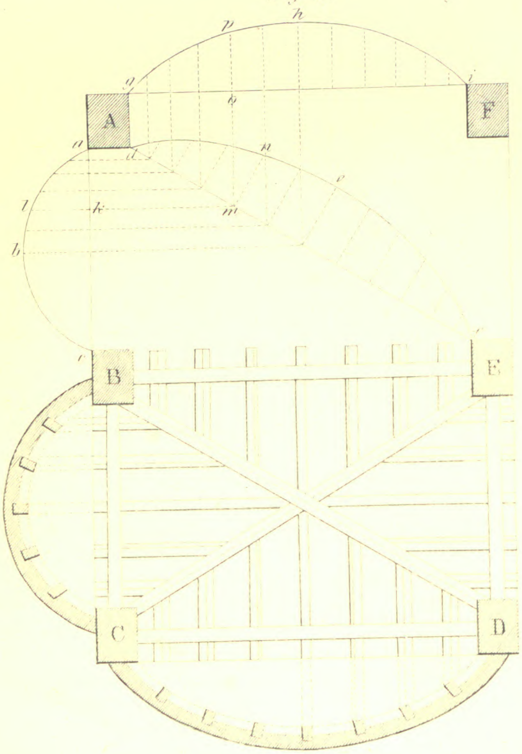


Fig. 2.

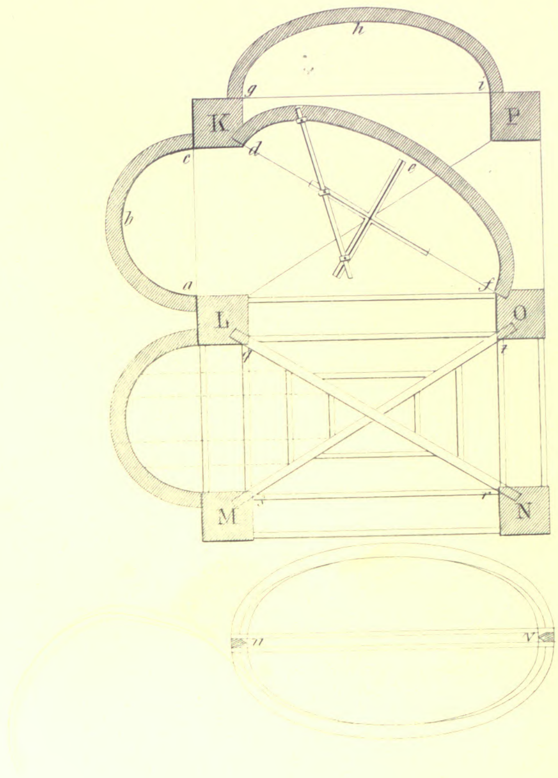


Fig. 3.

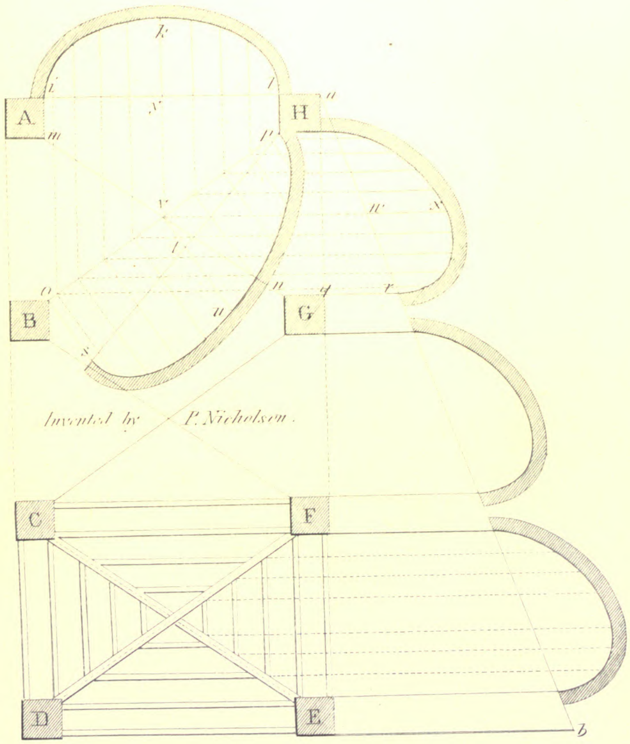
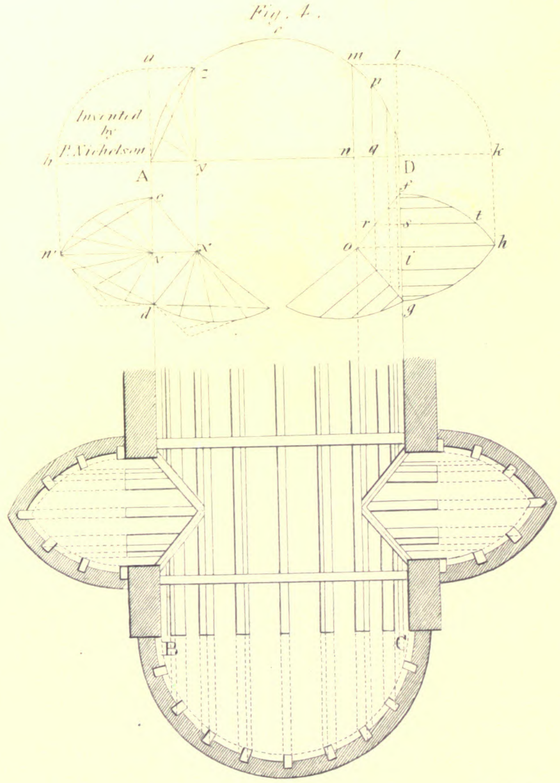


Fig. 4.



P. Nicholson. B. Thew.

extend, leaving about four feet of it out of the beach. The tops of these two piles may be taken for the general slope of the groin, unless the beach should be very steep, and much curved, in which case it becomes necessary to follow its curvature in some degree. From the high-water mark of neap-tides, the piles are carried back nearly level to that of spring-tides, and as much further as may be considered necessary. The piles are driven four feet asunder from centre to centre, and so as to admit the planking between them alternately, and they should be sunk about two-thirds of their length. The longest piles are placed between the high-water mark of neap-tides and the bottom of the shingle, particularly from 20 to 40 feet below the former point. The planking is, if possible, carried down to about two-thirds from the tops of the piles, and kept parallel with them. The land-ties are placed about one-third from the top of the planking (supposing the latter to commence from the tops of the piles,) and their tails are sunk to the level of the bottom of the planking or as nearly so as possible."

GROOVE, a channel cut in a piece of wood by taking away a rectangular prism, one of the sides of which is a portion of the side of the wood in which the excavation is made. A groove therefore forms two external, and two internal angles. It differs from the rebate thus: the rebate is formed by taking away a rectangular prism at the angle, and consequently the part taken away has two of its sides common to those of the piece, with one internal, and two external angles.

A groove is made in joinery by a plough, which is moveable so as to admit of the excavation being run at any distance from the arris.

Grooves are frequently used in order to insert a tongue in the joint of two pieces of wood, intended to be united. They are also used for inserting the panels in framed work, as in doors, shutters, partitions, &c.

In the present day, grooves are among the most fashionable ornaments; but there are few or no instances of their decorative use among the ancient Greeks and Romans.

GROTESQUE, that beautiful light style of ornament used by the ancient Romans, in the decoration of their palaces, baths, and villas. It is also to be seen in some of their amphitheatres, temples, and tombs, the greatest part of which being vaulted, and covered with ruins, have been dug up and cleared by the modern Italians, who for these reasons gave them the name of *grotte*, which is perhaps a corruption of the Latin *cryptæ*, a word borrowed from the Greeks, as the Romans did most of their terms in architecture: and hence the modern word *grotesque*, and the English word *grotto*, signifying a *cave*.

In the time of Raphael, Michael Angelo, Julio, Romano, Polidore, Giovanni d'Udine, Vasaro, Zuchero, and Algerdi, there is no doubt but there were much greater remains of the grotte than what are now to be seen, and in imitation of them were decorated the loggias of the Vatican, the villas of Madonna, Pamfili, Capraola, the old palace at Florence, and indeed whatever else is elegant or admirable in the finishing of modern Italy.

This classical style of ornament, by far the most perfect that has ever appeared for inside decorations, and which has stood the test for so many ages, like other works of genius, requires not only fancy and imagination in the composition, but taste and judgment in the application, and when these are happily combined, this gay and elegant mode is capable of inimitable beauties.

Vitruvius, with great reason, condemns an over licentiousness of this kind and blames the painters of his time for introducing monstrous extravagances. We do not mean to vindicate any thing that deserves such appellations; but surely in light and gay compositions, designed merely to amuse, it is not altogether necessary to exclude the whimsical.

Its origin is discernible in the Egyptian hieroglyphic writing, where the heads and limbs of men and beasts are attached to blocks of stone, to vases, or to foliage, &c., thereby characterizing the inclinations and the powers of the deity or person whose history they record, or whose peculiar transactions they are intended to preserve in the remembrance of future ages.

With the Egyptians it remained rude and unpolished; but when the Greeks adopted it, they made an ornamental use of it, and it became a medium to exhibit their general knowledge of nature. The taste with which they united in one form, not only parts of various animals, but objects so totally diverse in their nature and appearance, as the productions of the animal and vegetable kingdoms, is in the highest degree delightful to contemplate. The formation of chimerical beings, as the dragon, the sphinx, the griffin, &c., owe their origin to this taste; which received much of its force and interest in heathen days, from the mythological enigmas couched under these compound forms. Such is the character of that ornament so common on Egyptian structures, the winged serpent surrounding an egg. Now that these mysterious emblematic meanings are disregarded, and no longer treated with reverence, grotesque painting and sculpture are continued in use merely because the forms they produce are pleasing to the eye; and although the understanding is insulted by them, such is the power of the beauty of form, that we are gratified by it, in spite of our reason.

Those who wish to make themselves acquainted with it, will find the best exemplars on ancient Greek sarcophagi, altars, vases, friezes, &c., of which Piranesi and Rocchegiani have given an ample store to the public in their valuable works. Mr. C. H. Tatham has given likewise a tasteful and judicious series of examples of this kind, in his *Collection of Etchings of Ornamental Architecture, from the Antique at Rome*. Le Roy's, Le Pôtre's, and many other works of the like kind, may also be consulted with advantage.

GROTTO (from the French, *grotte*) is used for a little artificial edifice made in a garden, in imitation of a natural grotto.

The outsides of these grottos are usually adorned with rustic architecture, and their inside with shell-work, fossils, &c. finished likewise with *jets d'eau*, or fountains, &c.

A cement for artificial grottos may be made thus; take two parts of white rosin, melt it clear, and add to it four parts of bees' wax; when melted together, add two or three parts of the powder of the stone you design to cement, or so much as will give the cement the colour of the stone; to this add one part of flour of sulphur; incorporate all together over a gentle fire, and afterwards knead them with the hands in warm water. With this cement, the stones, shells, &c., after being well dried before the fire, may be cemented.

Artificial red coral branches, for the embellishment of grottos, may be made in the following manner: take clear rosin, dissolve it in a brass pan; to every ounce of which add two drams of the finest vermilion; when you have stirred them well together, and have chosen your twigs and branches, peeled and dried, take a pencil, and paint the branches all over whilst the composition is warm: afterwards shape them in imitation of natural coral. This done, hold the branches over a gentle coal fire, till all is smooth and even as if polished.

In the same manner white coral may be prepared with white lead, and black coral with lamp-black. A grotto may be built, with little expense, of glass, cinders, pebbles, pieces of large flint, shells, moss, stones, counterfeit coral, pieces of chalk, &c., all bound or cemented together with the above-described cement.

The grotto at Versailles is an excellent piece of building. Solomon de Caux has an express treatise of grottos and fountains.

GROUND CILL. *See* GROUND SILL.

GROUND JOISTS, the joists which rest upon sleepers laid upon the ground, or on bricks, prop-stones, or dwarf walls; they are consequently only used in basements and ground-floors.

GROUND LINE, in perspective, the intersection of the picture with the ground plane. *See* GROUND PLANE.

GROUND NICHE, a niche whose bottom is on a level with the floor.

GROUND PLAN, the plan of the story of a house on the same level with the surface of the ground, or elevated only a few steps before the door. The ground floor is not always the lowest floor, the basement being frequently beneath it.

GROUND PLANE, in perspective, the situation of the original plane in the supposed level of our horizon. It differs from the horizontal plane thus: the horizontal plane is any plane parallel to the horizon; whereas the ground plane is a tangent plane to the surface of the earth on which we walk, and is supposed to contain the objects to be represented, the earth itself being considered as a spherical body.

The term *ground plane* is used in a more confined sense than that of *original plane*, which may be any plane, whether horizontal or inclined.

GROUND PLATE. *See* GROUND SILL.

GROUND PLOT, the plan of the walls of a building, where they first commence above the foundation; though it is more properly the piece of ground selected for building upon. For dwellings, its chief properties are a healthy situation, a convenient supply of water and other necessaries of life, and an agreeable aspect. If for trade or manufacture, it must be convenient for receiving the raw materials, and for exporting the articles manufactured.

GROUND RENT. Rent paid for the privilege of building on another man's land. In the neighbourhood of London it is very difficult to obtain freehold-land, and most of the building-ground, therefore, is let on long leases, subject of course to the payment of ground-rent.

GROUND SILL, or GROUND PLATE, the lowest horizontal timber on which the exterior walls of a building are erected. It chiefly occurs in timber buildings; or in buildings whose outside walls are formed of brick panels with timber framings.

GROUND TABLE. The top of the plinth.

GROUND WORK. *See* FOUNDATION.

GROUNDS, in joinery, certain pieces of wood concealed in a wall, to which the facings or finishings are attached, having their surfaces flush with the plaster. Narrow grounds are those to which the bases and surbases of rooms are fastened. Grounds are used over apertures, not only to secure the architraves, but also to strengthen the plaster. In order to keep the plaster firm, should the materials happen to shrink, a groove is sometimes run on the edge of the ground next to the plaster, or the edge of the ground is rebated on the side next to the wall; so that in the act of plastering, the stuff is forced into the groove or rebate, which prevents it from shifting when it becomes dry.

GROUP, in painting or sculpture, an assemblage of two or more figures of men, beasts, or other things which have some relation to each other.

GROUPED COLUMNS, or PILASTERS, those which consist of more than two. Nothing of this description is to be found among the ruins of the ancients; nor are they conformable to the strict rules of architecture, though some few examples exist in modern buildings.

GROUT, a thin semi-liquid mortar, composed of quicklime with a portion of fine sand, which is prepared and poured into the internal joints of masonry. It is particularly used where the work consists of large masses of stone. The process is called *grouting*.

Grouting is also now generally used in street-paving.

GRY (Greek) a measure containing one-tenth of a line.

A line is one-tenth of a digit, a digit one-tenth of a foot, and a philosophical foot one-tenth of a pendulum, whose diodromes or vibrations, in the latitude of 45 degrees, are each equal to a second of time, or one-sixtieth of a minute.

GUARDS (from the French *garde*, a defence) in engineering, upright pieces of wood, nailed to the lock-gates of a canal, to prevent the barges from striking the planks of the gates.

GUERITE (French) in fortification, a sentry-box; being a small tower of wood or stone, placed usually on the point of a bastion, or on the angles of the shoulders, to hold a sentinel who is to take care of the ditch, and watch against a surprise.

GUILD-HALL, or GILD-HALL, the great court of judicature for the city of London, and other cities; where are kept the lord-mayor's court, the sheriff's court, the court of hustings, court of conscience, court of common-council, chamberlain's court, &c.

GUILLOCHI (Italian) an ornament in the form of two or more bands or strings twisting over each other, so as to repeat the same figure in a continued series by the spiral returnings of the bands. The term is also applied to the ornaments, consisting of bands turning at right angles, commonly called *frets*.

GULA, or GUEULE. *See* CYMATIUM.

GULBE, the same as GORGE, which *see*.

GULLIES, in engineering, a name applied in some places to the iron tram-plates or rails laid for the use of tram-waggons.

GULOICK, the same as IMPOST, which *see*.

GUNTER'S CHAIN, so called from the inventor, the chain commonly used by surveyors in measuring land. It is 66 feet long, or 22 yards, or 4 poles of $5\frac{1}{2}$ yards each; and is divided into 100 links of 7.92 inches each; 100,000 square links make one acre.

GURGOYLE, the same as GARGOYLE.

GUTTÆ (Latin) ornaments formed like the frustum of a cone, depending from the soffits of the mutules and regula under the band of the architraves of the Doric order. In several of the Grecian Dorics, the guttæ are cylindrical instead of being conical: their number on the soffits of the mutules is eighteen, disposed in three rows, each row parallel to the front.

They are sometimes also called *lachrymæ*, tears; and *campanæ*, or *campanulæ*, bells. Leon Baptista Alberti calls them *nails*. *See* DROPS, and DORIC ORDER.

GUTTER, in building, a channel for collecting and conveying the water from the roof, situated between the parapet and the inclined side of the covering, or between the inclined sides of a double roof, the intersection of the vertical plane of the wall and the inclined plane of the roof, or the two inclined planes forming horizontal lines. When two inclined sides of a roof meet each other at an internal angle, and form an inclined intersection to the horizon, the angle thus formed is called a *valley*. The external angles formed by two inclined planes are called *hips;* and hence hips are exactly the reverse of valleys, and thus we have the difference between gutters, hips, and valleys. The intersections of the planes which form the sides of gutters are horizontal, but the intersections of the planes which form hips and valleys are inclined. Gutters for lead are formed partly by a boarding perpendicular to the plane of the walls, and partly by the inclined sides of the roof and the vertical planes of the walls, and are supported by horizontal bearers from the walls to the sides of the rafters, against which they are nailed at one end; the other end is supported close to the wall upon small posts or puncheons, which are notched and nailed to the bearers. The boarding, which is supported by the bearers, and which stands perpendicular to the planes of the walls, forms the bottom of the gutter, and is laid with a declivity in the parallel direction of the plane of the wall, of about an inch in 10 feet, and with steps, called *drips*, at every 12 or 18 feet. The drips are formed in planes perpendicular to the horizon and to the walls, rising about two, or two inches and a half, so as to add to the descent of the gutters, and at such distances from each other as are equal to the length of the sheets. Gutters are laid with lead of such weight, that the superficial foot contains from seven to twelve pounds, according to the stress that is supposed to be on the surface. The sheets are laid from 12 to 18 feet in length, as the descent for the water may permit. When there is a sufficient current for the water, shorter sheets of 12 feet in length are to be recommended in preference to longer ones, on account of the latter sometimes cracking by expansion, as all metals are liable to do. Cast lead is preferable to milled lead, as being more solid in its texture, and on this account is more to be depended upon when it expands, so as to keep from tearing asunder; but milled lead is equally thick throughout, and has its surface regularly smooth, properties which are not to be found in cast lead; therefore, wherever beauty and neatness of workmanship are required, milled lead must be employed. The goodness of cast lead depends upon the equality of its thickness, which cannot at all times be depended upon; and it should be observed, that plumbers themselves are divided in their opinion whether cast or milled lead ought to have the preference.

In London, parapet walls and leaden gutters are indispensable on account of the Building Act, as the numerous inhabitants are less liable to accidents from the falling of broken slates or tiles; and in cases of fire in the lower part of the building, they are convenient for making an escape from the danger, and also for assisting in extinguishing the flames. Several attempts have been made to substitute copper, but this material has not been found to have the desired effect, though zinc has been extensively used of late years instead of lead. The water is conveyed from the gutters by leaden pipes. In the country, dripping eaves are much used, and are to be preferred in elevated situations, as in the winter season the gutters and pipes are frequently stopped by snow or frost, so as to bring down the ceilings and plastering, injure the walls, and rot the timber; and thus not only render the building unfit for living in, but reduce it to ruin in the course of a few years. On this account, many of the first-rate houses suffer much by the overflowing of the water, unless the gutters are so constructed, that the water may escape before it finds its way into the building. Gutters should never be soldered where it can be avoided, particularly when the soldering would make the sheets of unusual length, as in this case it would be impossible to ensure it from cracking; the expenses of repairing would be frequent, and the ultimate effect ruinous. The thickest lead is used in gutters and flats, each generally of the same weight, while the hips and ridges are from five to six pounds to the foot, and most generally of milled lead.

The following are the regulations in the Metropolitan Building Act relating to parapets and gutters. "If an external wall adjoin a gutter, then such external wall must be carried up, and remain one foot at the least above the highest part of such gutter. And the thickness of an external wall so carried up above the level of the under side of the gutter-plate, and forming a parapet, must be at the least.

"In every such wall of the extra first-rate of the first class, and in every such wall of the first-rate of the second class, 13 inches thick; and

"In every other external wall, of whatever rate, or whichever class, 8½ inches thick."

GUTTERING. *See* GUTTER.

GUTTUS (Latin) a term among antiquaries for a sort of vase, used in the Roman sacrifices, to receive the wine and sprinkle it *guttalim*, drop by drop, upon the victim.

Vigenere on T. Livy, gives the figures of the guttus as represented on divers medals and other ancient monuments.

GYMNASIUM, a place fitted for performing exercises of the body.

The word is *γυμνασιον*, formed of *γυμνος*, *naked;* because they anciently put off their clothes, to practise with the more freedom.

Among the ancients, the gymnasium was a public edifice destined for exercise, and where people were taught, and regularly disciplined, under proper masters.

According to Solon, in Lucian's *Anacharsis*, and Cicero, *De Orat.* lib. ii. the Greeks were the first who had gymnasia; and among the Greeks, the Lacedæmonians; after them the Athenians, from whom the Romans borrowed them.

There were three principal gymnasia at Athens: the Academy, where Plato taught; the Lyceum, famed for Aristotle's lectures; and the Cynosargus, allotted to the populace.

Vitruvius describes the structure and form of the ancient gymnasia, lib. v. cap. 2. They were called *gymnasia*, because the champions performed *naked;* and *palæstræ*, from wrestling; which was one of the most usual exercises there: the Romans sometimes also called them *Thermæ*, because the baths and bagnios made a principal part of the building.

It appears, that so early as the time of Homer, they did not perform their exercises quite naked, but always in drawers; these they did not lay aside before the thirty-second Olympiad. One Orsippus is said to have been the first who introduced the practice: for having been worsted, by means of his drawers undoing and entangling him, he threw them quite aside, and the rest afterwards imitated him.

The gymnasia consisted of seven members, or apartments. M. Burette, after Vitruvius, recites no less than twelve. viz. 1. The exterior *portico*, where the philosophers, rhetoricians, mathematicians, physicians, and other virtuosi, read public lectures, and where they also disputed, and rehearsed their performances. 2. The *ephebeum*, where the youth assembled very early, to learn their exercises in private, without any spectators. 3. The *coryceum*, *apodyterion*, or *gymnasterion*, a kind of wardrobe, where they stripped, either to bathe or exercise. 4. The *elæothesium*, *alipterion*, or *unctuarium*, appointed for the unctions, which either preceded or followed the use of the bath, wrestling, pancratia, &c. 5. The *conisterium*, or *conistra*, in which they covered themselves with sand, or dust, to dry up the oil, or sweat. 6. The *palæstra*, properly so called, where they practised wrestling, the pugillate, pancratia, and divers other exercises. 7. The *sphæristerium*, or tennis-court, reserved for exercises wherein they used balls. 8. Large unpaved alleys, which comprehended the space between the porticos and the walls wherewith the edifice was surrounded. 9. The *xysti*, which were porticos for the wrestlers in winter, or bad weather. 10. Other *xysti*, or open alleys, allotted for summer and fine weather, some of which were quite open, and others planted with trees. 11. The baths, consisting of several different apartments. 12. The *stadium*, a large space of a semicircular form, covered with sand, and surrounded with seats for the spectators. For the administration of the gymnasia, there were divers officers: the principal were, 1. The *gymnasiarch*, who was the director and superintendent of the whole. 2. The *xystarch*, who presided in the xystus or stadium. 3. The *gymnasta*, or master of the exercises, who understood their different effects, and could accommodate them to the different complexions of the athletæ. 4. The *pædotriba*, whose business was mechanically to teach the exercises, without understanding their theory or use. Under these four officers were a number of subalterns, whose names distinguished their different functions.

As to the kinds of exercises practised in the gymnasia, they may be reduced to two general classes, as they depend either on the action of the body alone, or as they require external agents or instruments. The former are chiefly of two kinds, *orchestice* and *palæstrice.*

The *orchestice* comprehended, 1. *Dancing*, 2. *Cubistice*, or the art of tumbling. 3. *Sphæristice*, or tennis, including all the exercises with pilæ, or balls.

The *palæstrice* comprised all exercises under the denomination of *palæstra;* as *wrestling*, *boxing*, *pancratia hoplomachia*, *running*, *leaping*, *throwing the discus*, the *exercise of the javelin*, and that of the *hoop*, denominated by the Greeks τροχος, which consisted in rolling an iron hoop five or six feet in diameter, beset with iron rings, the noise of which apprising the people to give way, afforded them also an amusement. Both strength and skill were requisite in directing this hoop, which was to be driven with an iron rod.

To these must also be added the exercises belonging to the medicinal gymnastics, as 1. *Walking.* 2. *Vociferation*, or shouting. 3. *Holding one's breath.*

The bodily exercises, which depended on external agents, may be reduced to *mounting* the horse; *riding* in a chaise, or other wheeled vehicle; *rocking* in beds or cradles, and sometimes *swinging:* to which may be added, the art of *swimming.* Hoffman enumerates no less than fifty-five sorts of gymnastic exercises.

The term *gymnasium* has descended to modern times. In Germany, the higher schools, intended especially as immediately preparatory to the universities, are termed gymnasia. Schools for the improvement of bodily strength, grace, or agility, are also called gymnasia. Within the last few years small portions of the newly-formed parks in the neighbourhood of London have been set aside for this purpose, and provided with the proper appurtenances for gymnastic exercises. To these the ancient word gymnasium is still applied.

GYNÆCEUM, (from the Greek γυνη, *a woman*, and οικος, *a house*,) among the ancients, the apartment of the women; or a separate place, in the inner part of the house, where the women kept themselves retired, employed in their spinning, out of the sight of the men.

Under the Roman emperors there was a particular establishment of gynæcea, being a kind of manufactories managed chiefly by women, for the making of clothes, furniture, &c., for the emperor's household. Mention is made of these gynæcea, in the Theodosian and Justinian code, and by divers other authors.

In imitation of these, divers of the modern manufactories, particularly those of silk, where a number of women and maids are associated and formed into a body, are called *gynæcea.*

GYPSOGRAPHY, a new method of engraving on plaster, to which this term has been given by the inventors. Gypsography, or metallic relief-engraving, is performed in the following manner. The surface of a copper-plate is prepared with a thin coating, or layer of plaster-of-paris, of uniform depth, through which the draughtsman etches with a point to the surface of the copper: he is enabled, as he proceeds, to observe the effect of every touch of the etching point. When the drawing or etching is completed, it forms a complete matrix or mould, and is cast in type-metal, in a similar manner to the process of stereotype-casting, and at once forms a block or plate, which must in every minute feature produce a perfect fac-simile of the original design of the artist, and from which, at the type-press or steam-machine, thousands of impressions can be worked in a few hours.

GYPSUM, a substance formed by the combination of sulphuric acid with calcareous earth.

Gypsum is found in a compact and crystallized state, as alabaster and selenite, or in the form of a soft chalky stone which in a very moderate heat gives out its water of crystallization, and becomes a very fine white powder, extensively used under the name of plaster-of-paris. This last is the most common, and is found in great masses near Paris, where it forms the hill Montmartre, near Aix in Provence, and near Burgos in Spain. It is found in smaller portions in various parts of Europe.

Of the different kinds of plaster the coarser sorts are employed, with the admixture of common lime-stone, for cements. The gypsum, which naturally contains carbonate of lime, makes very good cement; but that which has an admixture of clay and sand, affords a cement of an inferior quality.

The kilns in which the plaster-stones are burnt, are generally of a very simple construction; often they are built of gypsum itself. The fragments to be calcined are loosely put together, in such a manner as to form a parallelopiped heap, below which are vaulted pipes or flues, for the application of a moderate heat. The calcination must not be carried to excess, since in this case the plaster will be deprived of its quality of forming a solid mass when mixed with a certain portion of water. During the process of calcination, the water of crystallization rises as a white vapour, which, if the atmosphere be dry, is quickly dissolved in air.

On the river Wolga, in Russia, the burning of gypsum constitutes one of the chief occupations of the peasantry. They calcine all kinds of gypsum promiscuously, on grates made of wood, they then reduce the plaster to powder, pass it through a sieve, and form it into small round cakes, which they sell at from one, to one and a half rouble, per thousand.

In order to make use of the plaster, water is added to the powder, which is produced by pounding the calcined fragments; an operation performed either in mills constructed for the purpose, or by the hands of men. This work is exceedingly prejudicial to the persons employed in it, whose health is soon impaired by the pernicious effects which the dust of this substance has upon the lungs.

The less the gypsum intended for plaster is mixed with other substances, the better it is qualified for the purpose of making casts, stucco, &c.; the sparry gypsum, or selenite, which of course is the purest of all, is employed for taking impressions from coins and medals; and for those beautiful imitations of marble, granite, and porphyry, that are known by the name of *scagliola*, derived from the Italian word, *scagli*, or laminæ of selenite; the latter is vulgarly called *talc* in Italy and France, and also in England.

The *compact gypsum* of Kirwan (*alabastrite*, La Meth.; *albâtre gypseux*, de Lisle; *dichter gypstein*, Werner) when of a white, or yellowish, or greenish colour, semi-transparent, and capable of receiving a polish, is known among statuaries by the name of *alabaster*, which term is also retained as a secondary appellation in most books of mineralogy, and is certainly the *alabastrites* of Pliny, which is characterized by that author as a stone resembling gypsum. When its colours are disposed in bands or clouds, it is called, in the first case, *onyx alabaster*, and in the latter, *agate alabaster*. It not unfrequently contains a sufficient portion of carbonated lime to produce a brisk effervescence with nitrous acid; and hence has originated the confusion of authors, who make the circumstance of effervescence an essential distinctive character between the gypseous and calcareous alabasters. Its specific gravity seldom exceeds 1.9. Its fracture is compact, splintery, sometimes verging on the fine-grained foliated. In transparency, it is considerably superior to white wax, allowing light to pass readily through it, but not transmitting the forms of objects.

Gypseous alabaster is very easily worked, but it is not susceptible of a polish equal to marble. It is made into vases, columns, tables, and other ornamental articles of furniture; thin slabs of it have been used in one of the churches of Florence instead of window-glass. Its brittleness, however, and want of lustre, have caused it to be almost wholly superseded by more durable materials. Among the ancients, the most esteemed came from Caramania, Upper Egypt, and Syria: of the variety called *onyx*, the boxes for holding perfumes were mostly fabricated; thus, in Horace, we meet with "*Nardi parvus onyx.*"

The *calcareous alabaster*, or sinter, (*albâtre calcaire*,) is a stone of the same family as stalactite, consisting chiefly of carbonate of lime, and exhibiting a considerable variety of colours; such as pure white, yellowish, greenish, reddish, and bluish gray: its fracture is striated or fibrous, the striæ sometimes parallel and sometimes divergent: its hardness is somewhat inferior to that of marble, which nevertheless does not prevent it from receiving a good polish: its specific gravity from 2.4 to 2.8: its transparency is nearly equal to that of white wax: it effervesces with acids, and burns to lime. Two sorts of alabaster are distinguished by statuaries, the *common* and *oriental;* under the latter of these are ranked the hardest, the finest, and the best coloured pieces; a number of sub-varieties are also produced by the colours being in veins, or dentritic, or in concentric undulating zones. Italy and Spain yield the most beautiful specimens: the inferior kinds are found in Germany and France. It is manufactured, like the gypseous alabaster, into tables, vases, statues, chimney-pieces, &c.

Many of the hot sulphureous waters rise out of the ground of a turbid wheyish colour, on account of a large quantity of gypsum and chalk, which they hold suspended, and in a state of half solution; as these grow cool, and lose their carbonic acid, the earthy particles are for the most part deposited, lining the bottom and sides of the channels in which they flow with a compact alabaster. Advantage has been occasionally taken of this circumstance to obtain very beautiful impressions of bas-reliefs, by exposing the moulds to a current of such water till they have become filled with the earthy deposit. The most remarkable of these springs in Europe, is that which supplies the baths of St. Philip in Tuscany: it is situated on a mountain near Radicofani, and forms the source of the little river Paglia. The water as it issues forth is very hot, springs out with great impetuosity, has a strong sulphureous odour, and holds in solution a large quantity of calcareous matter. From its very source it flows in deep channels, covered with a thick crust of stalactite, of a dazzling white, especially when the sun shines upon it; and which is harder or softer in proportion to the rapidity of the stream, and the obliquity of its fall. This circumstance suggested to Dr. Vegni, the idea of establishing on this mountain, a manufacture of artificial alabaster. For this purpose, he first collected a number of plaster-models, of the best bas-reliefs, in Rome and other places of Italy. These models serve to form the hollow moulds which are made of sulphur, according to the following process. The plaster model is rubbed over with boiled linseed oil, and surrounded with an edging of plaster, of the same height as the intended thickness of the subsequent bas-relief. Then sulphur, melted with just sufficient heat to make it flow, is poured on the plaster-model, and fills it to the height of the edging. The sulphur mould thus made, is placed in a kind of wooden tub, roughly put together, open at top and bottom, and of less diameter below than above. This tub has on the inside a false bottom, made of slips of wood laid cross-wise, in order to detain, for a short time, the water which dashes on them. Just above this is a row of wooden pegs, fastened to the tub, around its whole inner circumference, on which the sulphur mould is let down, and thus supported. The whole is then placed under the boiling spring, and inclosed with walls, to prevent it from being displaced by the wind. The water, which dashing on the moulds, deposits its earth both within and without them, giving the impression of bas-relief within, and disposing itself in an undulated surface on the outside. The hardness of the alabaster depends on the degree of obliquity at which the mould is placed in order to receive the dashing of the water. The more vertical its position, the harder is the alabaster. However, as the hardest models are not so white as the softer, the water is in some cases caused to make a circuitous course, in order to deposit all its grosser particles before it arrives at the mould. Even the softer ones, however, are as hard as Carrara marble, and surpass it in whiteness. The time required for these productions varies, according to the thickness, from one month to four. When the sulphur mould is sufficiently filled, and the ground of the model has acquired a thickness capable of supporting the figures, the whole is removed from the water; the wooden supports are broken by gentle strokes of the hammer, and the incrustation on the outside of the mould is chipped off by repeated strokes. Then the tub is struck with a smart blow of a hammer, which separates the model from the mould; generally, however, cracking the latter. The brilliancy of the models is completed by brushing them with a stiff hair-brush, and rubbing with the palm of the hand.

The composition of this alabaster is gypsum, mixed with a small proportion of carbonated lime. Dr. Vegni, after many attempts, succeeded in giving a fine black, or flesh colour, to the figures thus formed, by putting a vessel half full of colouring matter into the water, before it arrives at the mould. The colouring may be also varied, by protecting particular parts of the mould, while the water continues charged with colouring matter.

A spring of the same kind as that just described, and applied to similar purposes, is that of Guancavelica in Peru. The water rises from the ground into a large bason, boiling hot, and of a muddy yellowish-white colour. At a little distance from the bason, the water becoming cool, deposits calcareous matter in such vast abundance, as to fill large moulds with a compact stone, of which some of the houses of the town are constructed. The moulds of statuaries, in like manner, being exposed to the water, are filled with hard, confusedly crystallized alabaster, and the bas-reliefs thus produced, by polishing, become semi-transparent, and very beautiful. The images made use of by the Catholics of Lima, in their religious ceremonies, are said to be formed in this manner

Gypsum, pulverized by grinding or burning, has been used as a manure in France and America; and its fertilizing properties highly extolled. The use of it in this country, however, does not seem to have been attended with similar successful results.

H.

HACKING, in walling, the interruption of a course of stone, by introducing another course upon a different level, in consequence of the want of stones to complete the whole thickness; and thus frequently making two courses at one end of the wall or pier, of the same height with one course at the other end. The last stone laid in one height is frequently notched, to receive the first stone of the other, where the two heights commence. Hacking is never employed in good workmanship, and ought always to be guarded against by the superintendent, in case of work performed by contract where the contractor furnishes the stones. The term is used in Scotland, and particularly in Glasgow.

HALF-MOON, in fortification, the same as RASELIN; which see.

HALF ROUND, a semicircular moulding, which may be either a *bead* or *torus*.

HALF SPACE, or PACE, as it is sometimes called, a resting place in a double parallel-flighted stair, where the higher riser of the lower flight is in the same vertical plane with the lowest riser of the higher flight. Also any raised platform such as the dais at the upper end of the halls of the middle ages.

HALF-TEINT, now more generally written Half-Tint, in painting, is, precisely speaking, the teint which lies exactly midway between the extreme light and the extreme dark which any colour is capable of receiving and reflecting. But painters use it in a far more general sense, viz., as inclusive of almost all the intermediate gradations between these two points; and therefore regard all objects, in what relates to colour and chiaro-oscuro, as composed of these three—*light*, *dark*, and *middle-tint*, or *half-tint*.

How much of the vision of objects is included within the sphere of half-tint, may be illustrated by imagining a ball of ivory placed opposite the sun, and viewed in nearly the same direction. In this situation, a small portion of it will reflect an image of the sun to the eye of the observer, which image, in the language of artists, will be termed its *high-light*. Towards its lower part a very small portion will be lost in shade. The far greater part of the ball, not reflecting light enough to come under the former of these denominations, nor being sufficiently deprived of it to receive the latter, is recognized under the term we are now discussing.

When pictures therefore represent the ordinary effect of day-light, where the illumination produces breadth of light, as the sun does, and still more in that kind of light produced by an illumined atmosphere when the sun is not clearly seen, it is evident that half-tint must be the reigning portion of tone and colour in them. Add to this that as objects recede in the plane of the picture from the source of light, they fall into comparative half-tint, their high-lights and shadows participating of the hue with which the intervening atmosphere envelopes them. From both these causes it may fairly be reckoned that nine-tenths at least, and a greater proportion occasionally, in subjects of this nature, will be half-tint, unless artificial shadows are introduced.

This being the case, too much attention cannot be given to the management of the half-tint, as it produces the prevailing tone of colour in the picture. The difficulty lies in giving each colour introduced a gradation participating of the same hue, but at the same time preserving the true characters of the original colours in the whole. The reason of blending this one hue with all colours is made evident by considering the mode of operation adopted by nature, in which all gradations of shade are the effect of privation of light, and consequently of colour, which depends upon it, till at last every colour is lost in one dark hue, by the total lack of illumination; and that hue is alike with all. It is that hue, therefore, in different degrees, which produces the gradation from extreme light to dark, and which, acting equally on all, produces harmony in the effects by breaking each with a participation of itself.

This is the simplest mode of producing the half-tint, and maintaining it with an harmonious effect throughout the various parts of a picture. It will of course allow of intermixtures of reflections, either from parts of the same body, as in the folds of draperies, or from different coloured objects acting upon each other; and thus with its simplicity, richness and variety may be combined. What the hue of the dark shade with which it is produced, may be, depends entirely upon the taste of the painter, and the nature of the illumination. One only rule can be given. It ought, in its mixture with the light, or local colour, to produce a tint more cool than that in its hue.

HALF-TIMBERED HOUSES, such as were in use during the reign of Elizabeth, and the period immediately preceding. They consisted of wooden framing, filled in with plaster, and had a very picturesque appearance.

HALL, (Saxon) a word anciently used for a mansion-house or habitation.

HALL, (French, *salle*) in architecture, a large room at the entrance of a fine house, palace, or the like.

Vitruvius mentions three sorts of halls: the *tetrastyle* which has four columns supporting the plafond or ceiling; the *Corinthian*, which has columns all round, let into the wall, and is vaulted over; and the *Egyptian*, which had a peristyle of insulated Corinthian columns, bearing a second order with a ceiling: these are called *œci*. The hall is properly the first and finest partition or member of an apartment; and in houses of ministers of state, public magistrates, &c., is that wherein they dispatch business, and give audience. In very magnificent buildings, where the hall is larger and loftier than ordinary, and placed in the middle of the house, it is called a *saloon*.

The length of the hall should be at least twice and a quarter its breadth; and in great buildings three times its breadth. As to the height, it may be two-thirds of the breadth; and if made with an arched ceiling, it will be rendered much handsomer, and less subject to accidents from fire. In this case, its height is found by dividing its breadth into six parts, five of which will be the height from the floor to the under side of the key of the arch.

A royal apartment is said to consist of a hall, or chamber, of guards, *aula prætoriana;* an ante-chamber, *procamera;* a chamber, *camera;* a cabinet, *conclave;* and a gallery, *porticus.*

Hall, also the principal apartment in the castles and mansions of the middle ages. These were usually of great length and size, having the chief entrance at one end, where was a screen surmounted with a minstrel's gallery. At the farther end was a raised platform or dais, with frequently an oriel window on one or both sides, where the principal guests dined. The fire-place was sometimes in the middle of the hall, with an aperture in the roof for the escape of the smoke; but at others at the side, with a chimney carried up in the walls. The aperture in the roof was often covered by an open lantern.

Amongst the larger halls in England, may be reckoned those of Westminster, and Crosby Hall, London; Eltham, and Penshurst, Kent; and that of Hampton-Court.

Hall, a public building erected for the administration of the police and justice of a city or corporation.

In this sense we say the *town-hall*, a *company's hall*, &c.

A stately building in the city of London, and the great court of judicature for that city, is called *Guild-hall;* and many of the City companies have very fine buildings, called their Halls, as the Goldsmiths' Hall, Fishmongers' Hall, &c.

Hall is also particularly used for a court of justice; or an edifice wherein there is one or more tribunals.

In Westminster-hall are held the great courts of this kingdom, viz., the Chancery, Exchequer, Queen's Bench, and Common-Pleas.

In adjoining apartments is likewise held the high court of parliament. Westminster-hall was the royal palace, or place of residence, of our ancient kings; who ordinarily held their parliaments and courts of judicature in their dwelling-houses, and frequently sat in person in the courts of judicature, as they still do in parliament.

The great hall, wherein the courts of Queen's Bench, &c. are kept, is said to have been built by William Rufus; others say by Richard I. or II. It is reckoned superior, in point of dimensions, to any hall in Europe; being 238 feet long, and 68 broad.

HALVING, a method of joining timbers by letting them into each other: it is preferable to mortising, even where the timbers do not pass each other, as they are less liable to be displaced by shrinking.

HAM, a Saxon word, signifying a house.

Ham, is also used to denote a street or village; whence it is, that the names of many of our towns end in *ham*, as Nottingham, Buckingham, &c.

HAMMER, an instrument used by carpenters, for driving nails, spikes, &c.; and by masons, for reducing stone, by breaking it in chips.

HAMMER-BEAM, a transverse beam at the foot of the rafter, in the usual place of a tie. Hammer-beams are constructed in pairs, having each a beam disposed on opposite sides of the roof. They are chiefly used in roofs constructed after the Gothic style; the end which hangs over, being frequently supported by a concave rib, springing from the wall as a tangent to the curve, and in its turn supporting another rib forming a Gothic arch with the counter-part. The ends of hammer-beams are decorated with various devices.

HANCES, or Haunches, the arcs of circles forming the ends of arches described with compasses, in imitation of elliptic arches. The figure representing the whole ellipsis is generally described with four circular segments, of which those that are opposite are equal to each other, and are bisected by each extremity of each axis; the two arcs which terminate the greater axis are called the *hances*, and those which terminate the shorter, the *schemes.*

HAND, a measure of four inches.

Hand-Irons. *See* End-Irons.

Hand-Rail, of a stair, a rail raised upon slender posts, called *balusters*, intended to assist persons in ascending and descending, and to protect them from falling down the well-hole.

Hand-Railing, the art of making hand-rails by moulds, according to geometrical principles.

The art of forming hand-rails was never, before the publication of the *Carpenter's Guide*, subjected to any certain geometrical principle. The best method then known, was that of tracing it, like an angle-bracket, from the rise and tread of as many steps as the rail was supposed to occupy in winders, and making the face-mould of a parallel breadth, after obtaining the middle of the concave side. This is manifestly false; and the magnitude of the error will be greater as the circumference of the arc at the plan of the rail is greater than its chord. A rail, or any portion of a rail, formed upon this principle, could never stand vertically over its plan. The method here shown is founded upon the following principles: that if a cylinder be cut in any direction except parallel to the axis or base, the section will be an ellipsis; if cut parallel to the axis, its section is a rectangle; and if parallel to the base, its section is a circle.

Let us suppose a hollow cylinder made to a given plan, the interior will be concave, and the exterior convex; and let this cylinder be cut by any inclined or oblique plane, the section formed will be bounded by two concentric similar ellipses; consequently, the section will be at its greatest bread that each extremity of the greater axis, and at its least breadth at each extremity of the lesser axis. Therefore, in any quarter of the ellipsis, there will be a continued increase of breadth from the extremity of the lesser axis to that of the greater. Now a cylinder can be cut by a plane through any three points; therefore suppose we have the height of the rail at any three points in the cylinder, and cut the cylinder through these points, the section will be a figure equal and similar to the face-mould of the rail; and if the cylinder be cut by another plane, parallel to the section, at such a distance from it as to contain the thickness of the rail, this portion of the cylinder will represent a part of the rail with its vertical surfaces already wrought; and if the back and lower surface of this cylindric portion be squared to vertical lines, either on the convex or concave side, through two certain parallel lines, drawn by a thin piece of wood bent upon that side; the portion of the cylinder thus formed will represent the part of the rail intended to be made.

The principles upon which this art depends are those of cutting a right prism through any three given points in space, and of forming a development of any portion of the surface of the prism.

Thus, let the interior surface of the surrounding wall be that of an entire cylinder, the breadth of the steps divided into the frustums of equal and similar sectors, and the heights all equal, as is universally the case; then, if an interior cylinder surface be erected concentric with the wall, and the ends of the steps or surfaces to be trodden upon, and the planes of the risers tending to the axis be supposed to meet the interior cylindric surface, it is evident that if the portion of the intercepted surface contained between the indented line formed by the ends of the steps, and the circumferent line at the base be developed, or stretched out, all the points of the indented line formed by the outward or salient angles, will be in the same straight line, and all the points formed by the inward or re-entrant angles will be in another straight line. It is equally evident, that this will not only be the case with cylinders, but with cylindroids, and every other description of prisms: that is, the points of the development of the indented line will always have such a position, that two straight lines parallel to each other may be drawn through the whole number of them.

The points of concourse of the salient angles, are called *the nosings of the steps.*

The line drawn through all the nosings of the steps, is called *the line of the nosings.*

Now let the portion of the cylinder before uncovered, be again enveloped, the development in this state becomes an envelope, and the line of nosings becomes a uniform helix, which would be the form of the rail for such a stair.

In this case, it would be easy to execute the rail to any length, in equal portions succeeding each other; for as the curvature of the helical line is everywhere the same, the same moulds which are used in the formation of one piece, would serve for every succeeding piece.

The steps around the circular part are termed *winders;* in these the risers tend to the axis of the cylinder.

Steps with their treads of the same breadth, are termed *flyers;* in these the risers are all parallel.

Very few staircases are entirely circular; but those of the semi-circular form, with winders in the semicircle, and flyers below and above, are very numerous; in such, the line of nosings would be crooked, and would form an angle at the junction of the flyers and the winders, and that round the semicircle would be an helix, consisting of half a revolution.

In the development of the steps, the line of nosings would consist of three straight lines; the two straight lines through the nosings of the flyers, would be parallel to each other, and each extremity of the middle one would join one extremity of each of the other two; but the angles are commonly taken away, by introducing a curve in their places.

A hand-rail, however, is not a mere helical line, but a solid, which may be contained between two concentric cylindric surfaces, or concentric prismatic surfaces. The principles are the same, whatever be the form of the plan. A solid erected upon any plan, is called *a prism;* a cylinder is therefore a round prism, and a cylindroid an elliptic prism. A hand-rail may stand upon a circular base, or partly circular and partly straight, or upon an entire elliptic base. In the construction of hand-rails, all prisms are excluded, which consist of plain surfaces; or, which is the same thing, where the sides of the plan consist entirely of straight lines; as in such cases, the rails themselves are either straight, or partly curved and partly straight upon the top and lower sides only, the sides being in vertical planes.

Let us therefore confine ourselves to prisms upon a circular or an elliptic base, or upon a base partly circular and partly straight; or lastly, upon a base partly elliptical and partly straight. The two last may be said to have compound bases or plans, and the two former simple bases or plans. Such a prism may be denominated *a curved prism.* The plan of any curved prism is understood to be of the same breadth, and consequently the solid erected thereon will be everywhere of the same thickness. The prism may therefore be a hollow cylinder, or a hollow clyindroid, or a concave body, partly cylindric and partly straight; the latter may be open on one side, and may have the four planes which join the curved surfaces parallel to each other, and tangent to each of the cylindric surfaces.

Let us therefore suppose such a prism as that last mentioned, to be cut entirely through its vertical surfaces, in such a manner that any point in the surface of division may coincide with a straight line everywhere perpendicular to the external prismatic surface, then, every such line will be parallel to the plane of its base, and those lines in the cylindrical part of the prism will tend to the axis. Now it is evident, that the cut, or dividing surface, will not be a plane, but will wind or twist between the cylindric surfaces. It is also evident, that the cut may pass through a line drawn in any manner we please, in one of the prismatic surfaces; or, that the development of this line may have any degree of curvature in the whole length, or in any portion of the length, or may even be a straight line. One of these being supposed to be the case, let the upper part of the prism be taken away, then the upper surface of its remaining part will be brought to view; let a line be drawn on the exterior surface parallel to the arris, and another on the concave side parallel to its arris; and let another cut or dividing surface be made to pass through the two lines thus drawn, and let the upper part be removed by this division; then the part thus removed will form a solid helix, or kind of half screw, which may be either uniform in its upper and lower surfaces, or have any degree of curvature in any part that may be required, according to the development before mentioned. This is the form of the rail for such a stair; but to form the solid helix, without cutting it from a hollow curved prism, is what is required in hand-railing.

Now, as two of its sides are actually cylindrical, and would be vertical if placed in position, and the other two winding surfaces may be formed to any development desired; take any determinate portion of the helical solid, as a quarter of a revolution, or perhaps something more, as occasion may require, and endeavour to form such a portion, or wreath, out of a thin plank, instead of cutting it from a solid curved prism. Before this can be done, it is necessary to understand the principle of cutting a prism through any three fixed points in space, by a plane passing through those points; the points may be in the surface of the prism itself, and may be either all in the concave side, or all in the convex side; or partly in the concave side, and partly in the convex side;—that such a supposition is possible will readily appear, since any three points are always in the same plane; and, therefore, the plane may cut the prism through any three given points.

The three points through which the section is cut, are said to be given, when the seats are given on the plane of the base of the prism, which plane is understood to be at right angles to the axis of the prism, and when the distances or heights from the seats to the points themselves are given.

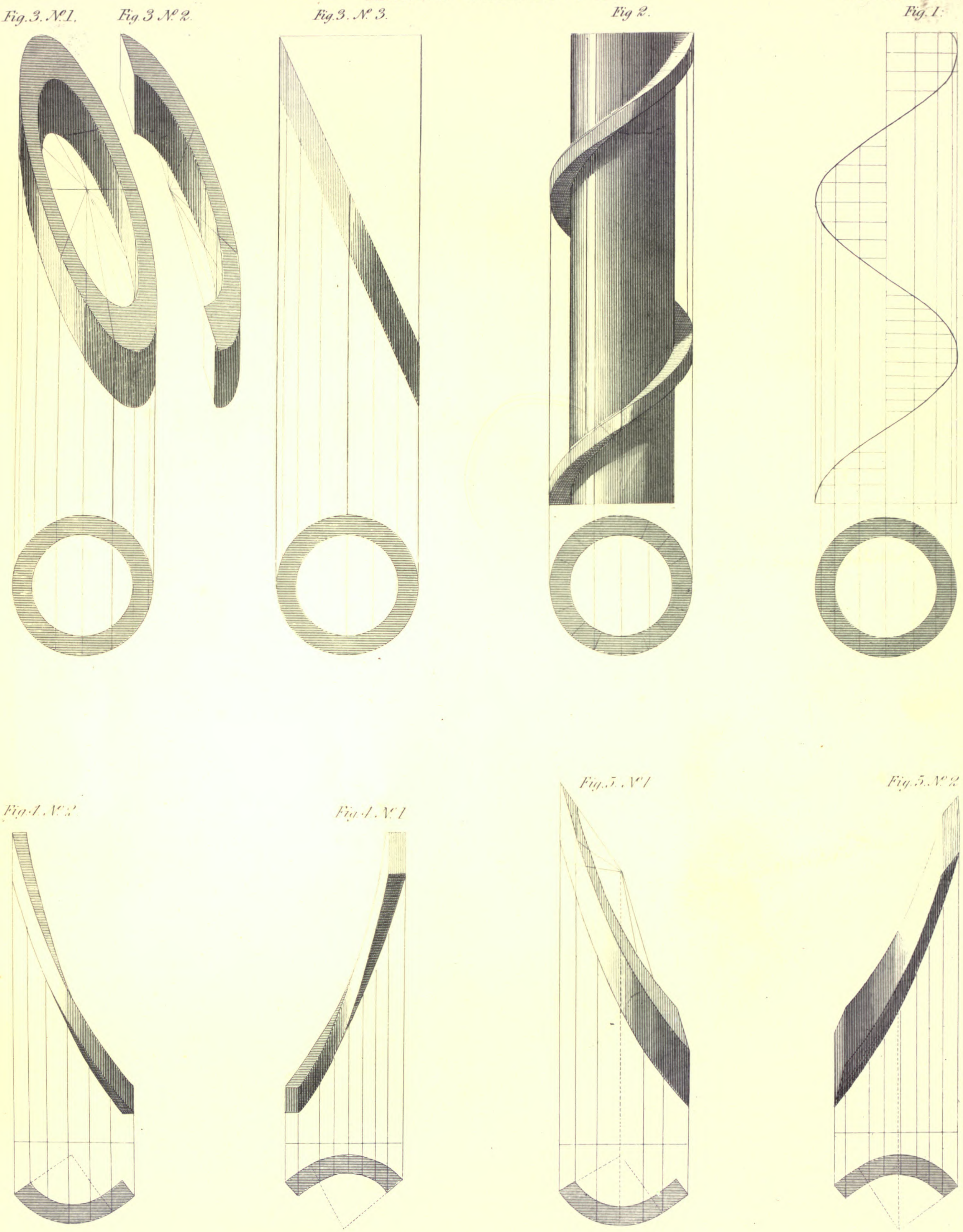
It is always to be understood, that the three seats are not in a straight line, and consequently the three points themselves not a straight line.

The seat of a point in space on any plane, is that point in the plane where a perpendicular drawn through the point in space cuts the plane.

In the helical solid, the winding surface connecting the two prismatic surfaces, has been defined to be of such a property as to coincide with a straight line perpendicular to the exterior prismatic surface, and, consequently, if the axis of the curved prism be perpendicular to the horizon, every such line will be parallel to the base; now, let the seats of three such lines be given on the plan, viz., let each extreme boundary be one, and let another be taken in the convex side passing through the point, which would give the middle of the development of the said side of the plan; the three seats would be terminated by the convex and concave sides of the plan, and will always be perpendicular to the convex side, and equal in length to each other. Call the three level lines,

HAND RAILING.

PLATE. VIII.



A. Nicholson, del.

of which their seats are given, *the lines of support;* let a plane be laid on the three lines of support, and it will rest either upon three points, or upon one of the said lines and two points; hence the points which come in contact with the plane, will be at one extremity of each line of support; let each of the points, which come in contact with the plane thus posited, be called *a resting point.* The three resting points are the three points in space, through which the plane is supposed to pass that cuts the curved prism.

Now because each line of support has two extremities, there will be six extreme points in all, but as only three can be resting points, unless the plane coincides with one of the lines of support, it will be proper to show, which three of the six are the resting points. Let the plane, thus laid upon some three extremities of the lines of support, be continued to intersect the base of the curved prism, then the nearest extremity of the seat of any line of support, to the intersecting line, is the seat of the resting point of that line. For this purpose, let a development of the convex side of the rail be made according to the plan and rise of the steps. The part of this development that is made to bend round the concave or convex cylindric surface of the helical portion or wreath, is called a *falling-mould,* which is supposed to be brought to an equal breadth throughout its length. Only one falling-mould is used in the construction of hand rails. Let therefore the falling-mould for the convex side be constructed, and let two straight lines be drawn from the ends of the upper edge of that part of the falling-mould corresponding to the ends of the wreath perpendicular to the base of the whole development; also let another intermediate line be drawn parallel to the other two, so as to bisect the part of the base intercepted by the said two parallels, the three parallels will give us the heights of the three resting points, the shortest height is at one extreme, and the longest at the other. Suppose now the shortest of these three heights taken from each of the three, and the remainders taken as heights, instead of the whole, then the height of the first resting point will be nothing and will therefore coincide with its seat; and if the middle height be less than half the length of the remaining height, the seats of the resting points will be the first and second extremities of the first and second lines of support taken on the convex side, and the extremity of the third on the concave side. The first resting point is a point in the intersection of the plane of the base with the inclined plane.

The process is now completely reduced to that of finding the section of a prism through three given points, which suppose to be done, and the plane of section will touch the supposed wreath at the resting points of each line of support without cutting the wreath at any such line; then the three lines of support will be on the same side of the plane, viz., on the under side. Suppose now another section taken below, and parallel to the former, so that the wreath may be just contained between these parallel sections or planes, and the distance between the two sections will represent the thickness of the plank. The section of the prism through its vertical surfaces is called *the rake* or *the rake of the plan;* and a mould being cut to the rake is called *the face-mould.*

The manner of forming a helical line or screw is as follows:—

Plate VIII. *Figure* 1. Divide the circumference of the outer circle of the base into equal parts; draw a line through the centre to represent the axis of the cylinder, parallel to the axis, and through the points of division in the outer circumference draw lines; divide the line of heights or the line representing the axis, into as many equal parts as the circumference of the base is divided into, and through the points of division draw lines at right angles to the axis, intersecting, as in the figure; through the points of intersection, draw a curve which will represent the helix, or one of the arris lines of the rail.

Figure 2.—The projection of the solid helix coiling round the cylinder; which helix represents the hand-rail before it is moulded.

Figure 3.—No. 1.—A solid section of a cylinder contained between two parallel planes, a part of the side of this solid contained between two planes passing through the axis is the form of a piece from which the rail is made after it is cut out of the plank. No. 2, half the solid section, No. 3, the inclination of the cutting planes.

Such large portions as these, however, are by no means proper to be employed in hand-railing, as the size would necessarily occasion the fibres of the wood to run in a transverse direction to the length of the rail, and consequently weaken it, but they are useful in this place to convey clear ideas of the principle upon which the art is founded.

Figure 5.—No. 1.—The proper form of a part from which a portion of the rail is to be made after it has been cut out of the blank; exhibiting the convex side of the same, and the upper plain surface, which is that of the plank. No. 2. The concave side of the same, with the joints and lower surface of the plank.

Figure 4.—A portion of the rail completely squared with the concave side, the joints, the bottom part of the upper winding surface, and the upper part of the lower winding surface, brought into view. No. 3. The convex side of the same, showing the upper part of the upper surface, and the lower part of the lower surface.

The business of hand-railing is to find the mould for cutting a rail out of planks.

Though hand railing is only treated of here, as connected with cylindrical well-holes: it is equally applicable to rails erected upon any seat whatever.

The mould, which applies to the two faces of the plank, regulated by a line drawn on its edge, so as to be vertical when the plank is elevated to its natural position, is called the *face-mould*; or sometimes the *raking-mould.*

A parallel mould, applied and bent to the side of the rail-piece, for the purpose of drawing the back and lower surface (which are to be so formed that every level straight line, directed to the axis of the well-hole, from every point of the side of the rail formed by the edges of the falling-mould, shall coincide with the surface) is called a *falling-mould.*

When the upper surface of the plank is not at right angles to a vertical plane passing through the chord of the plan, in order to cut the corresponding portion of the rail out of the least thickness of wood, the plank is said to be *sprung.*

A right-angled triangular board, made to the rise and tread of a step, is called the *pitch-board.*

In a stair-case, where there are both winders and flyers, two pitch-boards will be concerned, of different treads, but of the same heights, as the height of the steps must be equal.

The bevel by which the edge of the plank is reduced from the right angle, when the plank is sprung, in order to apply the face-mould, is called *the spring of the plank;* and the edge or narrow side thus reduced, is called the *sprung edge.*

The bevel by which the face-mould is regulated to each side of the plank, is called the *pitch.*

The formation of the upper and lower surface of a rail is called the *falling of the rail.*

The upper surface of the rail is called *the back.*

The first thing in the practice is to spring the plank, then to cut away the superfluous wood, as directed by the draughts formed by the face-mould. This may be cut so very exactly with a saw, by an experienced hand, as to require no further reduction; and when set in its place, the surface on both sides will be vertical in all parts, and in a surface perpendicular to the plan. In order to form the back and lower surface, the falling-mould is applied to one side, which is generally the convex side, in such a manner, that the upper edge of the falling-mould at one end may coincide with the face of the plank, the same in the middle, and to leave so much wood at the other end to be taken away, as not to reduce the plank on the concave side. The piece of wood to be thus formed into the wreath or twist, being agreeable to three given heights. This description is general, in order to comprehend the following construction of the moulds themselves, which when explained, we shall then enter into a more particular detail of their application.

To construct the falling and face-moulds of a rail to a level landing, supposing the plane of the plank to rest upon the middle point of the section, which separates the upper and lower circular parts, and to rest upon the line parallel to, and in the middle of the straight part, so as to have the grain of the wood parallel.

Plate I. *Figure* 1.—The falling-mould of the hand-rail: B C the extension of the semicircular part; B A and C D the treads of the adjoining flyers.

To find the extension of the semicircular part, from the middle point, I, of B C, draw I K L perpendicular to B C; divide the radius I K into four equal parts, and repeat one of these parts from K to L seven times; draw the diameter M N parallel to B C; join L M and L N, and produce each of these lines to B and C; then B C is the rectification of the semi-circumference M I N. Draw B T and D H perpendicular to A D; make B E equal to the height of a step; I O on the straight line I L, one step and a half; C F equal to the height of two steps; and D H equal to the height of three steps; join A E and H F, and through O draw P Q parallel to B C; produce A E and H F to meet P Q at P and Q; then cut off the angles at P and Q by equal touching curves, one at each; then A E O F is the middle of the falling-mould; and as the rail is generally made two inches deep, draw two parallel lines each an inch distant from this central line, and S U & will be the upper edge of the falling-mould, and δ Y J the lower edge.

To find the face-mould of the hand-rail.

Figure 2.—At any convenient place lay down the half plan, *a b c d e f a*, of the hand-rail; *a b c f* being the straight part of the rail, and *c d e f* the plan of the circular part; draw *g e d* parallel to *a f* or *b c*; bisect *d e* at *h*, and draw *h i* perpendicular to *g d*; make *h i* equal to I U, *Figure* 1, and the angle *h i k* equal to the angle G H F; let *h* represent the middle point of the section between the two circular parts; and suppose *n* to represent the resting point in the middle of the section, which separates the straight and circular parts; make B R, *Figure* 1, equal to *c b* or *f a*, *Figure* 2, and draw R S, *Figure* 1, perpendicular to A B, cutting the upper edge of the falling-mould at S; make *h r*, *Figure* 2, equal to B T, *Figure* 1, and draw *r s*, *Figure* 2, parallel to *g d*, cutting *i k* at *s*; make *h m* equal to *r s*, and join *m n*, which is the directing ordinate; from *k* draw *k l* parallel to *m n*, and *k l* is the intersection of the plane of the plank; find the countersection *k t*, as in the SECTIONS OF CYLINDERS, or as in the subsequent part of this Work, under SOLID ANGLES.

To find any point in the curve of the face-mould.—Draw *u v w* parallel to *k l*, cutting *k d* at *u*, and the concave side of the plan at *v*, and the convex side at *w*; draw *u x* parallel to *h i*, cutting *k i* at *x*; draw *x y z* parallel to *k t*; make *x y* equal to *u v*, and *x z* equal to *u w*; then *y* is a point in the concave side of the face-mould, and *z* is a point in the convex side. The pitch-bevel shown by the dark lines, is found by drawing a vertical line to the pitch-line, and the angle formed by these lines is the pitch-bevel.

In this manner as many points may be found as will be necessary to complete the concave and convex sides of the falling-mould; or rule each system of lines at the same line, thus; take as many points in the convex side of the plan as will be found requisite; through all these points draw lines parallel to *k l*, to cut *g d*; from all the points of division in *g d* draw lines parallel to *h i*, cutting *k i*; through all the points of division in *k i* draw lines parallel to *k t*; terminate each line from the point of intersection equal to the corresponding outer and inner ordinates of the plan, and through the points found by its concave side draw a line; also through the points found by the convex side of the plan draw another curve: then the corresponding points found for each extremity of the plan will complete the face-mould. It is evident that the parts 3-4, 5-6 of the face-mould corresponding to *a b*, *c f* on the plan, is a parallelogram, therefore if the point 6, where the concave side and the straight parts meet, and the point 5, where the convex and straight parts meet, are found and joined by the line 5-6; and if 5-4 and 6-3 be drawn parallel to *k i*, and the point *q* corresponding to *o*, be found, by drawing 4-3 through *q*, the straight part of the face-mould will be completed.

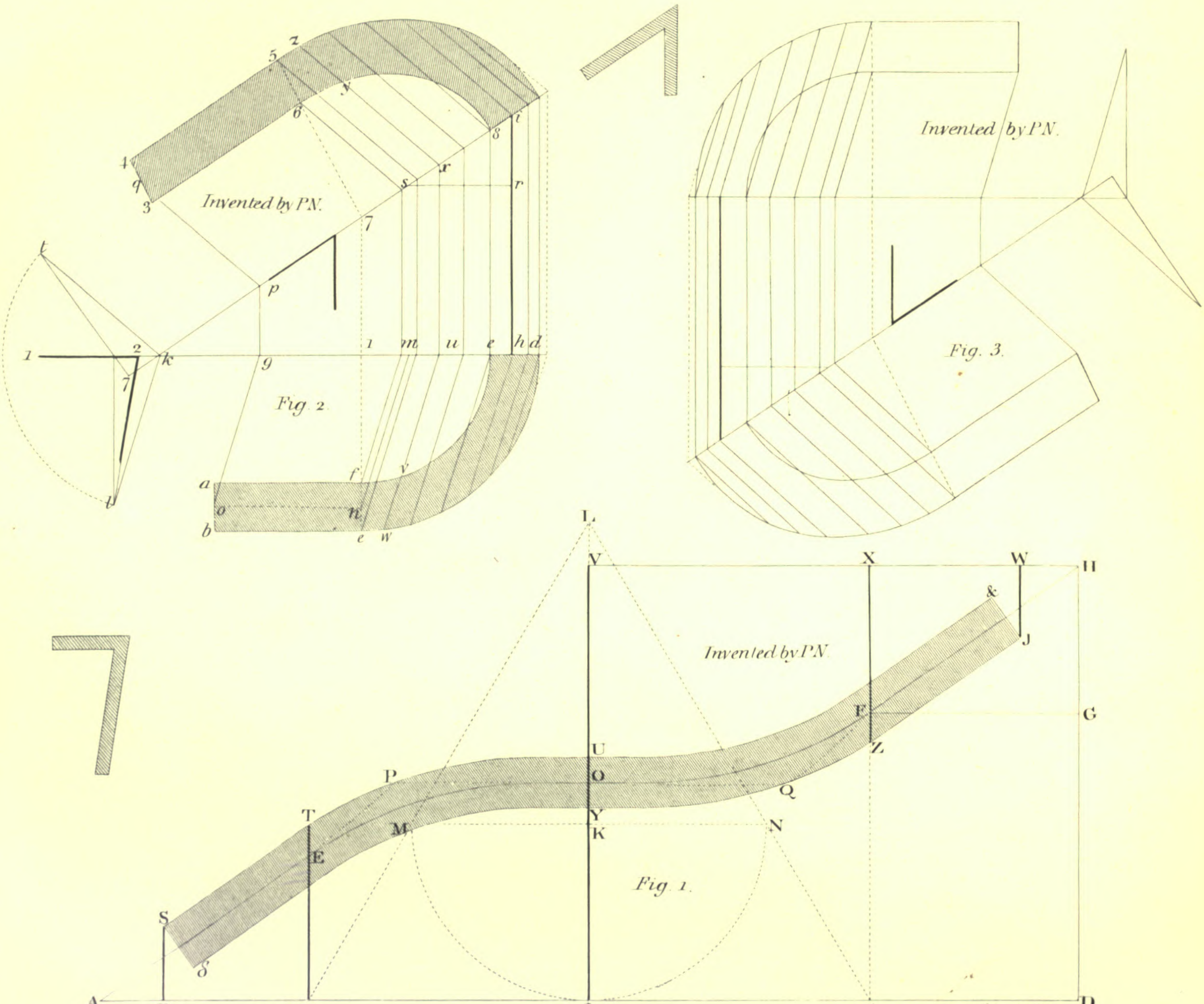
The line of separation 5-6 will be more exactly determined as follows: Through *n* draw *n* 7 parallel to *h i*, cutting *k i* at 7; then find only one of the points 5 or 6, say 5; draw 5-7; then 5-6, which is a part of 5-7, is the line of separation.

This face-mould will answer for the upper, as well as the lower half.

The angle *l* 2-1 is the spring of the plank, and is found in the same manner as in solid angles, and having the intersection and cointersection, the face-mould is found as in the sections of a cylinder. The face-mould might have been found as in *Figure* 3, by taking the heights from a line drawn over the face-mould parallel to A D, *Figure* 1, and laying the plan upwards, as in *Figure* 3, then proceeding with the operation downwards, as directed in *Figure* 2 upwards. Or, if the drawing is inverted, the line V H, *Figure* 1, will become the base of the heights, and everything else will be in the same position as in *Figure* 2.

In the application of the moulds, imagine the plank set up to the pitch, and in the same way spring the edge from the under side for the lower piece, and from the upper side for the upper piece. To apply the moulds to the plank, now supposed to be sprung or beveled, take the pitch and draw the vertical line, the stock of the bevel being applied to the acute edge of the plank, upwards or downwards, as the case may require: then draw a line equal to the distance of 3-6 from *k i*, upon each plane of the plank parallel to the side; then the point 8 being kept to the end of the vertical line, and the side 3-6 upon the parallel line, draw round all the edges of the mould; turn the mould to the other side, apply the point 8 to the other end of the vertical line, and the part 3-6 upon the line drawn parallel to the face, and draw round all the edges as before; then cut away the superfluous stuff. The sides of the piece intended to form the twist must be perfectly cylindrical, and all the parts so formed, that a straight line or edge may apply to any point, at the same time that it coincides with the surface, and is parallel to the vertical line drawn on the edge of the plank.

The falling-mould is thus applied: Draw a line upon the ends of the solid piece, at right angles to the vertical sides, from *zero* at each end, next to the upper side; then apply the upper edge of the face-mould next to the top of the plank, and each end to the corresponding end of the piece, bending it so that all parts may be in contact with the stuff; then



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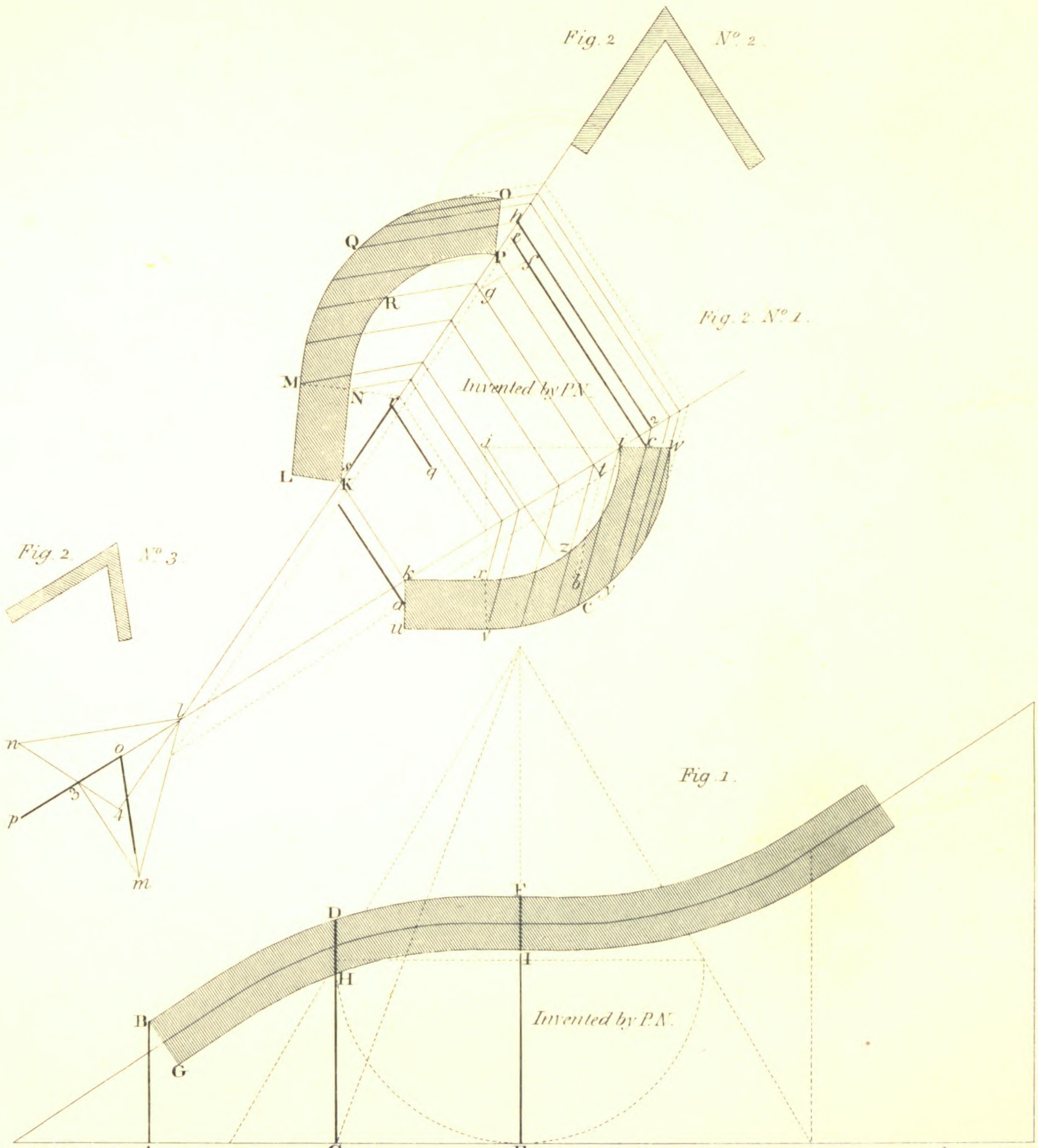

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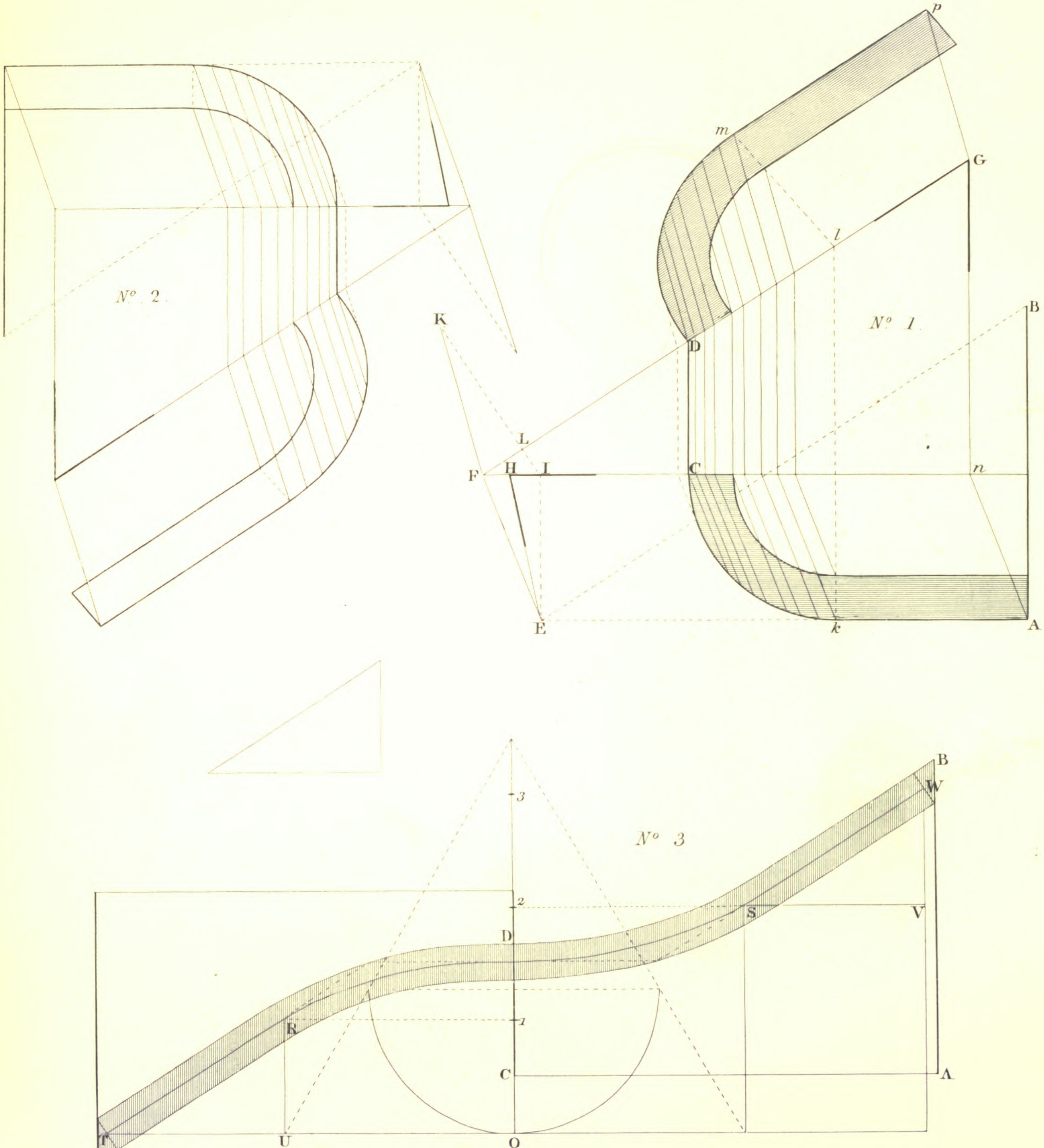

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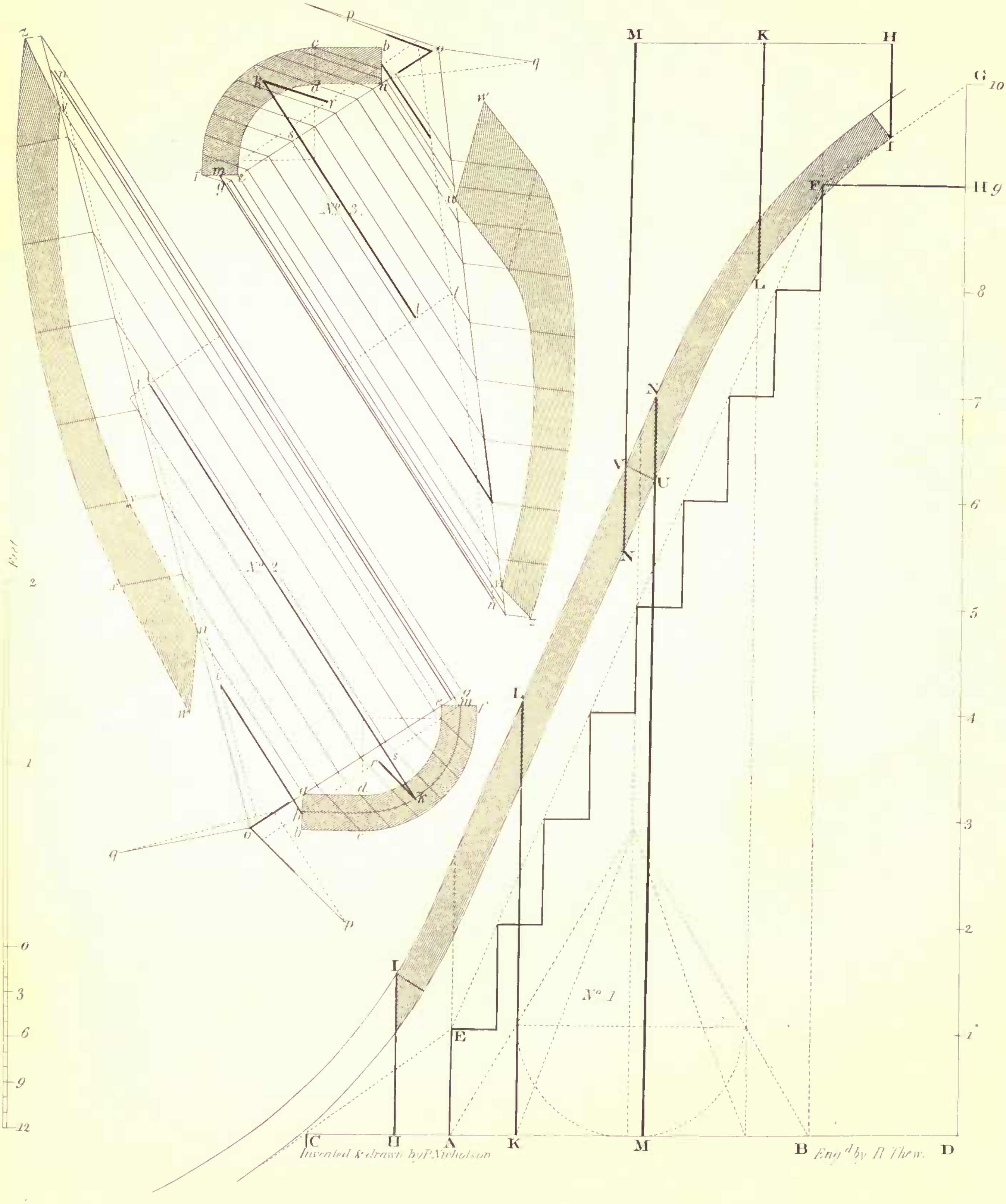

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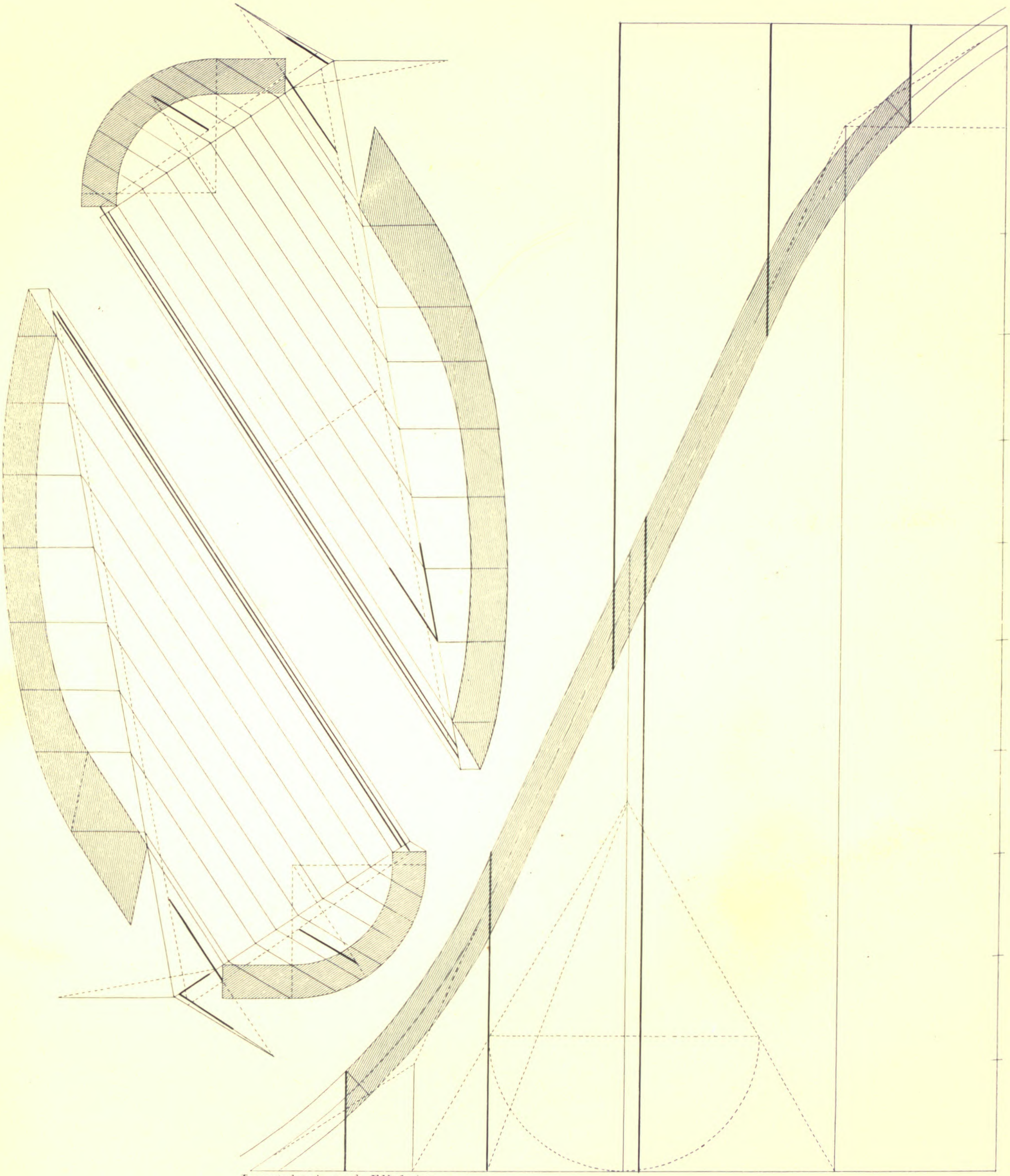

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draw a line round all the edges, and it will show the superfluous wood to be cut off.

To construct the face-mould of a hand-rail to a stair upon a level landing, in two parts, round a semicircular newel; so that when the two pieces are united or fixed in their places, the grain or fibres of the wood will mitre at the joint.

Plate II.—Let *Figure* 1 be the rail stretched out, as in the preceding example: draw the chord of the rail, *i k*, *Figure* 2, No. 1; bisect the end *k u* at *a*, and the other end *i w* at *c*; draw *j z b c* perpendicular to the chord *k i*, cutting the concave and convex sides at *z* and C; make *z b* equal to *i c*, and E C, *Figure* 1, equal to *w* C, *Figure* 2, No. 1, extended: draw C D, *Figure* 1, perpendicular to A E, cutting the upper edge of the falling-mould at D, and the lower edge at H. In *Figure* 2, No. 1, draw *a d* perpendicular to *k i*, and *c e* parallel to *a d*; make *a d* equal to A B, *Figure* 1; *c e*, *Figure* 2, No. 1, equal to E F, *Figure* 1; and *c f*, *Figure* 2, No. 1, equal to C D, *Figure* 1; join *a c* and *d e*, *Figure* 2, No. 1; draw *f g* parallel to *a c*, cutting *d e* in *g*; draw *g t* parallel to *e c*, cutting *a c* in *t*; join *t b*; draw *c y* parallel to *t b*, cutting the convex side of the plan at *y*; produce *y c* to cut the chord *k i* at 2; draw 2 *h* parallel to *c e*; make 2 *h* equal to *c e*; draw *k* K parallel to *a d*; make *k* K equal to *a d*; join *h* K; produce *h* K and *i k* to meet each other in *l*; draw *l m* parallel to *t b*: from any point, *m*, in *l m*, draw *m* 3 perpendicular to *l i*; produce *i l* to *p*, cutting *m* 3 at 3; through 3 draw 4 *n* perpendicular to *h l*; produce *h l* to 4; make 3 *o* on *p l* equal to 3-4; join *o m*; make 4 *n* equal to *o m*, and join *n l*: then draw ordinates on the plan parallel to *l m*, to cut both sides of it, and also the chord *k i*; from the intersections in *k i*, draw lines parallel to *c e*, to cut *h l*; from the points of section in *h l*, draw lines parallel to *l n*; make the lines thus drawn parallel to *l n*, equal to the corresponding lines on the plan; and a curve drawn through these respective points will give the face-mould.

In drawing ordinates upon the plan, care should be taken that an ordinate be drawn through the points upon each side of the plan at the line of separation of the straight and circular parts, and also through each extremity of the ends; or, by finding M N, the line of separation, and the point K, the point L will be found by drawing K L parallel to N M, and M L parallel to N K; and thus the portion M N K L, corresponding to *v x k u* on the plan, will be obtained.

The angle *p o m* gives the spring-bevel, *Figure* 2, No. 3; and the angle *s r q* gives the pitch-bevel, *Figure* 2, No. 2. The face-mould is applied to the plank by laying the points P and K close to the edge that is sprung; then drawing the pitch-bevel, No. 2, from either point P or K; for it is not necessary to draw them from both, as the corresponding point will be found upon the other side of the plank; then proceed with the remaining parts as before directed.

To spring the plank for a level landing through two given points, so as to parallel the grain.

Plate III.—Let No. 3 be the falling-mould, as before: draw any line, C A, for the base of the heights of the face-mould; then C D is the lower height, where the two wreathed pieces meet, and A B is the upper height, making allowance for the squaring of the joint. Lay down the plan A *k* C, No. 1; draw C *n* parallel to A *k*; draw A B perpendicular to A *k*; make A B equal to A B, No. 3, and the angle A B E, No. 1, equal to the angle V W S, No. 3; produce A *k* to E; draw C D parallel to A B; make C D equal to C D, No. 3, and the angle C D F equal to the angle A B E, that is, equal to the angle V W S, No. 3: produce *n* C to F; join F E; in F E take any point, E, and draw E I perpendicular to F C, meeting it in I; from I draw I K perpendicular to F O, cutting it in L; make I H equal to I L, and join H E; make L K equal to H E, and join F K; then F E is the director of the ordinates of the base, and F K that of the face-mould. Proceed with the rest as in *Plate* I. *Figure* 1.

No. 2 shows the other mould; but it must be observed, that one mould is sufficient for both wreaths.

Plate IV. shows the falling and face-moulds of a rail with winders. As to the method of laying down the moulds from three given heights, the principle is the same as described in *Plate* I. for a level landing. It therefore only remains to speak of the manner of forming the butt-joints. Draw a line at right angles to the sides of the falling-mould, through the middle of the vertical line, where otherwise would have been the splice joint; from the end of this line draw another at the upper edge, and also one from the under edge, perpendicular to the base line; then the middle height being taken as usual, the remote line is the height of the face-mould.

Thus, H I, No. 1, is the height of *h i*, No. 2; K L, No. 1, the height of *k l*, No. 2; and M N, No. 1, the height of *m n*, No. 2; the remaining part of the construction is as usual. No. 3 is the upper face-mould, taken from inverted heights: or the falling-mould may be considered as inverted. The same letters are put upon both constructions, to show the similar parts. Here are eight winders, all drawn to a scale, to show the proportion of the parts in practice. This hand-rail requires two moulds, on account of the middle of the falling-mould being much higher than the hypothenuse of the winders.

Plate V. shows the falling and face-moulds for a rail constructed as in *Plate* IV. The only difference is, that in this Plate the middle of the falling-mould is the hypothenuse of the wreath. This situation of the falling-moulds will cause both the face-moulds to be identical: that is, their figures will be equal and similar, so that considerable time will be saved in the preparation. This position, and the identification of the moulds, may always be adopted when the distance between the opposite parts of the string is more than ten inches. The mode of making the height of the rail in the middle of the winders the same as that of the flyers, is practised by several celebrated staircase hands, though it is nothing more than a mere matter of opinion, and may be adopted or not, at the option of the architect, or of the workman, if left to him.

It is worthy of notice, that the springing of the plank is of the utmost consequence in the saving of stuff, where the well-hole is wide; but where it is narrow, very little will be gained by it.

To draw the scroll of a hand-rail, and to find the mould for executing the twist.

Plate VI. Figure 1, No. 1, represents the plan of the rail. The scroll is drawn by centres, in the following manner: Make a circle in the centre, 3½ inches in diameter; divide the diameter into three equal parts; one of which subdivide into six equal parts; set one part from the centre upwards, draw a line from the end of that part, at right angles, towards the left hand, and limit this perpendicular to two parts; from the end of the last perpendicular draw a third downward, limiting it to three equal parts; proceed in this manner till six perpendiculars have been drawn, each differing in length by one from the preceding, and the form of a spiral fret will be obtained. The points of concourse of every two lines will give the centres, which are six in number, besides the centre of the circle, and are numbered in order from such centre: draw a straight line downward from the first centre, by continuing the line already drawn till it cuts the circle: continue the second perpendicular to the right hand, and the third upwards to the left hand; these will form the limiting lines for the four arcs, which will complete one revolution.

Continue the lines in the same order for the next revolution, or for the portion of it required. Begin with the centre next to that of the circle for the first centre, and describe a quarter arc from the point of contact of the circle to the next limiting line; then around the second centre, with the distance to the intersection of the preceding arc, on the preceding limiting line, describe another arc; proceed in this manner till the whole spiral is completed. Set the breadth of the rail from *o* to *a*, and describe another spiral by the same centres, by turning the arcs the contrary way, till the last arc of the spiral cuts the first; which will complete the scroll of the rail; then the addition of a part of the straight of the rail will complete the whole.

The outer spiral consists of one revolution and a half, and the inner of only about half a revolution, which also makes the scroll itself appear only half a revolution; but if more is required, every additional centre will add a quarter of a revolution to the scroll.

To find the face-mould for the shank of the scroll.

Figure 1, No. 1. Lay the base of the pitch-board upon the outside of the shank of the scroll, with the acute angle turned to the outside, or largest convexity: draw a line parallel to the base of the pitch-board, to touch the convex side of the scroll next to the straight part; let this line cut the outside of the rail at 6: between 0 and 6 take any number of intermediate points, 1, 2, 3, 4, 5, and draw lines perpendicular to the base of the pitch-board, to cut the hypothenuse of the said pitch-board; from the points of section draw lines at right angles to the hypothenuse; let the perpendiculars parallel to the base line of the pitch-board be continued downwards, to cut the concave side of the shank; and let one of the perpendiculars be drawn from the concave, and another from the convex side of the rail, where it is intersected by the line parallel to the base line; make all the lines at right angles to the hypothenuse equal to the respective ordinates of the shank taken from both concave and convex sides of it: then curves being traced, and the straight parts joined to the angular points, will be the face-mould.

To find the falling-mould.

Divide the distance between 0 and 6, *Figure* 1, No. 1, into six equal parts, and run the chord on the convex side as far as the rail is required to fall: upon any convenient line, A D, No. 2, run the chord of the part from 0 to 13; place the angular point, C, of the pitch-board at 4; with the base A C, upon A D, tange the angle B C D made by the hypothenuse of the pitch-board and the line A D, with a curve to touch at B and D, as shown at No. 3; then draw another curvilinear parallel, containing the depth of the rail between the two curves; and the falling-mould, No. 2, will be completed as far as the rail has a descent, which ends at 13. The block of the scroll, which is the remaining part after the shank is taken away, is wrought out of a solid piece of wood, the height of the perpendicular upon 0. The shank is squared in the same manner as shown in *Plate* II.

No. 4. The falling-mould for the concave side of the rail is exhibited here, in order to show, that if the ramp and the curve of the scroll do not begin together, and if the rail be made absolutely square, that is, having all its plumb sections rectangles, and the convex side made agreeable to its falling-mould, with an easy curve, it will be impossible to form the back with a regular curve on the concave side, and a hump will always be formed. Therefore, in reducing the hump to an agreeable curve, the rail will be thrown out of the square; but the degree by which it deflects from the truth is so small as not to be perceived.

The inside of the falling-mould is formed by taking the stretch out of *a b*, *b e*, *c d*, &c., of the corresponding parts 0 1, 1 2, 2 3, &c., in No. 1, and applying them from *a* to *b*, from *b* to *c*, from *c* to *d*, &c., No. 4; then drawing the perpendiculars from the points *a*, *b*, *c*, &c., and transferring thereto the corresponding perpendiculars insisting upon 0, 1, 2, &c., No. 2, and then tracing the curves. According to the principles of hand-railing, a vertical or plumb section of the rail at right angles to the cylindric sides, or tending to the axis of the cylinder, is level on the back; therefore, as the concave and convex sides of the plan of the scroll are concentric circles, the arc on the concave side, so far as relates to the same quadrant, will be divided equally, as well as the outside; and therefore drawing lines to the centres from the points of section on the convex side will divide each quadrant equally, and the lines thus radiating will be perpendicular to the curve on both sides of the plan; all the parts throughout the same quadrant will be equal on the concave side as well as on the convex side; and on the convex side the parts will be equal throughout all the quadrants; but on the concave side the parts of each succeeding quadrant, in turning towards the centre, will be quicker than those in the preceding quadrant. In the part of the rail which is straight upon the plan, the sections at right angles to the sides divide each side into equal parts, and the parts on the one side equal to those of the other: hence the reason why the hump takes place at the junction of the ramp and twist.

If a scroll is made agreeable to the form of the plan as struck round centres with compasses, it will always appear to the eye as if crippled at the separating section of the straight and twisted parts. To remedy this defect, the curve of the vertical sides, or that which relates to the plan, ought to be extended with an easy curve into the straight part.

No. 5. An elevation of the shank of the scroll. The portion of the plan is taken from No. 1, and the heights which give the curves are taken from the falling-mould, No. 2; its use is to show the thickness of stuff which is contained between two parallel lines; the lower line comes in contact with the projection at two points, the upper one comes in contact with the projection in one point only.

To show the method of forming the curtail of the first step.

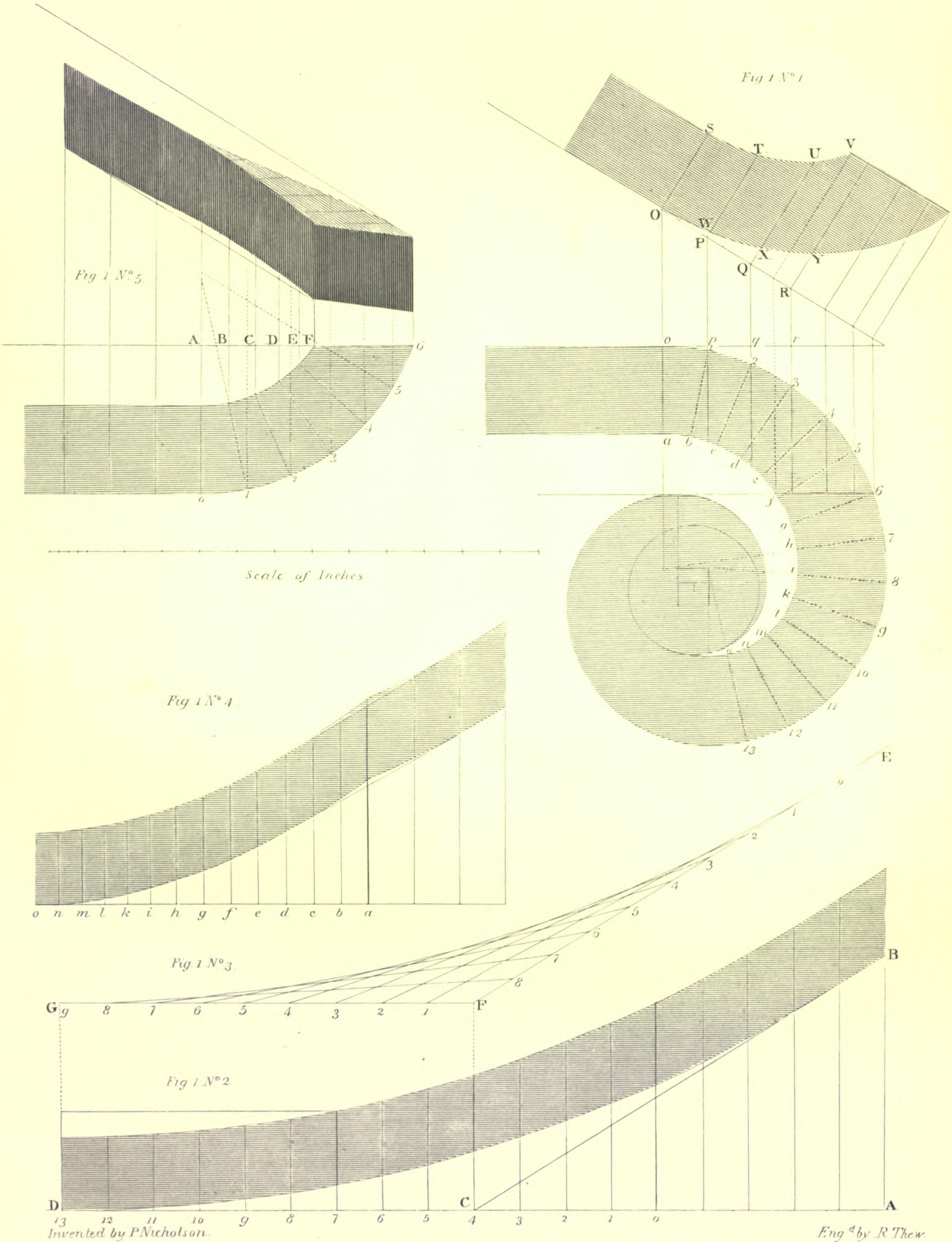
Plate VII. *Figure* 1, No. 1.—Draw the scroll as in the preceding Plate; set the balusters in the middle of the breadth, putting one at the beginning of every quarter; then the front of the balusters is in the plane of the face of the riser, and the opposite side in the plane of the string-board: set the projection of the nosing before the baluster on both sides, and draw two spiral lines parallel to the sides of the scroll, till the curves intersect each other, and they will then form the curtail end of the step, as required, F G H I K represent the convex side of the scroll; L M N, the convex side of the curtail; and A, B, C, D, E, the centre points of the balusters.

No. 2 shows the profile of the curtail, the end of the second step, and part of the end of the third.

Figure 1, No. 3, shows the centres for drawing the curtail, which are the same as for drawing the scroll.

To describe a section of the rail, supposing it to be two inches deep, and two and a quarter inches broad, the usual dimensions.

Figure 2.—Let A B C D be a section of the rail, as squared. On A B describe an equilateral triangle, A B *g;* from *g*, as a centre, describe an arc to touch A B, and to meet *g* A and *g* B: take the distance between the point of section in *g* A and the point A, and transfer it from the point of section to *k*, upon the same line *g* A; join D *k;* from *k*, with the distance between *k* and the end of the arc, describe another arc, to



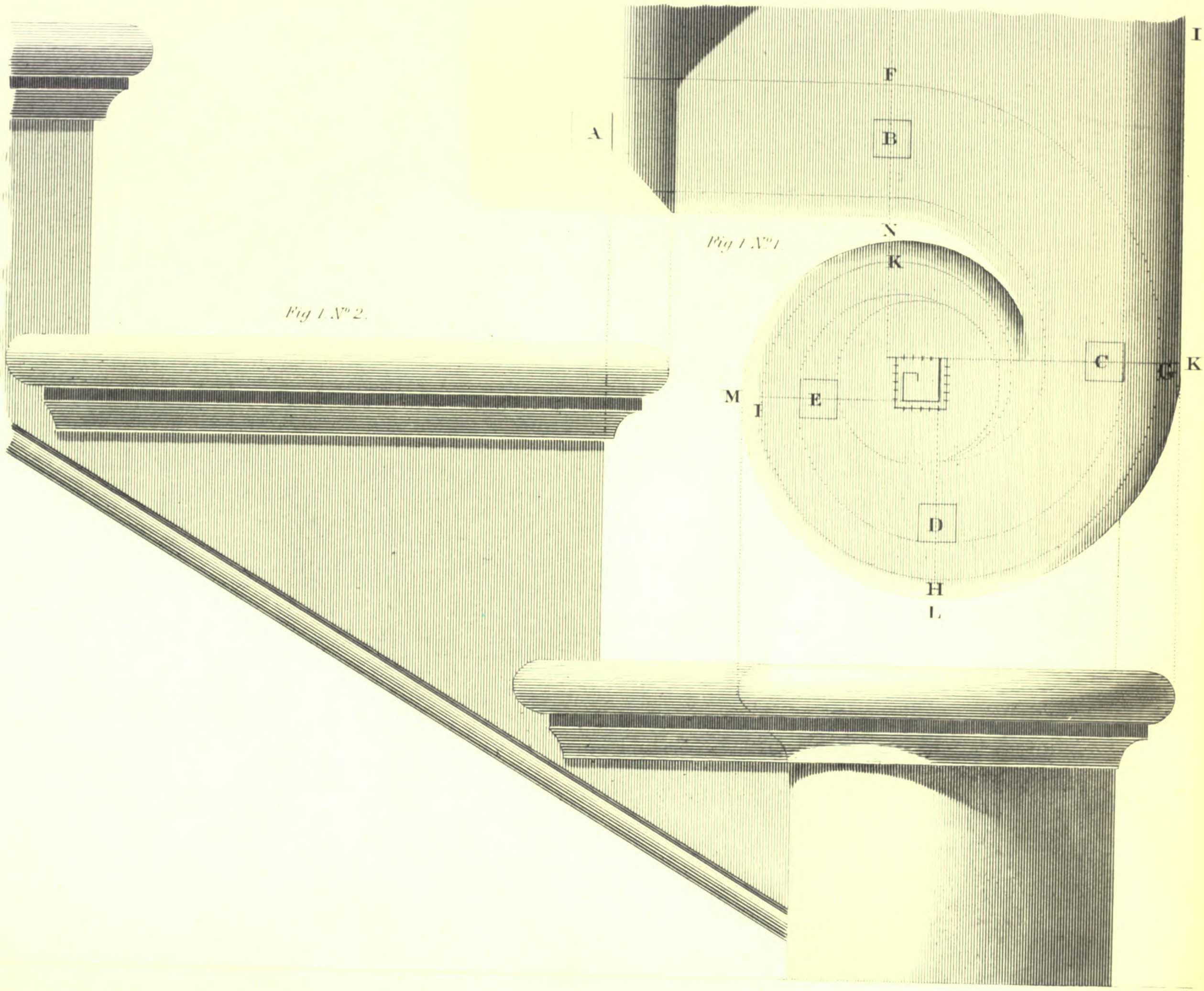
Invented by P.Nicholson.

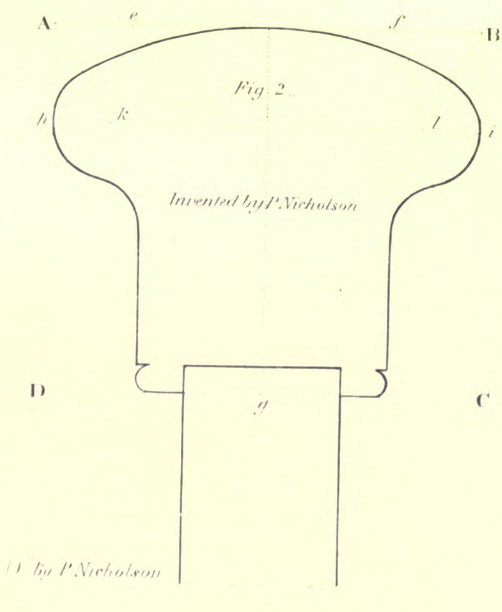
Eng.d by R Thew.

HAND RAILING.

PLATE VII.

Invented by P. Nicholson





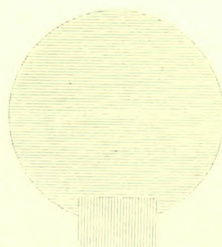
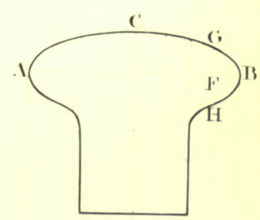
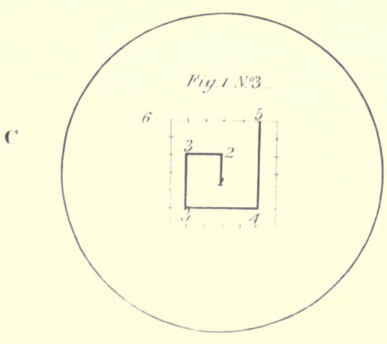
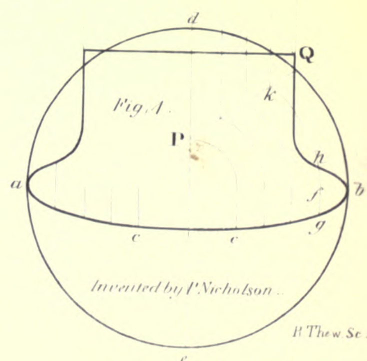


Fig. 3







B. Thew Sc.

meet D *k;* with the same distance describe a third arc, of contrary curvature, and draw a vertical line to touch it; thus will one side of the section of the rail be formed. The counter-part is formed by a similar operation.

Figure 3 is the most simple form for the section of a rail, being that of a circle.

To describe the mitre-cap of a rail.

Figure 4.—Describe a circle, *a e b d*, to the intended size (the proportion here between the rail and the cap is as 2 to 3); draw the diameters *a b* and *e d* at right angles; produce *e d*, and place the middle of the section of the rail upon *e d;* draw B Q to touch the section of the rail, and to cut the circle *a e b d* in Q; draw the side P Q of the mitre; draw A B to meet the points of contact, A and B, of the lines parallel to *e d*, which are tangents to the section. Then to find any point in the curve of the section of the mitre-cap: let G be a point in the section of the rail; draw G *k*, meeting P Q in *k;* from the centre of the circle *a e b d*, describe an arc, *k f*, meeting *a b* in *f;* from the point of section, *f*, draw *f g*, perpendicular to *a b;* and make *f g* equal to F G.

All other points are found in the same manner; or a series of lines may be drawn from any number of assumed points in the section, and lines parallel to *e d*, drawn from them to cut P Q; arcs may then be described from each point of section to meet *a b*, and perpendiculars drawn from the points of section in *a b;* all these perpendiculars should be made equal to the respective ordinates of the section, and a curve drawn through their extremities will form the curve of the mitre-cap.

HANGING, of doors, or shutters, the act of placing them upon centres or hinges, for the convenience of opening and shutting. *See* HINGING.

HANGING STYLE, the style of a door or shutter, to which the hinge is fastened.

The term is also applied to a narrow style fixed on the jamb, on which the door or shutter is sometimes hung. In this case the hanging style is used with the view of making the shutter or door revolve more than a right angle, in order to turn it into a given position; as to bring a door close to a partition, to keep it out of the way.

HANGINGS, linings for rooms, made of arris, tapestry, or the like.

HANGS OVER, an expression used in speaking of a wall, when the top projects beyond the bottom.

HARD BODIES, such bodies as are absolutely inflexible to any shock or collision whatever.

This is the common meaning of the term; but Huygens, by hard bodies (*corpora dura*) meant what others call perfectly elastic bodies: for he thus expresses himself: "Quæcunque sit causa, corporibus duris, a mutuo contactu resiliendi cum se invicem impinguntur: ponimus, cum corpora duo inter se æqualia, æquali celeritate, ex adverso ac directe sibi mutuo occurrent, resilire utrumque eadem qua advenit celeritate." Huyg. *De Motu Corp. ex Percuss. Hypoth.* 2. But this hypothesis is consistent only with perfect elasticity, and not with the common supposition of hardness or inflexibility, which produces no resilition. The laws of motion for hard bodies are the same as for soft bodies, and these two sorts of bodies might be comprised under the common name of *unelastic.*

Some who follow Leibnitz's doctrine, concerning the measure of the moving force of bodies, deny the existence of hard or inflexible bodies. And it is so far true, that no experience ever taught us that there are any such. The hardest bodies to appearance do not preserve their figures in collision, such bodies being only elastic, yielding to the shock, and then restoring themselves.

M. Bernoulli goes so far as to say, that hardness, in the vulgar sense, is absolutely impossible, being contrary to the law of continuity. For supposing two such hard bodies of equal masses, and with equal velocities, to meet directly, they must either stop or return after the collision. The first supposition is commonly admitted; but then it follows, that these bodies must instantaneously pass from motion to rest, without going through successive diminutions of their velocities till they stop: but this is thought to be contrary to the fundamental laws of nature. Hence this author rejects perfectly solid and inflexible atoms, which others think a consequence of the impenetrability of matter.

HARD, a name given to a ford or passable place in a river, particularly in and near the Fens, where many of these formerly occurred, composed of gravel, probably brought thither for the purpose. These HARDS proved very detrimental to navigation in dry seasons, and obstructed and augmented the floods in wet ones, until they were removed. Frequent mention is made of them by Mr. Smeaton, and by other writers on the navigation and drainage of those districts.

HARD FINISHING. *See* PLASTERING.

HARDENING OF TIMBER. *See* TIMBER.

HARMONIC or HARMONICAL PROPORTION, is when, in a series of quantities, any three adjoining terms being taken, the difference between the first and second is to the difference between the second and third as the first is to the third. The reciprocals of a series of numbers in arithmetical progression are in harmonical proportion: thus the reciprocals $\frac{1}{1}$, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, &c. of 1, 2, 3, 4, &c.. are in harmonical proportion; also, the reciprocals $\frac{1}{1}$, $\frac{1}{3}$, $\frac{1}{5}$, $\frac{1}{7}$, &c., of 1, 3, 5, 7, &c. are harmonicals.

HARMONY, an agreement between all the parts of a building; the word is of similar import with SYMMETRY, which *see.*

HARNESS ROOM, a small apartment for keeping the harness in, that it may be preserved from mouldiness. The harness-room should be perfectly dry, and placed as near the stable as possible.

HASP, a fastening; it is in form a small clasp that passes over a staple to be fastened by a padlock.

HATCH-WAY, an aperture through the ceiling, to afford a passage to the roof.

HATCHET (from the French *hachette*) a small axe, used by joiners for reducing the edges of boards.

HAUNCH. That part of an arch between the vertex and the springing.

HEAD (from the Saxon) an ornament of sculpture of carved work, frequently serving as the key of an arch or platband.

These heads usually represent some of the heathen deities, virtues, seasons, or ages, with their attributes. The heads of beasts are also used in suitable places; as a bullock's or sheep's head, for a shambles or market-house; a dog's, for a kennel; a deer's or boar's, for a park or forest; or a horse's, for a stable.

In the metopes for the friezes and other antique Doric temples, we meet with representations of bullocks' or rams' heads flayed, as a symbol of the sacrifices offered there.

HEAD, *Jerkin, See* JERKIN HEAD.

HEADER. *See* HEADING COURSE.

HEADING COURSE, in masonry, a course of stones in which their length is inserted in the thickness of the wall; those with their length in the face of the wall are called *stretchers.* The same is also to be understood of brickwork.

HEADING JOINT, in joinery, the joint of two or more boards at right angles to the fibres; or, in hand-railing, at right angles to the back; this is done with a view to continue the length of the board when too short. The heading-joints in good work are always ploughed and tongued, as in flooring, dado, &c. In dado, the heading-joints, besides being ploughed and tongued, are also glued.

Head-Way of a Stair, the clear distance, measured perpendicular to the horizon, from the tread of any step, resting-place, or landing, to the ceiling immediately above, in one revolution, making allowance for the thickness of the steps.

HEARSE or Herse, a metal frame sometimes set over effigies on tombs.

HEART-BOND, in masonry, the lapping of one stone over two others, which together make the breadth of the wall. This is practised when thorough-stones cannot be procured. *See* Masonry.

HEARTH. *See* Chimney.

HEATHER-ROOF, that kind of roof employed in building which is thatched over or covered with heather or heath, instead of some other material. It is recommended, as well adapted to buildings of the farm description, by the writer of the *Survey of the County of Argyle, in Scotland*, on the principle that it does well with timber of the ordinary sort, is capable of being procured for a trifle, lasts nearly as long as slates, and gives less trouble in the repair. It is asserted that a roof of this material, when well put on, will last one hundred years, provided the timber continues good that length of time. And it is stated, that formerly, most of the churches in the above county were covered with this sort of roof; likewise that heather-roofs are frequently met with in the district of Cowal, and that there are a few of them in Kintyre.

This sort of material may certainly be employed with advantage as a covering for small houses and other buildings, where other kinds of substances cannot be procured, except at a great expense; but at the same time it is very inferior to slate, and other similar matters, in forming the coverings of such erections.

HECATOMPEDON (from ἑκατον, a *hundred*, and πες *a foot*) a name given to the Parthenon, or temple of Minerva, at Athens.

HECATONSTYLON (ἑκατονςυλον) in ancient architecture, a portico with a hundred columns. This name was peculiar to the great Portico of Pompey's theatre at Rome.

HECK, a rack.

HEEL, in mouldings, the same as the sima-inversa.

Heel of a Rafter, the foot of the rafter, as it is formed to rest upon the wall-plate.

HEIGHT, the perpendicular distance of the most remote part of a body from the plane on which it rests.

HELICOID PARABOLA, or the Parabolic Spiral, a curve arising upon the supposition of the axis of the common Apollonian parabola being bent round into the periphery of a circle. The helicoid parabola, therefore, is a line passing through the extremities of the ordinates, which converge towards the centre of the said circle.

HELIOPOLIS, or The City of the Sun, in ancient geography, a city of Egypt, placed by geographers not far from Helle, at some distance from the eastern point of the Delta. It was built, according to Strabo, on a long artificial mount of earth, so as to be out of the reach of the inundation. This causeway, covered with rubbish, is still visible two leagues to the north-east of Grand Cairo, and three from the separation of the Nile. This city had a temple to the sun, where a particular place was set apart for the feeding of the sacred ox, which was there adored under the name of Menevis, as he was at Memphis under that of Apis. There was also in this city another magnificent temple, in the ancient Egyptian taste, with avenues of sphinxes and superb obelisks, before the principal entry. These temples were fallen into decay under the reign of Augustus; as the city had been laid waste with fire and sword by the fury of Cambyses. Of the four obelisks built by Sochis in that town, two were removed to Rome; another has been destroyed by the Arabs; and the last of them is still standing on its pedestal. It is composed of a block of Thebaic stone, perfectly polished, and is, without including its base, 68 feet high, and about 6½ feet wide on each aspect. It is covered with hieroglyphics. This beautiful monument, and a sphinx of yellowish marble, overset in the mud, are the only remains of Heliopolis. *See* Egyptian Architecture.

HELIX, a term applied to the little scrolls in the Corinthian capital, called also *urillæ;* they are sixteen in number, viz. two at every angle, and two in the middle of the abacus, branching out of the caulicoli or stalks which rise between the leaves.

HELMET, a warlike ornament, in imitation of the helmet worn by the cavaliers, both in war and in tournaments, as a cover and defence of the head; the helmet is known by divers other names, as the *head-piece*, *steel-cap*, &c. The Germans call it *helen* or *hellem;* the Italians *elmo;* the French *casque*, as did also the ancient English.

The helmet covered the head and face, only leaving an aperture about the eyes, secured by bars, which served as a visor.

HEM, the protuberant part of the Ionic capital, formed by spirals.

HEMI, a word used in the composition of divers terms. It signifies the same with *semi* or *demi*, viz., *half;* being an abbreviation of ἡμισυς, *hemisys*, which signifies the same. The Greeks retrenched the last syllable of the word ἡμισυς in the composition of words; and, after their example, we have done so too, in most of the compounds borrowed from them.

HEMICYCLE, (Latin, *hemicyclium*, compounded of ἡμισυς, *half*, and κυκλος, *circle*) a semicircle. This word is particularly applied, in architecture, to vaults in the cradle form; and arches, or sweeps of vaults, constituting a perfect semicircle. To construct an arch of hewn stone, they divide the hemicycle into so many voussoirs; taking care to make them an uneven number. that there be no joint in the middle, where the key-stone should be.

HEMICYCLIUM, a part of the orchestra in the ancient theatre. Scaliger, however, observes, it was no standing part of the orchestra; being only used in dramatic pieces, where some person was supposed to be arrived from sea, as in Plautius's *Rudens*.

HEMISPHERE, (Latin, *hemispherium*, compounded of ἡμισυς, *half*, and σφαιρα, *sphere*) in geometry, one half of a globe, or sphere, when divided into two by a plane passing through its centre.

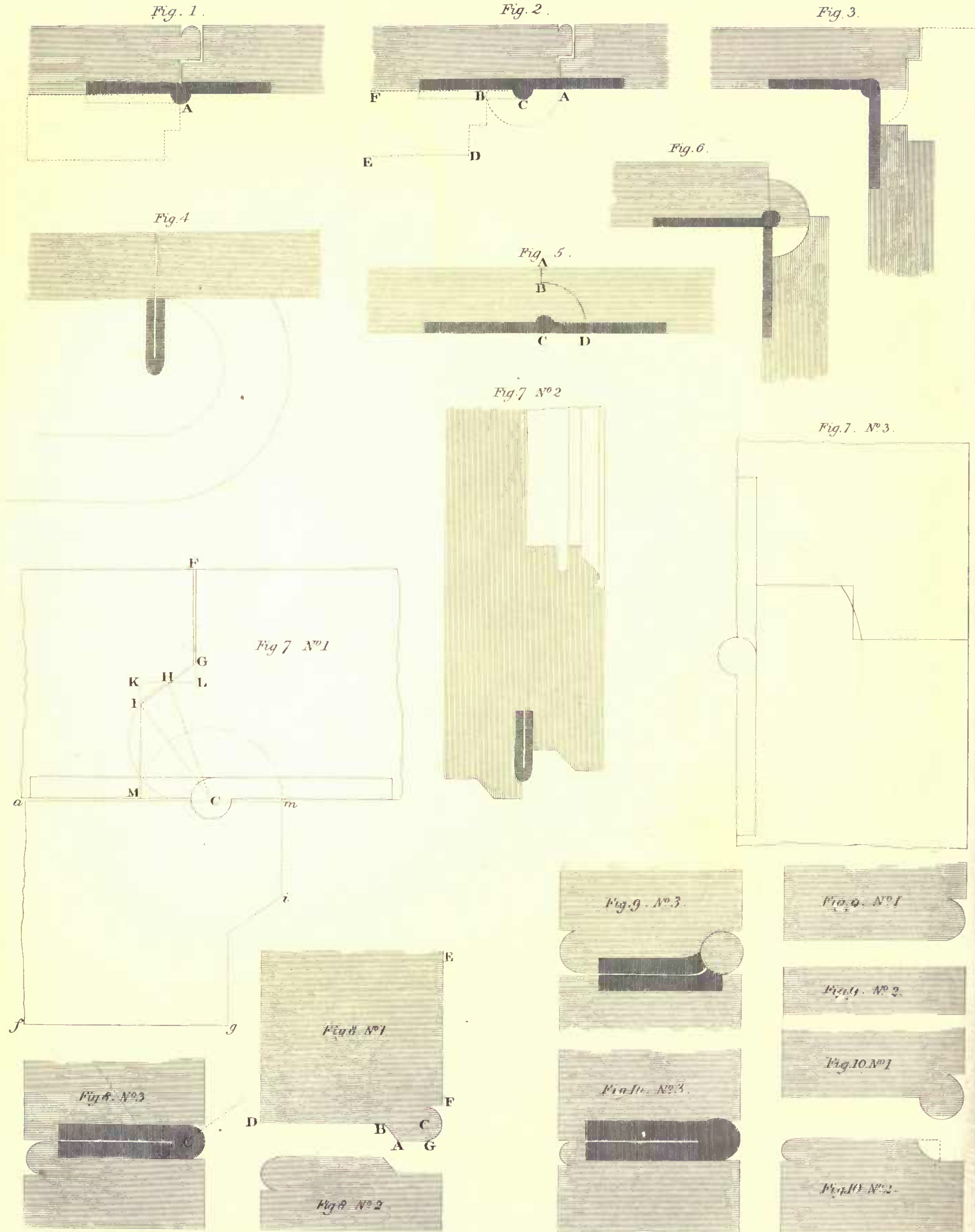
HEMISPHEROIDAL, a body approaching to the figure of a hemisphere, but not exactly so; of this description are what may be termed *elliptical domes*, upon either axis.

HEMITRIGLYPH, the half triglyph.

HENDECAGON, Endecagon, or Undecagon, (compounded of ἑνδεκα, *eleven*, and γωνια, *angle*) in geometry, a figure which has eleven sides, and as many angles. If each side of this figure be 1, its area will be equal to 9.3656399 $=\frac{11}{4}$ tangent $73\frac{7}{11}$°, radius being 1.

HEPTAGON, (of ἑπτα, *septem*, *seven*, and γωνια, *angle*) in geometry, a figure consisting of seven sides and seven angles. If the sides and angles be all equal, it is called *a regular heptagon*. The area of a regular heptagon is equal to the square of one of its sides multiplied by 3.6339126.

HINGING



Invented. by P. Nicholson.

Engd. by R. Thew.

HEPTAGONAL, consisting of seven angles, and therefore also of seven sides.

HERBOSUM MARMOR, a species of marble, much esteemed and used by the ancient architects and statuaries. It was of a beautiful green colour, but had always with it some cast of yellow. It was dug in the quarries of Taygetum, but was esteemed by the workmen the same in all respects, except colour, with the black marble dug at Tænarus in Lacædemonia, and thence called *Tænarian marble.*

HERRING-BONE, a term applied to a particular kind of masonry, in which the stones are laid aslant, inclining alternately right and left. Such work was common in Roman and Saxon structures.

HERMOGENES, the inventor of the eustyle intercolumniation; also of the octostyle pseudodipteros. He is mentioned by Vitruvius, chap. 2. book iii.

HEWN STONE, any stone when reduced to a given form by means of the mallet and chisel.

HEXAEDRON, or HEXAHEDRON (formed of ἑξ, *six*, and ἡδρα, *seat*) in geometry, one of the five regular bodies, popularly called *a cube*. *See* CUBE.

The square of the side of a hexaedron is in a subtriple ratio to the square of the diameter of the circumscribed sphere. Hence, the side of the hexaedron is to the diameter of the sphere in which it is inscribed, as one to the $\sqrt{3}$: and consequently it is incommensurable to it.

HEXAGON, (from ἑξ, *six*, and γωνια, *angle*) a figure of six angles, and consequently of six sides. If the angles and sides are equal, the figure is called a *regular hexagon*. If the side of a hexagon be denoted by *s*, its area will be 2.5980762 *s*.

HEXASTYLE, (from ἑξ, *six*, and ϛυλος, *column*) a building with six columns in front.

HINDOO ARCHITECTURE. *See* INDIAN ARCHITECTURE.

HINGES, metal ligaments, upon which doors, shutters, folds, lids, &c., turn in the act of opening and shutting.

There are many species of hinges, viz., butts, rising-hinges, pew-hinges, casement-hinges, casting-hinges, chest-hinges, coach-hinges, desk-hinges, dovetail-hinges, esses, folding-hinges, garnets, weighty side, side-hinges with rising joints, side-hinges with squares, screw-hinges, scuttle-hinges, shutter-hinges, trunk-hinges, of various descriptions, hook-and-eye-hinges, and centre-pin-hinges.

HINGING, a branch of joinery, which shows the art of hanging a board to the side of an aperture, so as to permit or exclude entrance at pleasure. The board which performs this office is called *a closure*. The placing of hinges depends entirely on the form of the joint, and as the motion of the closure is angular, and performed round a fixed line as an axis, the hinge must be so fixed that the motion may not be interrupted; thus if the joint contain the surfaces of two cylinders, the convex one in motion upon the edge of the closure, sliding upon the concave one at rest on the fixed body, the motion of the closure must be performed on the axis of the cylinder, which axis must be the centre of the hinges; in this case the joint will be close, whether the aperture be shut or open. But if the joint be a plane surface, it must be considered upon what side of the aperture the motion is to be performed, as the hinge must be placed on the side of the closure where it revolves.

The hinge is made in two parts, movable in any angular direction, one upon the other.

The knuckle of the hinge is a portion contained under a cylindric surface, and is common to both the moving part and the other part at rest; the cylinders are indented into each other, and made hollow to receive a concentric cylindric pin which passes through the hollow, and connects the moving parts together.

The axis of the cylindrical pin is called the *axis of the hinge.*

When two or more hinges are placed upon a closure, the axes of the hinges must be in the same straight line.

The straight line in which the axes of the hinges are placed is called the *line of hinges.*

The following are examples of the different cases.

The principle of hanging doors, shutters, or flaps, with hinges.

The centre of the hinge is generally put in the middle of the joint, as at A, *Figure* 1; but in many cases there is a necessity for throwing back the flap to a certain distance from the joint; in order to effect this, suppose the flap, when folded back, were required to be at a certain distance, as A B in *Figure* 2, from the joint; divide A B in two equal parts at the point C, which will give the centre of the hinge; the dotted lines B D E F, show the position when folded back.

Note.—The centre of the hinge must be placed a small degree beyond the surface of the closure, otherwise it will not fall freely back on the jamb or partition.

It must also be observed, that the centre of the hinge must be on that side that the rebate is on, otherwise it will not open without the joint being constructed in a particular form, as will be afterwards shown.

Figure 3 shows the same thing opened to a right angle.

To hang two flaps, so that when folded back, they shall be at a certain distance from each other.

This is easily accomplished by means of hinges having knees projecting to half that distance, as appears from *Figure* 4; this sort of hinges is used in hanging the doors of pews, in order to clear the moulding of the coping.

To make a rule joint for a window-shutter, or other folding-flaps.

Figure 5.—Let A be the place of the joint; draw A C at right angles to the flap, shutter, or door; take C, in the line A C, for the centre of the hinge; and the plain part A B, as may be thought necessary; on C, with a radius, C B, describe the arc B D; then will A B D be the true joint.

Note.—The knuckle of the hinge is always placed in the wood, because the farther it is inserted the more of the joint will be covered, when it is opened out to a right angle, as in *Figure* 6; but if the centre of the hinge were placed the least without the thickness of the wood, it would show an open space, which would be a defect in workmanship.

To form the joints of styles, to be hung together, when the knuckle of the hinge is placed on the contrary side of the rebate.

Figure 7.—Let C be the centre of the hinge, M I the joint on the same side of the hinge; K L the depth of the rebate in the middle of the thickness of the styles, perpendicular to K M, and L F the joint on the other side, parallel to K M; bisect K L at H, join H C; on H C describe a semicircle, C I H, cutting K M at I: through the points I and H, draw I H G, cutting F L at G; then will F G I M be the true joint; but if the rebate were made in the form of M K L F, neither of the styles could move round the joint or hinge.

To form the edges or joint of door-styles, to be hung to each other, so that the door may open to a right angle, and show a bead to correspond exactly to the knuckle of the hinge. Also the manner of constructing the hinges for the various forms of joints, so as to be let in equally upon each side.

Figure 8, No. 1, shows the edge of a style, or it may in some cases be a jamb, on which a bead is constructed exactly to the size of the knuckle of the hinge, and rebated backwards, equal to half the thickness of the bead: the manner of constructing the rebate will be shown as follows:

Through C, the centre of the bead, which must also be the centre of the hinge, draw C B D perpendicular to E F; draw A G parallel to it, touching the bead at G; make G A equal to G C, the radius of the bead; join C A; make A B perpendicular to A C, cutting C D at B; then will G A B D be the joint required.

No. 2, shows a part of the hanging style constructed so as to receive the edge of No. 1.

No. 3, shows the above hinged together with common butt-hinges.

Note.—It must be observed in this, and all the following examples of hinges, that the joints are not made to fit exactly close, as sufficient space for the paint must be allowed.

Figure 9, No. 1 and 2. The manner of constructing these being only a plain joint at right angles to the face of the style, no farther description is necessary.

No. 3 shows No. 1 and 2 hinged together, and the particular construction of the hinge, so as to be seen as a part of the bead, and the strap of the hinge to be let equally into each style: this construction will admit of a bead of the same size exactly opposite to it.

Figure 10, No. 1 and 2. The manner of constructing the edges of styles to be hinged together with common butts, to be let equally into each style: the manner of constructing this joint is so plain, by the figure, that it would be useless to give any other description of it. No. 3, the two pieces hinged together.

Methods of jointing styles together so as to prevent seeing through the joints, each side of the styles to finish with beads of the same size, exactly opposite to each other, and for the strap of the hinges to be let equally into both parts or styles.

Figure 11, No. 1 and 2, the manner of constructing the joint before hinged together.

No. 3 shows No. 1 and 2 hinged together with common butts.

Figure 12, No. 1 and 2, shows another method of constructing the joints, before hinged together.

No. 3, shows No. 1 and 2 hinged, and the particular form of the hinges for the joint.

The principle of concealing hinges, showing the manner of making them, and of forming the joint of the hanging style, with the other style connected to it by the hinges, either for doors or windows.

Figure 13, for a window:

X, inside bead of the sash-frame.

Y, inside lining.

Z, style of the shutter.

Let A be the intersection of the face of the shutter, or door, with that of the inside lining of the sash-frame.

A R, the face of the inside lining.

Bisect the angle P A R by the right line A A; now the centre C being determined in A A at C, so that the knuckle of the hinge may be at a given distance from the face P A of the shutter; through C draw the line D D, at right angles to A A; then one side of the hinge must come to the line C D, the hinge being made as is shown by the figure.

To construct the jamb to be clear of the shutter.—

On C, as a centre, with a radius C A, describe an arc A M, and it will be the joint required.

Note.—When these sort of hinges are used in shutters, the strap of the hinge may be made longer on the inside lining, than that which is connected with the shutter.

Figure 14, is the manner of hanging a door on the same principle: the shadowed part must be cut out, so that the other strap of the hinge may revolve; the edge, C D, of the hinge, will come into the position of the line A A, when the window is shut in.

Here the strap part of the hinge may be of equal lengths.

Figure 15, the common method of hanging shutters together, the hinge being let the whole of its thickness into the shutter, and not into the sash-frame.

By this mode it is not so firmly hung, as when half is let into the shutter and half into the sash-frame, but the lining may be of thinner stuff.

Note.—It is proper to notice, that the centre of the hinge must be in the same plane with the face of the shutter, or beyond it, but not within the thickness.

Figure 16, the method of hanging a door with centres. Let A D be the thickness of the door and bisect it in B; draw B C perpendicular to A B; make B C equal to B A or B D; on C (the centre of the hinge) with a radius C A or C D, describe an arc, A E D, which will give the true joint for the edge of the door to revolve in.

HIP, in architecture, a piece of timber placed between every two adjacent inclined sides of a hip-roof, for the purpose of fixing the jack rafters. For the manner of finding the length and backing of the hips, *see* HIP-ROOF.

HIP-KNOB, a pinnacle, finial, or other ornament placed on the top of the hips of a roof, or on the apex of a gable, especially where barge-boards are employed.

HIP-MOULD, a mould by which the back of the hip-rafter is formed: it ought to be so constructed as to apply to the side of the hip, otherwise there will be no guide for its application.

HIP-ROOF, a roof whose ends rise immediately from the wall-plate, with the same inclination to the horizon as the other two sides of the roof have.

The backing of a hip is the angle made on its upper edge, to range with the two sides or planes of the roof between which it is placed.

Jack-rafters are those short rafters fixed to hips equidistantly disposed in the planes of the sides and ends of the roof, and parallel to the common rafters, to fill up the triangular spaces, each of which is contained by a hip-rafter, the adjoining common rafter, and the wall-plate, between them. The seat or base of the rafter is its ichnographic projection on the plane of the wall-head, or on any other horizontal plane.

The principal angles concerned in hip-roofing are, the angle which a common rafter makes with its seat on the plane of the wall-head; the vertical angle of the roof; the angle which a hip makes with the adjoining common rafter; the angles which a hip makes with the wall-plate on both sides of it; the angle which a hip-rafter makes with its seat; and the acute angle which a hip-rafter makes with a vertical line. The principal lengths concerned are, the height of the roof; the length of the common rafters and their seats; the length of the hips and their seats; and, lastly, the length of the wall-plate contained between the lower end of a hip and the lower end of the adjacent common rafter.

The sides and angles may be found by geometrical construction or trigonometrical calculation. It is evident, that if the hipped end of a roof be cut off by a vertical plane parallel to the wall, through the upper extremity of the hips, it will form a rectangular pyramid, or one whose base is a rectangle. The base of this pyramid is bounded by the wall-plate between the two hips on one side, and on the opposite side by the seat of the two adjoining common rafters; on the other two opposite sides, by that part of the wall-plate on each side contained by the lower end of the hip and the next common rafter adjoining. One of the sides is the isosceles triangle contained by the two adjoining common rafters with their seat; the opposite side is the hipped end of the roof, forming

HINGING.

PLATE II.

Fig. 11. No. 3.

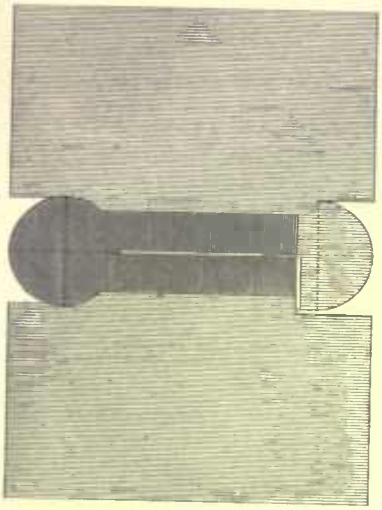


Fig. 11. No. 1.

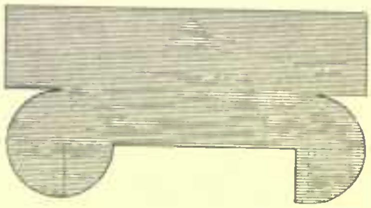


Fig. 12. No. 1.

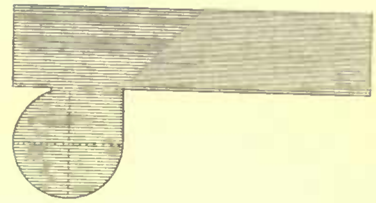
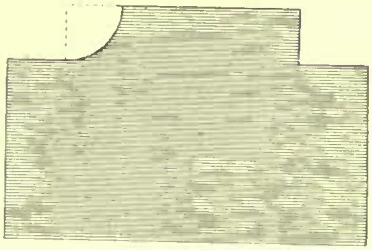


Fig. 11. No. 2.



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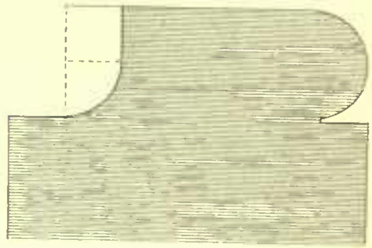


Fig. 12. No. 3.

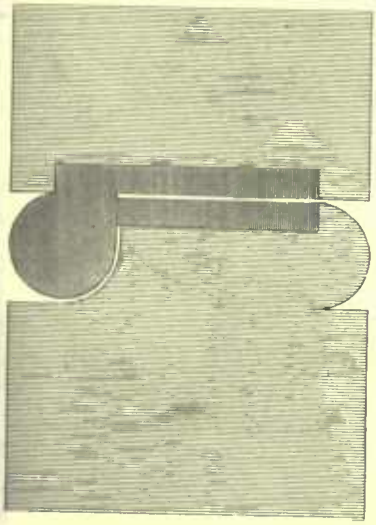


Fig. 14.

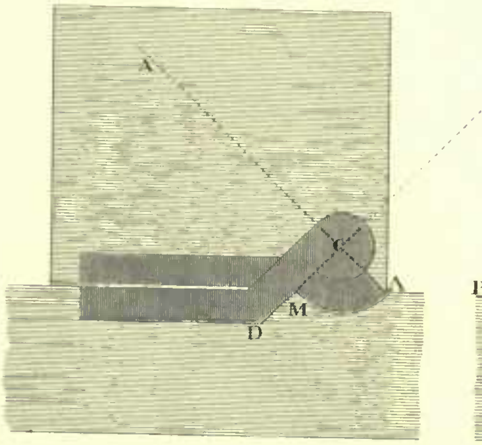


Fig. 13.

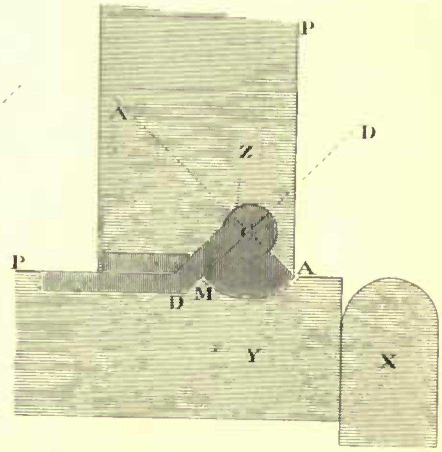


Fig. 15.

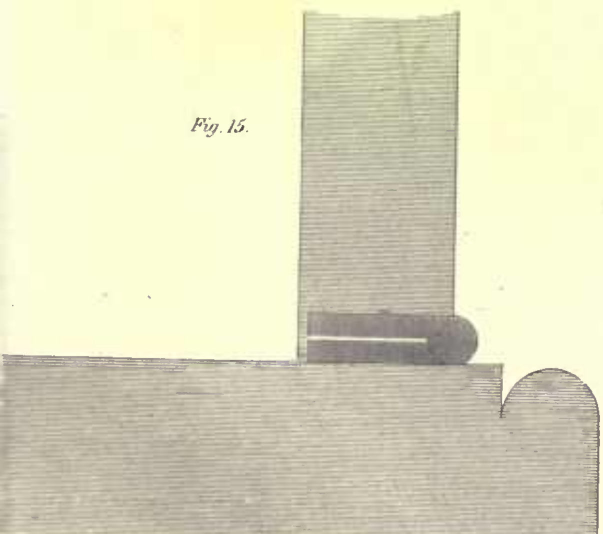
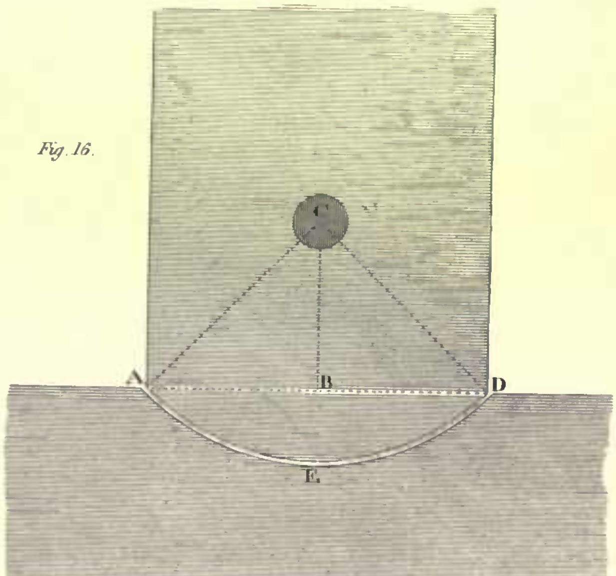


Fig. 16.



Drawn by P. Nicholson.

Eng'd by R. Thew.

also an isosceles triangle; the other two opposite sides are the right-angled triangles contained by the two hips and the two adjoining rafters on the side of the roof. This rectangular pyramid may be divided into three triangular pyramids by the two vertical triangular planes, formed by the hip-rafters, their seats, and the common perpendicular from their vertex.

Two of these pyramids, when the plan of the building is a rectangle, are equal and opposite. In each of these equal and opposite pyramids the base is a right-angled triangle, contained by the seat of the hip-rafter, the seat of the adjoining common rafter, and the part of the wall-plate between the hip and the adjoining common rafter. One of the sides is a right-angled triangle contained by the adjoining common rafter, its seat, and perpendicular: a second side is a right-angled triangle contained by the common rafter, the hip-rafters, and the wall-plate, between them; and the remaining third side is the triangle contained by the hip-rafter, its seat, and perpendicular. With regard to the remaining pyramid, its base is a right-angled triangle contained by the seats of the two hips and the wall-plate between them, the right angle being that contained by the seats of the two hips; two of its sides are the triangular planes passing the hip-rafter, which are also common to the other two pyramids; its third side is the hipped end of the roof.

Given the plan of a building, or the form of a wall-plate of a hip-roof, and the pitch of the roof, to find the various lengths and angles concerned, whether the roof is square or bevel.

EXAMPLE I.—*To find the length of the rafters, the backing of the hips, and the shoulders of jack-rafters and purlins, geometrically.*

Plate I.—*Figure* I.—Let A B C D be the plan. Draw E F parallel to the sides, A D and B C, in the middle of the distance between them. On D C, as a diameter, describe the semicircle D F C: draw F D and F C, then the angle D F C is a right angle. Draw G F H perpendicular to E F, cutting the sides A D and B C in G and H; from F E cut off F I equal to the height or pitch of the roof, and join G I; from F C cut off F K equal to F I, and join K D; then G I is the length of a common rafter, and D K that of the hip; for if the triangles G F I and D F K be turned round their seats, G F and D F, until their planes become perpendicular to the triangle G F D, the perpendicular F I will coincide with F K, and the point I will coincide with the point K; the lines G I and D K, representing the rafters, will then be in their true position.

The same by calculation. $GI^2 = GF_2 + FI^2$ (Euclid i. 47.) therefore, $GI = (GF^2 + FI^2)\frac{1}{2}$ the length of the common rafter, $DF^2 = GF^2 + GD^2$ the square of the seat of the hip. $DK^2 = DF^2 + FK^2 = GF^2 + GD^2 + FI^2$, therefore $DK = \overline{GF^2 + GD^2 + FI^2}^{\frac{1}{2}}$.

In the same manner the other hip-rafter C L is found, as also the hip-rafters A M and B N.

Let it be required to find the backing of the hip-rafter whose seat is C F.

Geometrically.—Imagine the triangle C F L to be raised upon its seat C F, until its plane becomes perpendicular to the plane of the wall-plate A B C D, then there will be two right-angled solid angles; the three sides of the one are the plane angles of F C D, F C L, and the hypothenusal plane angle D C L. In each of these solid angles the two sides, containing the right angle, viz., the plane angles F C H, F C D, and the perpendicular plane angle C F L, which is common to both, being given to find the two opposite inclinations to the sides F C H and F C D, and the remaining third sides.

Now the angles G D C and H C D are besected by the seats F D and F C of the hip-rafters; for if E F is produced to meet D C in U, U will be the centre of the circle D F C; and U C, U F, U D, are equal to each other; and because U F is equal to U C, the angle C F U is equal to F C U; but C F U is equal to the alternate angle F C H; therefore, the angle F C U is equal to F C H; that is, the angle U C H is besected by the seat F C of the hip-rafter. In the same manner may be shown that U D G is besected by the seat D F of the other hip-rafter. From any point, O, in F C, draw O V perpendicular to L C, cutting it in P, and O W perpendicular to F C, cutting D C in W; from O C cut off O Q equal to O P. Join Q W, then O Q W will be the inclination opposite the plane angle F C U, and this is the angle which the end of the roof makes with the vertical triangle contained by the hip-rafter, its seat, and perpendicular. Produce W O to meet D C in X, and join Q X, then W Q X is the inclination of the two planes of a side and end of the roof, whose intersections are B C and C D, on the plane of the wall-head. Now, the angle W Q X, which is double the angle W Q O, is the backing of the hip. Make P V equal to Q W, and join C V, then will P C V be the angle contained by the two sides L C, C D, or that of the hypothenusal plane angle contained by the intersection B C, and the hip-rafter L C. This angle may be otherwise found thus:—Produce G H to R; make C R equal to C L, then the angle H C R is equal to P C V. Now the angle H C R, or P C V, is the angle which the purlins (when one of their faces is in the side of the roof) make with the hip-rafter L C; and the angle C V P, or C R H, is the angle which a jack-rafter makes with the same hip; in the same manner may the backings of the other hips be found. The other bevel of the jack-rafters is the angle H I F. To find the other bevel for cutting the shoulder of the purlin, proceed thus: on F, as a centre, with the distance F O, describe the arc G Y; draw F Y perpendicular to G I, Y Z parallel to E F, cutting F D in Z, and Z & parallel to G H, cutting A D in &. Join & F, then G & F is the angle which the other side of the shoulder makes with the length of the purlin.

At the other end of this diagram is shown the manner of finding the two bevels for cutting the shoulder of the purlin against the hip-rafter when the side of the purlin is not in the plane of the side of the roof.

To find the same things by calculation.—The backing of the hip-rafter and hypothenusal side is obtained as follows:—It has been shown that the three plane angles, and the three inclinations of solid angles, consisting of three plane angles, are found exactly as the sides and angles of spheric triangles, any three parts being given; the degrees of the plane angles being exactly the same as the sides of the spheric triangles, and the inclinations the proper measures of the spheric angles; therefore, if two of the plane angles should be perpendicular to each other, the spheric triangle representing this solid angle will have also two of its sides perpendicular to each other. Now, in this, there are given the two sides containing the right angle to find the hypothenuse and angles.

It is shown, by writers on spherical trigonometry, that in any right-angled spherical triangle, radius is to the cosine of either of the sides, as the cosine of the other side to the cosine of the hypothenuse. Suppose the plane angle F C L to be 27°, and the angle F C H 52°, to find the hypothenuse and angles of a right-angled spherical triangle, one of whose legs is 27° and the other 52°, it will therefore be—

As radius, sine of 90°	=	10.00000
Is to the cosine of F C L, 27°	=	9.94988
So is the cosine of F C H 52°	=	9.78934
		19,73922
		10.00000
To the cosine of the hypothenusal side 56° 44′		9.73922

This ascertains the angle which the jack-rafter makes with the hip. Since all the sides are now given, we shall have, by another well-known property, of the sines of the sides being as the sides of the opposite angles, the following proportion :—

As the sine of the hypothenuse 56° 44′	=	9.92227
Is to the sine of a right angle, or 90°	=	10.00000
So is the sine of the side F C H, 52°	=	9.89653
		10.89753
		9.92227
To the sine of the opposite angle 70° 28′	=	9.97426
Therefore the backing is twice 70° 28′	=	140° 56′

In finding the angle opposite the side F C H, it was not necessary that the hypothenusal side should have first been found. It might have been found independently thus :—The sine of either of the sides about the right angle is to radius, as the tangent of the remaining side is to the tangent of the angle opposite to that side ; therefore,

As the sine of the side F C L, 27°	=	9.65705
Is to the tangent of the side F C H 52°	=	10.10719
So is radius, sine of 90°	=	10.00000
		20.10719
		9.65705
To the tangent of the angle opposite the side F C H, 70° 28′	=	10.45014

In the same manner may other bevels be found by trigonometrical calculations; but as such extreme exactness is not necessary, the geometrical constructions ought to be well understood.

EXAMPLE II.—*The figure* A B C D (*Figure* 2) *of the wall plate of a hip span-roof, and the height of the roof being given; to find the backing of the hips, the angles made upon the sides of the purlins by their longitudinal arrises, and the angles made upon the sides of the jack-rafters; the roof being equally inclined to the different sides of the building, except at the oblique end*, A B.

Figure 2.—Let the two sides, A B, A D, and D C of the wall-plate be at right angles to each other, and the end C B at oblique angles to A B and C D; draw the seat, E F, of the ridge in the middle of the breadth, parallel to A B and D C ; make A G and D H equal to half the breadth of the building ; join G H, which will be the seat of the common rafters adjoining the hips ; make E I equal to the height of the roof; and draw I G and I H, which are the length of the common rafters. Draw E D and E A, the seats of the hips ; make E K equal to E I ; and draw K A, which gives the length of each hip. Through any point, L, in the seat of the hip A E, draw M N perpendicular to A E, cutting the adjacent sides of the wall-plate at M and N ; take the nearest distance from L to the rafter A K, and make L O equal to it ; and draw O M and O N ; and M O N is the backing of the hips, represented by their seats A E and D E.

This operation is the same as having the two legs of a right-angled solid angle to find the angle opposite to one of the legs; the angle M O N being exactly the double of the angle so found; for the hip angle of the roof consists of two equal solid angles.

Suppose the bevel end at C B to be inclined at a different angle to the other sides, and let F C and F B be the seats of the hips; draw F Q perpendicular to F C, and F P perpendicular to F B, each equal to the height of the roof; then draw Q C and P B, which are the lengths of the hip-rafters.

The backings S U T and V W X, are found in the same manner as above, and may be described in the same words.

From A, with the distance A K, describe an arc cutting G H at J, and join A J; then G J A will be the side bevel, which the jack-rafters make with the hips; and if a right angle be added to G J A, it will form an obtuse angle, which is that made by the upper arris of the side of a purlin placed in the inclined side of the roof with the hip-rafter.

Let *a* be the position of a purlin in the rafter H I ; in G H take any point, *b*, and draw *b c* parallel to the inward direction of the purlin *a;* from *b*, with any distance, *b c*, describe an arc *c d*, cutting G H at *d;* draw *b e*, *c f*, and *d g*, parallel to E F; the former two cutting E D at *e* and *f;* draw *f g* parallel to G H, and join *e g;* produce *b e* to *h;* and *h e g*, or *b e g* will be the angle required, according to which side it is applied: this will be found synonymous to one of the legs, and the adjacent angle of a right-angled solid angle being given, to find the hypothenuse. In the same manner, if neither side of the purlin should be parallel to the inclined side of the roof, as at *k* in the rafter G I, the bevel or angle upon each side may be found, as shown.

Plate II.—*Figure* 3, shows half the angle of the backing of the hips, the length of the common and hip-rafters, the bevel of the jack-rafters on their upper sides in an equal inclined roof, without laying down or drawing any more than the necessary seats; and this is all that is necessary when each side of the roof is alike; A B being the wall-plate between the hip and the rafter which joins the top of the hip, A C the seat of the rafter which joins the top of the hip, B C that of the hip, A F the length of the rafter which joins the hip, B E the length of the hips, C H G half the backing, A D B the angle which the jack-rafters form with the upper sides of the hips, and, consequently, with the addition of a right-angle, the side bevel of the purlin.

Figure 4, shows the same bevels, except that the side joint of the purlin is found by a different process, thus: from B, with the distance B A, describe an arc at D; from O, with the distance A C, describe another arc, cutting the former at D; join B D, and the angle G B D will be the angle in the plane of the roof, made by the lower arris of the purlin and the joint against the hip-rafter.

Besides the angles already mentioned, A F C *Figure* 3, shows the angle formed by the upper side of the rafter and the ridge-piece, and the angle B E C, the angle which the top side of the hips makes with a vertical or plumb-line; also the angle F A C shows the form of the heel of the common rafters, and E B C that of the hips.

Figure 5, is a diagram showing the length of the parts and angles concerned in the roof, in the same manner as above; but the plan of the building, or form of the wall-plate, is a quadrilateral, which has neither part of its opposite sides parallel; the method of executing the roof in this case is to form a level on the top, from the top of the hips at the narrow end to the other extremity, as otherwise the roof must either wind, or be brought to a ridge forming a line inclined to the horizon; and either of the two last cases is very unsightly. But, that nothing should be wanting, the construction is given in the next figure.

Plate III.—*Figure* 6.—*To lay out an irregular roof in ledgment, with all its beams bevel upon the plan, so that the ridge may be level when finished ; the plan and height of the roof being given.*

The length of the common and hip-rafters are found as usual. From each side in the broadest end of the roof, through C and D, draw two lines parallel to the ridge-line

HIP. ROOF.

Fig 1.

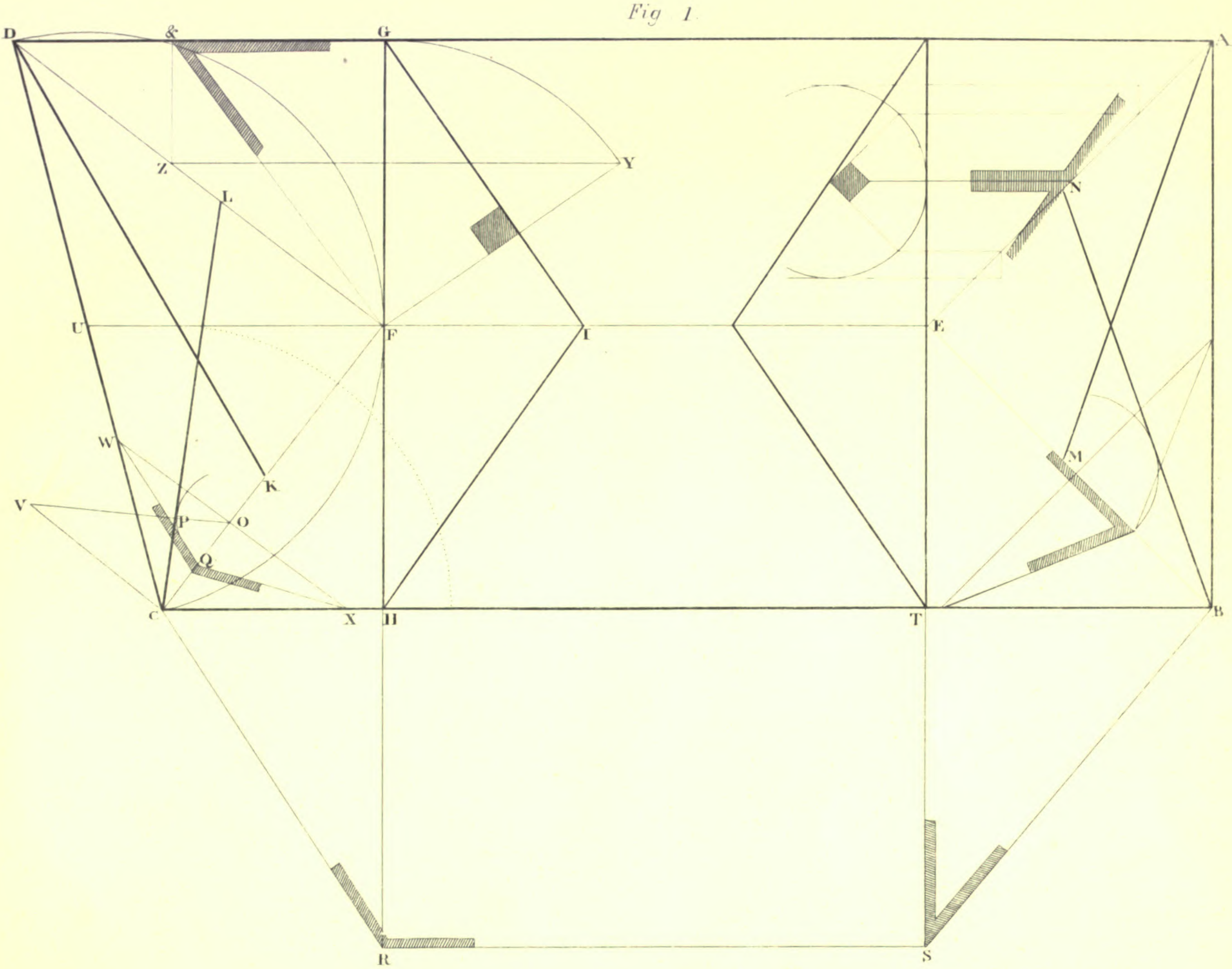
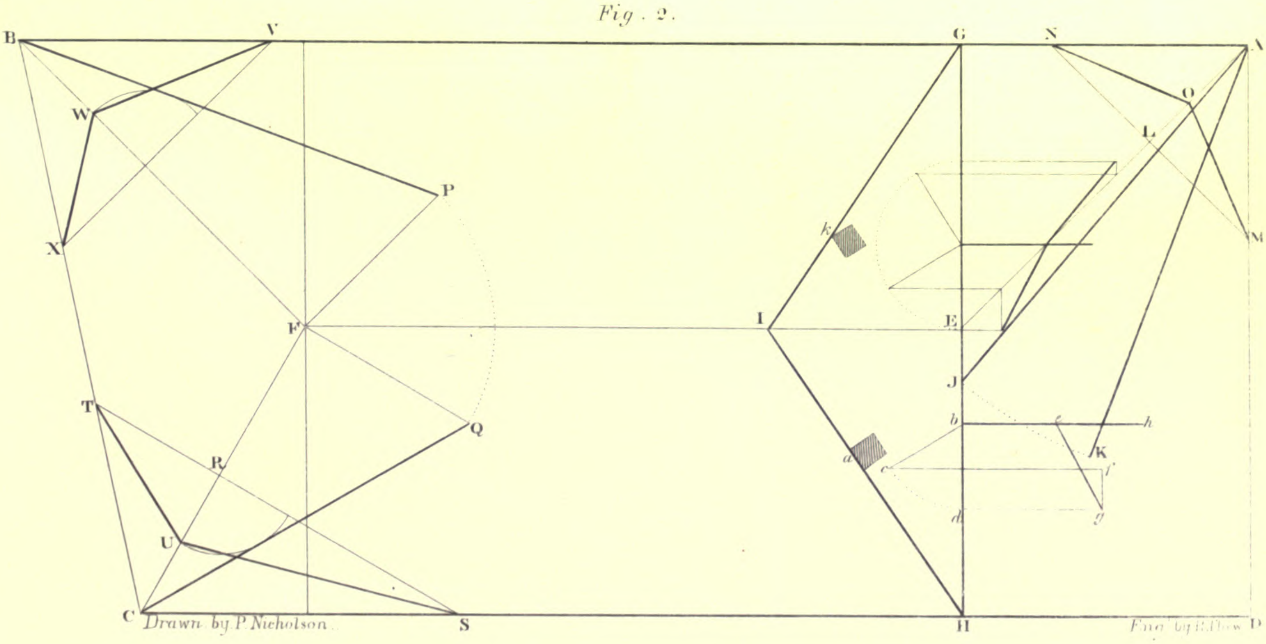


Fig. 2.



Drawn by P. Nicholson.

Eng. by R. Dew

Fig. 5.

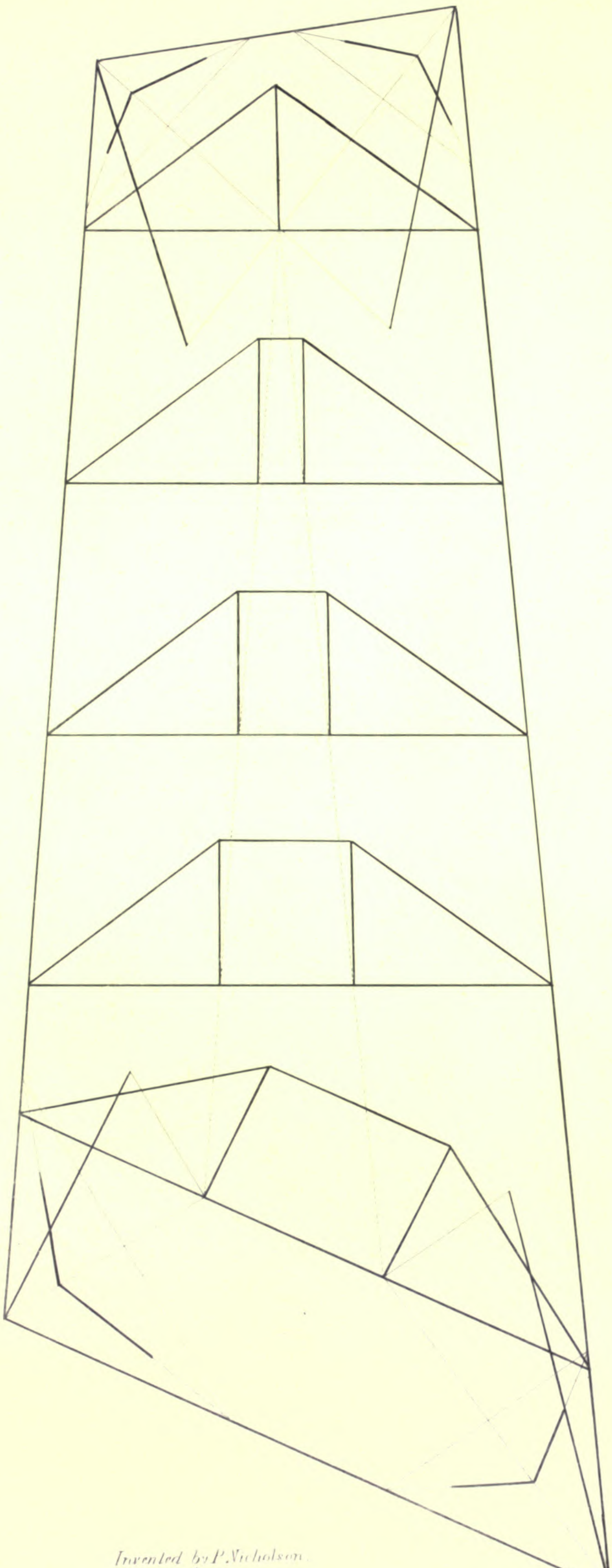


Fig. 3.

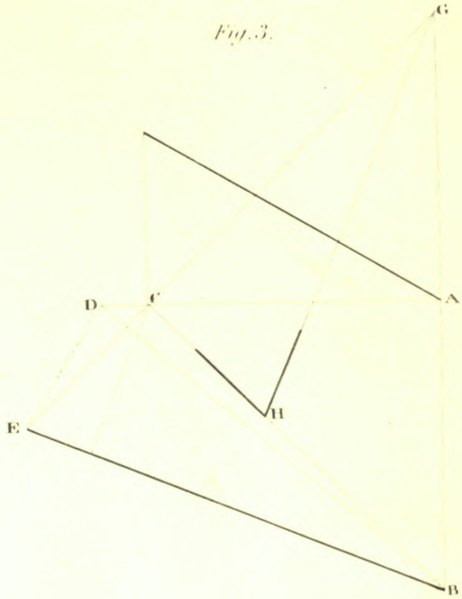
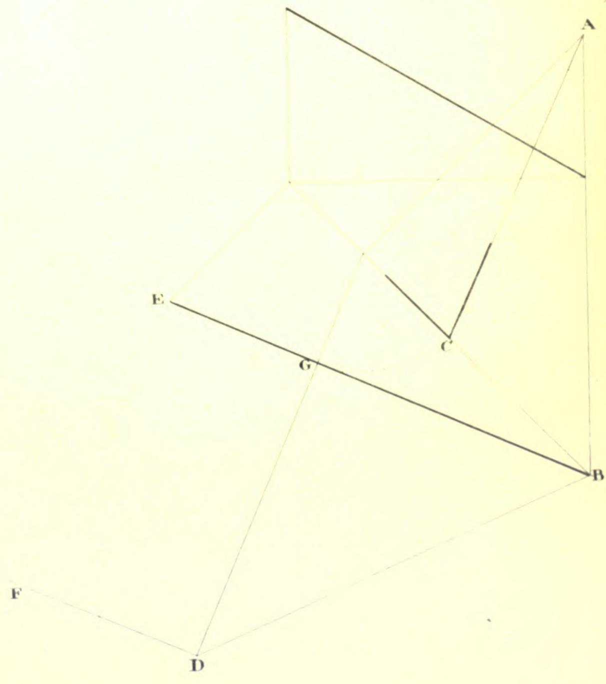


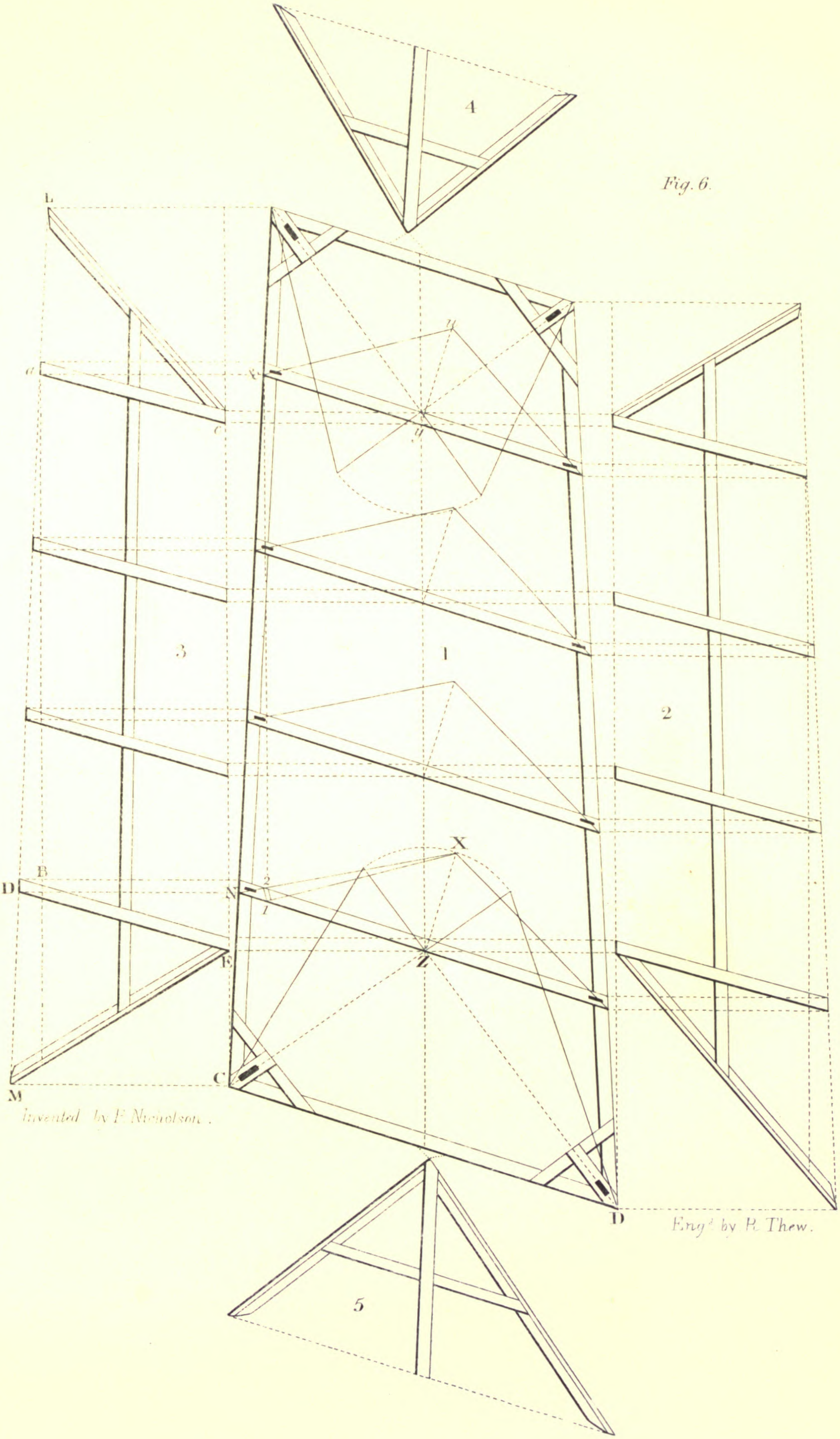
Fig. 4.



Invented by P. Nicholson.

Eng^d by R. Thew

HIP ROOF



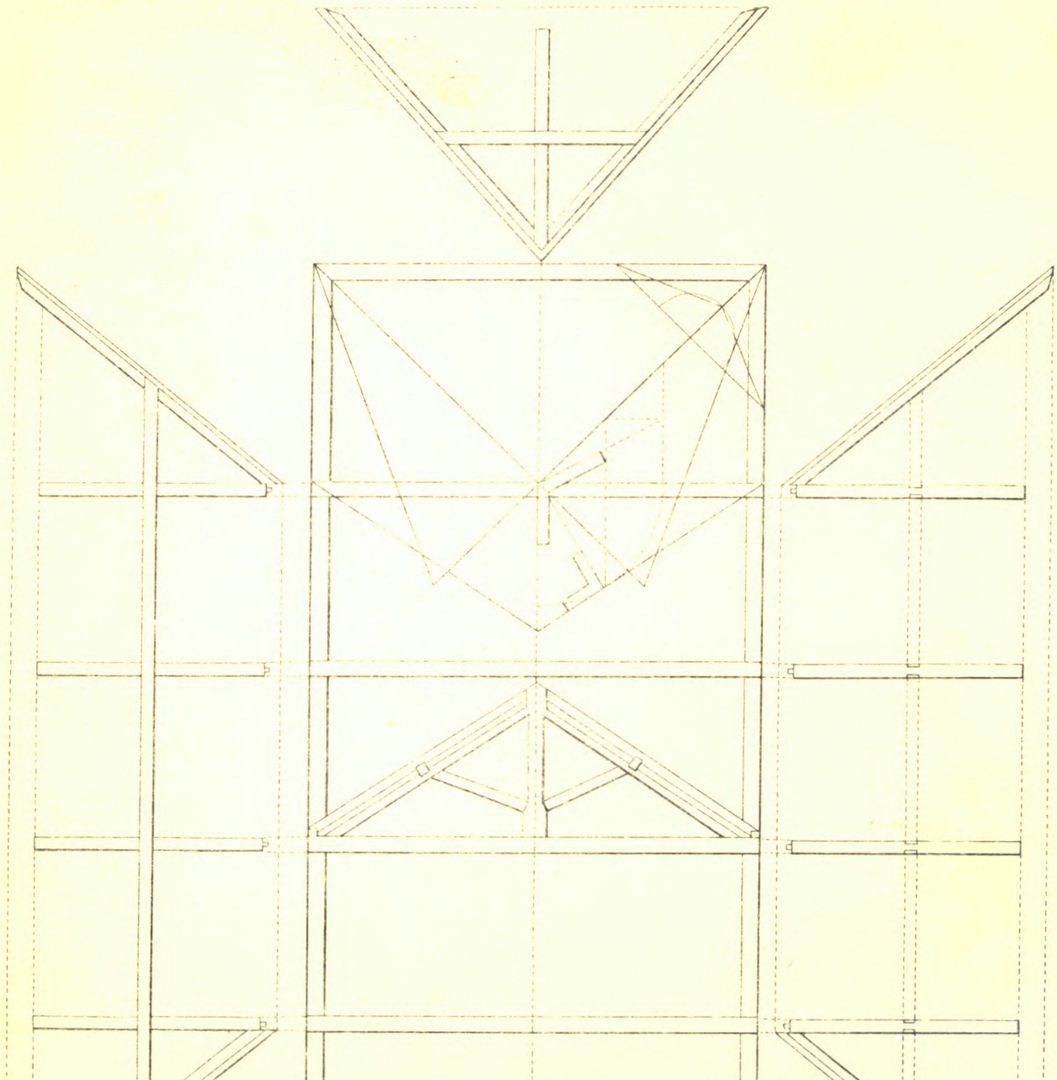
Invented by P. Nicholson.

Engd. by R. Thew.

HIP ROOF.

PLATE IV.

Fig. 7.



Invented by P. Nicholson

Eng.d by R. Thew.

draw lines from the centres and ends of the beams, perpendicular to the ridge-line, and lay out the two sides of the roof 2 and 3, by making E D at 3 equal to X N in 1, the length of the longest common rafter, and *c a* in 3 equal to *u &* at A, and so on with all the other rafters.

To find the winding of this roof.—Take *y &*, half the base of the shortest rafter, and apply this to the base of the longest rafter from *z* to 1; then the distance from 1 to 2 shows the quantity of winding.

To lay the sides in winding.—Lay a straight beam along the top ends of the rafters at E, that is, from *c* to E, and lay another beam along the line A B, parallel to it, to take the ends of the hip-rafters at M and L, and the beams to be made out of winding at first. Raise the beam that lies from *a* to B, at the point B, to the distance 1 2 above the level; which beam, being thus raised, will elevate all the ends of the rafters gradually, the same as they would be when in their places.

The same is to be understood of the other side D; the ends are laid down in the same manner as in making a triangle of any three dimensions.

In this example, the purlins are supposed to be framed into the sides of the rafters flush, so that the top of the purlins may be flush with the back of the rafters. The manner of framing the dragon beams and diagonal ties, is shown at the angles.

Plate IV.—*Figure* 7, shows the manner of framing a roof when the sides are square. The purlins are prepared to bridge over the rafters, which are notched out of the sides next to the back, in order to receive them.

HIPPIUM, in antiquity, that part of the hippodrome which was beaten by the horses' feet.

HIPPODROME, (from the Latin, *hippodromus*, composed of ἱππος, *horse*, and δρομος, *course*, of the verb δρεμω, *curro*, *I run*,) in antiquity, a list, or course, wherein chariot and horse-races were performed, and horses exercised.

The Olympian hippodrome, or horse-course, was a space of ground 600 paces long, surrounded with a wall, near the city Elis, and on the banks of the river Alpheus. It was uneven and in some degree irregular, on account of the situation; in one part was a hill of moderate height, and the circuit was adorned with temples, altars, and other embellishments. Pausanias has given us the following account of this hippodrome, or horse-course:—"As you pass out of the stadium, by the seat of the Hellanodics, into the place appointed for the horse-races, you come to the barrier (αφεςις) where the horses and chariots rendezvous before they enter into the course. This barrier, in its figure, resembles the prow of a ship, with the rostrum or beak turned towards the course. The other end, which joins on to the portico of Agaptus, (so called from him who built it) is very broad. At the extremity of the rostrum or beak, over a bar that runs across the entrance (επι κανονος,) is placed a figure of a dolphin in brass. (This dolphin is a symbol of Neptune, surnamed Hippian or Equestrian, for his having produced a horse by striking the earth with his trident, according to the fable; without the recollection of this circumstance, the reader might be surprised to meet with the figure of a dolphin in a horse-course.) On the two sides of the barrier, each of which is above 400 feet in length, are built stands or lodges, as well for the riding-horses as the chariots, which are distributed by lot among the competitors in those races; and before all these lodges is stretched a cable, from one end to the other, to serve the purpose of a barrier. About the middle of the prow is erected an altar, built of unburnt brick, which, every Olympiad, is plastered over with fresh mortar; and upon the altar stands a brazen eagle, which spreads out its wings to a great length. This eagle, by means of a machine, which is put in motion by the president of the horse-races, is made to mount up at once to such a height in the air, as to become visible to all the spectators; and, at the same time, the brazen dolphin before mentioned sinks to the ground. Upon that signal, the cables stretched before the lodges, on either side of the portico of Agaptus, are first let loose, and the horses there stationed move out and advance, till they come over against the lodges of those who drew the second lot, which are then likewise opened. The same order is observed by all the rest, and in this manner they proceed through the beak or rostrum; before which they are drawn up in one line, or front, ready to begin the race, and make trial of the skill of the charioteers and fleetness of the horses. On that side of the course, which is formed by a terrace raised with earth, and which is the largest of the two sides, near to the passage that leads out of the course across the terrace, stands an altar, of a round figure, dedicated to Taraxippus, the terror of the horses, as his name imports. The other side of the course is formed, not by a terrace of earth, but a hill of moderate height, at the end of which is erected a temple, consecrated to Ceres Chamyne, whose priestess has the privilege of seeing the Olympic games."

There is a very famous hippodrome at Constantinople, which was begun by Alexander Severus, and finished by Constantine. This circus, called by the Turks *Atmeidan*, is 400 paces long, and above 100 paces wide, *i. e.* geometrical paces of five feet each. Wheeler says, it was in length about 550 ordinary paces, and in breadth about 120; or, allowing each pace to be five feet, 2,750 feet long and 600 broad. At the entrance of the hippodrome there is a pyramidal obelisk of granite, in one piece, about 50 feet high, terminating in a point, and charged with hieroglyphics, erected on a pedestal of eight or ten feet above the ground. The Greek and Latin inscriptions on its base show that it was erected by Theodosius; the machines that were employed to raise it were represented upon it in basso-relievo.

The beauty of the hippodrome at Constantinople has been long since defaced by the rude hands of the Turkish conquerors; but, under the similar appellation of *Atmeidan*, it still serves as a place of exercise for their horses. Whether the Olympic hippodrome was so long or so wide as this of Constantinople, it is not now easy to determine; but it must evidently have been considerably longer than an ordinary stadium, in order to allow for the turnings of the chariots and horses round the pillars which served as metas or goals, without running against them, or against one another. The length of the course, or the distances between the two metas or goals, is not easily ascertained. It is probable, however, that the two pillars, *viz.*, that from which the horses started, and that round which they turned, which divided the course into two equal lengths, were two stadia distant from each other; consequently, the whole length of the race, for a chariot drawn by full-aged horses, consisting of 12 rounds, amounted to 48 stadia, or six Grecian miles; and that of the chariot drawn by colts consisted of eight rounds, or 32 stadia, or four Grecian miles—a Grecian mile, according to Arbuthnot's computation, being somewhat more than 800 paces, whereas an English mile is equal to 1,056. Pausanias informs us, that in the Olympic hippodrome, near that pillar called Nyssé, probably that which was erected at the lower end of the course, stood a brazen statue of Hippodamia, holding in her hand a sacred fillet or diadem, prepared to bind the head of Pelops for his victory over Œnomaus; and it is probable that the whole space between the pillars was filled with statues or altars, as that in the hippodrome at Constantinople seems to have been. Here, however, stood the tripod, or table, on which were placed the olive-crowns and the branches of palm destined for the victors. Besides the hippodromes at Olympia and Constantinople, there were courses of a similar kind at Carthage, Alexandria in Egypt, and other places.

We have some vestiges in England of the hippodrome, in which the ancient inhabitants of this country performed their races. The most remarkable is that near Stonehenge, which is a long tract of ground, about 350 feet, or 200 druid cubits wide, and more than a mile and three-quarters, or 6,000 druid cubits in length, enclosed quite round with a bank of earth, extending directly east and west. The goal and career are at the east end. The goal is a high bank of earth, raised with a slope inwards, on which the judges are supposed to have sat. The metæ are two tumuli, or small barrows, at the west end of the course. These hippodromes were called, in the language of the country, *rhedagua*, the racer *rhedagwr*, and the carriage *rheda*, from the British word *rhedeg, to run.* One of these hippodromes, about half a mile to the southward of Leicester, retains evident traces of the old name *rhedagua*, in the corrupted one of *rawdikes.* There is another of these, says Dr. Stukely, near Dorchester, another on the banks of the river Lowther, near Penryth, in Cumberland, and another in the valley just without the town of Royston.

HISTORICAL COLUMNS. *See* Column.

HOARDING, (from the Saxon,) an enclosure about a building, while erecting or under repair.

HOIST, an apparatus, or lift, for raising bodies from a lower to an upper story in a building.

HOLLOW, (from *hole*,) a concave moulding, whose section is about the quadrant of a circle. It is, by some writers, called *easement.*

Hollow Bricks, a kind of brick recently invented, moulded of various sizes and shapes, but usually of larger size than those commonly in use. They are mere shells, as it were, the heart of the brick being removed. The advantages claimed for such bricks are their superior strength when considered with reference to the quantity of material; and as a consequence, their comparative lightness, a quality which tells in very many ways. In the manufacture, they are more evenly baked and dried, the heat being equally distributed over every part; and hence their texture and hardness are more to be depended upon than in solid bricks. When used for houses, there is much less fear of damp than in new work as at present constructed; and an equability of temperature is ensured in the interior. Sound also is much less easily communicated by them than by common bricks. It has been proposed to construct them with grooves and ledges, or with some similar contrivance, so that they may be fitted compactly together in a short space of time, for temporary or other purposes. Floors also are proposed to be constructed of the same materials, so as to render buildings entirely fire-proof.

Hollow Newel, an opening in the middle of a staircase. The term is used in contradistinction to *solid newel*, into which the ends of the steps are built. In the hollow newel, or well-hole, the steps are only supported at one end by the surrounding wall of the staircase, the ends next the hollow being unsupported.

Hollow Wall, a wall built in two thicknesses, having a cavity between, either for the purpose of saving materials, or to preserve a uniform temperature in the apartments.

Hollow Quoins, in engineering, piers of stone or large bricks, made behind each lock-gate of a canal, which are formed into a hollow from top to bottom, to receive the rounded head of the lock-gates. In some instances the hollow quoin is formed of one piece of oak, cut to the proper shape, and fixed vertically against the wall. Cast-iron is also now frequently used for forming the hollow quoin or hinge for the lock-gates of large canals, or the entrance-basons to docks.

HOMESTALL, or HOMESTEAD, the place of a mansion-house; the word is used in some countries to signify the original house or dwelling attached to an estate.

HOMOLOGOUS, (from ὁμνος, *similar*, λογος, *reason*,) in geometry, the correspondent sides of similar figures.

HOOD-MOULD, a band or string carried over any aperture, such as a door or window; more particularly employed in Pointed architecture: the term is synonymous with Label and Weather Moulding.

HOOK PINS, in carpentry, iron pins made tapering towards one end, for the purpose of drawing the pieces of a frame together, as in floors, roofs, &c. In joinery, the pins which answer a similar purpose are called Draw-Bore Pins.

HOOKS, (Saxon) bent pieces of iron, used to fasten bodies together, or to hang articles on, out of the way. They are of various kinds, some of iron and some of brass; as casement-hooks, chimney-hooks, which are made of both brass and iron; curtain-hooks, hooks for doors and gates, double-line-hooks, tenter-hooks, armour-hooks, &c.

HORDING. *See* Hoarding.

HORIZONTAL CORNICE, of a pediment, the level part under the two inclined cornices.

Horizontal Line, in perspective, the vanishing lines of planes parallel to the horizon.

Horizontal Plane, a plane passing through the eye, parallel to the horizon, and producing the vanishing line of all level planes.

Horizontal Projection, the projection made on a plane parallel to the horizon. This may be understood either perspectively or orthographically, according as the projecting rays are directed to a given point, or are perpendicular to the horizon.

HORN, (Saxon) a name sometimes applied to the Ionic volute.

HORSE PATH, in engineering, a name sometimes applied to the towing-path by the side of canals, and narrow navigable rivers, for the use of the towing or track horses.

Horse Run, in engineering, a simple and useful modern contrivance, for drawing up loaded wheel-barrows of soil from the deep cuttings of canals, docks, &c. by the help of a horse which goes backwards and forwards, instead of round, as in a horse-gin.

HORSING BLOCK, a square frame of strong boards, used by navvigators or canal diggers for elevating the ends of their wheeling planks.

HOSPITAL. According to present usage, the term is applied to buildings endowed by public or private charity, as infirmaries, in which invalids are lodged and attended; but in olden times the term was used to signify any building erected for charitable purposes, as for the relief of the indigent, the entertainment of travellers, &c.

HOSTEL, or Hotel, a French term, anciently signifying a house, but now more commonly used for the palaces or houses of the king, princes, dukes, and great lords. The word is also applied to large inns, taverns, or places of public entertainment.

HOT-HOUSE, in horticulture, is a structure in which exotic plants are cultivated, under circumstances approximating, as closely as possible, to those under which they naturally exist; or it is used for accelerating the production of flowers and fruits of either indigenous or exotic plants. Hot-houses appropriated to the latter purposes are very frequently termed *forcing-houses.*

In the beginning of the seventeenth century, that description of hot-house generally termed the *green-house* began to be constructed in Germany; and one in the Apothecaries' Garden at Chelsea is mentioned by Ray in 1684. These, like many others of a later construction, had glass only in the front, which was perpendicular; and the mode of applying artificial heat exhibited little more knowledge of means for the end, than the remains of flues found in the ruins of the dwelling-houses and baths of the Romans.

In 1724, when Switzer published his treatise entitled "The Practical Fruit Gardener," the principles of managing hot-houses were still very imperfectly understood; for he observes, p. 305, that "peaches, nectarines, and apricots don't love to be forced; at least, the fruit is very seldom good: there being much occasion to keep the glasses close, the fruit is always rendered flat and insipid. This is not pure speculation, but the result of the practice that I have observed in the glass-houses at Brompton Park."

Considerable alterations, particularly in houses for grapes, were made towards the end of the last century. The most material improvement was the substitution of a slanting glass roof for a perpendicular glass front; but the advantages of this were much diminished by the heaviness of the sashes, and the large quantity of opaque matter which it was thought necessary to employ in order to ensure the durability of such structures.

In the present century great advances have been made in hot-house building, and more particularly since 1815. The application of heat by steam or hot water through iron pipes, and the admission of a greater quantity of light by glazing on metallic bars, instead of wooden sashes, are the principal features of these improvements. The employment of hollow bricks, too, will probably prove of great advantage, although we are not aware of their adoption in any building at present erected. *See* CONSERVATORY.

Those houses which are intended for the peach, nectarine, cherry, fig, &c. should in cold situations, be constructed against walls, and made with glass on one side. But in climates less severe, houses formed of glass on all the sides, having the trees so planted as to grow irregularly in the standard method, will be more beneficial as well as more ornamental.

For the forcing of vines, they may be of any kind of form, either small or large, according to the season at which the trees are to be brought into fruit. But a double-roofed house, with an inner roofing, is recommended as the most proper for general crops, as well as the cheapest in cost of erecting.

In the general construction of these houses, a wall of eight or ten feet in height, or more, is raised behind, with a low wall in front and both ends, on which is placed upright glass-work, four, five, or six feet in height, and a sloping glass roof, extending from the top of the front to the back wall. Internal flues for fire-heat, in winter, are also contrived, and a capacious oblong or square pit in the bottom space, in which to have a constant bark-bed, to furnish a continual regular heat at all seasons; so as in the whole to warm the enclosed internal air always to a certain temperature. Houses thus formed are generally used in raising pines.

Hot-houses are mostly ranged lengthwise, nearly east and west, that the glasses of the front and roof may have the full influence of the sun. This is the most convenient situation for common houses, either for pines or exotic plants. But some houses of the sort, instead of being placed in this direction, are ranged directly south and north, having a sloped roof to each side, like the roof of a house; as also to the front or south end; both sides and the south-end front being of glass. These houses are made from ten or twelve to fifteen or twenty feet wide, the length at pleasure; and from ten to twelve feet high in the middle, both sides fully head-height; being formed by a brick wall all round, raised only two or three feet on both sides, and south end; but carried up at the north end like the gable of a house. Upon the top of the side and south-end walling is erected the framing for the glass-work, which is sometimes formed two or three feet upright, immediately on the top of the wall, having the sloped glass-work above; and sometimes wholly of a continued slope on both sides, rising immediately from the top of the side-walls to that of the middle ridge. They are furnished either with one or two bark-pits; but if of any considerable width, generally with two, ranging parallel, one under each slope of the top glass, and separated by a two-foot path running along the middle of the house, and sometimes continued all round each pit, with flues ranged along against the inside walls; the whole terminating in an upright funnel, or chimney, at the north end of the building. There are other hot-houses which are formed entirely on the square, having a ten or twelve feet brick wall behind; that of the front, and both sides, being only two or three feet high, for the support of the glass-work, which is placed nearly upright almost the same height, and sloped above on both sides and front, which are wholly of glass. These are furnished within with bark-pits and flues, as in the previous instances.

In particular cases they are made semicircular, or entirely circular, being formed with a two or three feet brick wall supporting the glass-framing, which is continued quite round. The bark-pit is also circular, and the flues, after being carried all round the inside of the walling, terminate in a chimney on the northern side of the house. However, the first forms are probably the best for general purposes.

Hothouses on these plans are made of different dimensions, according to the size of the plants they are designed to contain. For common purposes they should be only of a moderate height, not exceeding ten or twelve to fourteen feet behind, and five or six in front; some are, however, built much more lofty behind, to give sufficient height for the taller-growing exotics, placed toward the back part. Those of the first-described size are, however, best adapted to the culture of pines, and other moderate-growing plants, as well as for forcing in. Very lofty houses require a greater force of heat, and by the glasses being so high, the plants naturally tending towards the glasses, receive less benefit from the sun and are apt to draw up too fast into long slender leaves and stems. Where the top-glasses are at a moderate distance from the plants, they receive the benefit of the sun's heat more fully, which is essential in winter, become more stalky at bottom, assume (particularly the pine-apple) a more robust and firm growth, and are rendered more capable of producing large fruit in the season.

After having determined on the dimensions of the house as to length and width, the foundations of brick-work should be set out accordingly, allowing due width at the bottom to support the flues a foot wide, wholly on the brick basis; detached an inch or two from the main walls; then setting off the back or north-wall, a brick and a half or two bricks thick, and the front and end walls nine inches, carry up the back wall from ten to fourteen feet high; those of the front and ends to be only from about two feet to a yard. Take care in carrying up the walls to allot a proper space for a door-way, at one or both ends, towards the back part; setting out also the furnace or fire-place of the flues in the bottom foundation towards one end of the back wall behind, formed also of brick-work, made to communicate with the lowermost flue within. When the house is of great length, as forty feet or more, a fire-place at each end may be necessary; or, if more convenient, both may be in the back part of the end walls, or in the middle way of the back wall; each must communicate with a separate range of flues. In either case they should be formed wholly on the outside of the walls, about twelve or fourteen inches wide in the clear, but more in lengthwise inward; the inner end terminating in a funnel to communicate internally with the flues. An iron-barred grate should be fixed at bottom to support the fuel, and calculated for coal, wood, peat, turf, &c. An ash-hole should be made underneath. The mouth or fuel-door should be about ten or twelve inches square, having an iron frame and door fixed to shut with an iron latch, as close as possible. The whole furnace should be raised sixteen or eighteen inches in the clear, finishing the top archwise. Then continue carrying up the walls of the building regularly, and on the inside erect the flues close along the walls.

It is sometimes advantageous to have the flues a little detached from the walls, one, two, or three inches, that, by being thus distinct, the heat may arise from both sides, which will be an advantage in more effectually diffusing the whole heat internally in the house; as, when they are attached close to the walls, a very considerable portion of the heat is lost in the part of the wall behind. In contriving the flues, they should be continued along the front and both ends, in one range at least, in this order. But it is better if they are raised as high as the outward front and end walls, in one or two ranges, one over the other. On the tops of these may be placed pots of many small plants, both of the exotic and forcing kinds, with much convenience.

In the construction of the flues, make them generally about a foot wide in the whole, including six or eight inches in the clear, formed with a brick-work on edge; the first lower flue should communicate with the furnace or fire-place without, and be raised a little above it, to promote the draught of heat more freely. Continue it along above the internal level of the floor of the back alley or walk of the house the above width, and three bricks on edge deep, returning it in two or three ranges over one another, next the back wall, and in one or two along the ends and front wall, as the height may admit; each return two bricks on edge deep, and tiled or bricked over. In the beginning of the first bottom-flue a sliding iron regulator may be fixed, to use occasionally, in admitting more or less heat, being careful that the brick-work of each flue is closely jointed with the best sort of mortar for that purpose, and well pointed within, that no smoke may break out. Have each return closely covered with broad square paving tiles on the brick-work; covering the uppermost flues also with broad thick flat tiles, the whole width, all very closely laid, and joined in mortar. The uppermost, or last range of flues, should terminate in an upright vent or chimney, at one end of the back wall; and where there are two separate sets of flues, there should be a chimney at each end. An iron slider in the termination of the last flue next the chimney may also be provided, to confine the heat more or less on particular occasions, as may be found necessary.

Sometimes, in very wide houses, in erecting the flues, spare ones, for occasional use, are continued round the bark-pit, carried up against the surrounding wall, but detached an inch or two, to form a vacancy for the heat to come up more beneficially, and that, by having vent, it may not dry the tan of the bark-bed too much. In the beginning a sliding iron regulator may be fixed, either to admit or exclude the heat, as expedient; so that the smoke, by running through a larger extent, may expend its heat wholly in the flues; before it be discharged at the chimney. Great care should be taken that neither the fire-place nor flues be carried too near any of the wood-work of the buildings.

After this work is done, proceed to set out the cavity for the bark-pit, first allowing a space next the flues for an alley or walk, eighteen inches or two feet all round, and then in the middle space form the pit for the bark-bed, six or seven feet wide, the length in proportion to that of the house, and a yard or more deep; enclosing it by a surrounding wall. It may either be sunk at bottom a little in the ground, raising the rest above by means of the parapet wall; or, if there is danger of wet below, it should be raised a little above the general surface. The surrounding wall should be nine inches, but a half-brick wall is often made to do, especially for that part which forms the parapet above ground. It should be coped all round with a timber plate or kirb, framed and mortised together, which effectually secures the brick-work in its proper situation.

The bottom of the pit should be levelled and well rammed, and, if paved with any coarse material, it is of advantage in preserving the bark. The path or alley round the pit should also be neatly paved with brick or stone, as may be most convenient.

The glass part for enclosing the whole, should consist of a close continued range of glass sashes all along the front, both ends and roof, quite up to the back wall; each sash being three feet or three feet six inches wide; and for the support of these, framings of timber must be erected in the brick walling, conformable to the width and length of the sashes, the whole being neatly fixed.

For the reception of the perpendicular glasses in the front and ends, a substantial timber plate must be placed along the top of the front and end walls, upon which should be erected uprights, at proper distances, framed to a plate or crown-piece above, of sufficient height to raise the whole front head-high, both ends corresponding with the front and back. To receive the sloping bars from the frame-work in front, a plate of timber must be framed to the back wall above, proper grooves being formed in the front plate below and above, to receive the ends of the perpendicular sashes, sliding close against the outside of the uprights all the way along the front. Or they may be contrived for only every other sash, to slide one on the side of the other, but the former is the better method.

From the top of the upright framing in front should be carried substantial cross-bars or bearers, sloping to the back wall, where they are framed at both ends to the wood-work or plates, at regular distances, to receive and support the sloping glass sashes of the roof. These are placed close together upon the cross-bars or rafters, and generally range in two or more tiers, sliding one over the other, of sufficient length together to reach quite from the top of the upright framing in front to the top of the back wall. The cross-bars should be grooved lengthwise above, to carry off wet falling between the frames of the sloping lights; and the upper end of the tier of glasses should shut close up to the plate in the wall behind, running under a proper coping of wood or lead which must be fixed along above close to the wall, and lapped down, of due width to cover, and shoot off the wet sufficiently from the upper termination of the top sashes. Some wide houses have, exclusive of the sliding glass sashes of the main slope, a shorter upper tier of glass fixed; the upper ends being secured under a coping as above, and the lower ends lapping over the top ends of the upper sliding tier, and this over that below in the same manner, so as to shoot the wet clear over each upper end or termination. Likewise, along the under outer edge of the top plate or crown-piece in front may be a small channel to receive the water from the sloping glass sashes, and convey it to one or both ends without running down upon the upright sashes, being careful that the top part behind be well framed and secured water-tight, and the top of the back wall finished a little higher than the glass with a neat coping the whole length of the building.

The bars of wood which support the glasses should be neatly formed, and made neither very broad nor thick, to intercept the rays of the sun. Those, however, at top, should be made strong enough to supp rt the glasses without bending under them. In wide houses, uprights are arranged within, at proper distances to support the cross rafters more perfectly than could otherwise be the case.

But in respect to the glass-work in the sloping sashes, the panes of glass should be laid in putty, with the ends lapping over each other about half an inch, the vacancies of which are, in some, closed up at bottom with putty; others leave each lapping of the panes open, for the admission of air, and that the rancid vapours arising from the fermentation of the bark-bed, &c., within, may thereby be kept in constant motion, to diminish condensation, and also, that such as condense against the glasses may discharge themselves at those places without dropping upon the plants. The upright sashes in front may either be glazed as above, or the panes laid in lead-work; being very careful to have the glazing well performed, and proof against any wet that may happen to beat against them. The doors should have the upper parts sashed and glazed to correspond with the other glass-work of the house.

On the inside, the walls should be plastered, pargeted, and white-washed: and all the wood-work, within and without, painted white in oil-colour. Some, however, have the back wall painted or coloured rather dark.

Ranges of narrow shelves, for pots of small plants, may be erected where most convenient, some behind over the flues, a single range near the top glasses towards the back part, supported either by brackets suspended from the cross-bars above, or by uprights erected on the parapet wall of the bark-pit. A range or two of narrow ones may also be placed occasionally along both ends above the flues, where there is a necessity for a very great number.

In wide houses, where the cross-bars or bearers of the sloping or top glass sashes appear to want support, some neat uprights, either of wood or iron, may be erected upon the bark-bed walling, at convenient distances, and high enough to reach the bearers above. This is a neat mode of affording them support.

On the outside, behind, should be erected a close shed, the whole length, or at least a small covered shed over each fire-place, with a door to shut, for the convenience of attending the fires. The former is much the best, as it will serve to defend the back of the house from the outward air, and to stow fuel; also for garden tools when not in use; as well as to lay portions of earth in occasionally, to have it dry for particular purposes in winter and early spring, as in forcing-frames, &c.

Sometimes hot-houses are furnished with top-covers, to draw over the glass sashes occasionally, in time of severe frosts and storms; and sometimes by slight sliding shutters, fitted to the width of the separate sashes; but these are inconvenient, and require considerable time and trouble in their application. At other times they are formed of painted canvass, on long poles or rollers, fixed lengthwise along the tops of the houses, just above the upper ends of the top sashes, which, by means of lines and pulleys, are readily let down and rolled up, as there may be occasion.

HOVEL (Saxon), a low building, with some part of the lower side open, to afford shelter to young animals during stormy weather.

HOVELING, the carrying up of the sides of a chimney, that when the wind rushes over the mouth, the smoke may escape below the current, or against any one side of it. The working up of the sides is covered at the top with tiles or bricks in a pyramidal form, in order to get rid of the inconvenience occasioned by adjoining buildings being higher than the chimney, or by its being in the eddy of any very lofty buildings, or in the vicinity of high trees; in which cases the covered side must be towards the building.

HOUSE, a habitation, or a building constructed for sheltering a man's person and goods from the inclemencies of the weather, and the injuries of ill-disposed persons. Houses differ in magnitude, being of two or three, and four stories; in the materials of which they consist, as wood, brick, or stone; and in the purposes for which they are designed, as a manor-house, farm-house, cottage, &c.

A pleasure-house, or country-house, is one built for occasional residence, and for the pleasure and benefit of retirement, air, &c. This is the *villa* of the ancient Romans; and what in Spain and Portugal they call *quinta;* in Provence, *cassino;* in some other parts of France, *closerie;* in Italy, *vigna.*

The citizens of Paris have also their *maisons de bouteilles* (bottle-houses) to retire to, and entertain their friends; which, in Latin, might be called *micæ;* the emperor Domitian having a house built for the like purpose, mentioned under this name by Martial.

It is a thing principally to be aimed at, in the site or situation of a country-house, or seat, that it have wood and water near it.

It is far better to have a house defended by trees than hills: for trees yield a cooling, refreshing, sweet, and healthy air and shade during the heat of the summer, and very much break the cold winds and tempests from every point in the winter. The hills, according to their situation, defend only from certain winds; and, if they are on the north side of the house, as they defend from the cold air in the winter, so they also deprive you of the cool refreshing breezes which are commonly blown from thence in the summer; and if the hills are situate on the south side, they then prove also very inconvenient.

A house should not be too low-seated, since this precludes the convenience of cellars. If you cannot avoid building on low grounds, set the first floor above the ground the higher, to supply what you want to sink in your cellar in the ground; for in such low and moist grounds, it conduces much to the dryness and healthiness of the air to have cellars under the house, so that the floors be good, and ceiled underneath. Houses built too high, in places obvious to the winds, and not well defended by hills or trees, require more materials to build them, and more also of reparations to maintain them; and they are not so commodious to the inhabitants as the lower-built houses, which may be built at a much easier rate, and also as complete and beautiful as the other.

In houses not above two stories with the ground-room, and not exceeding twenty feet to the wall-plate, and upon a good foundation, the length of two bricks, or eighteen inches for the heading course, will be sufficient for the ground-work of any common structure, and six or seven courses above the earth to a water-table, where the thickness of the walls is abated or taken in on either side the thickness of brick, namely, two inches and a quarter.

For large and high houses, or buildings of three, four, or five stories, with the garrets, the walls of such edifices ought to be from the foundation to the first water-table three heading courses of brick, or 28 inches at least; and at every story a water-table, or taking in on the inside for the girders and joists to rest upon, laid into the middle, or one quarter of the wall at least, for the better bond. But as for the innermost or partition wall, a half brick will be sufficiently thick;

and for the upper stories, nine inches or a brick length will suffice.

The general principles of the construction of edifices and private houses will be found under the article Building. We shall under this head give a description of the private houses of the ancients: —

Of the private dwellings of the ancients, we have but little or no account, and it is probable that they possessed but small pretensions to architectural grandeur. We hear of temples, palaces, and such like public buildings, and of these we have careful and detailed descriptions, but of the habitations of the mass of the people, we have only a cursory notice. This fact would lead us to believe that but little attention was paid to domestic buildings of the earlier periods of history, and such indeed seems to have been the case; all the care of the people being confined to the temples of their gods, and the palaces of their governors. With a proper though misplaced zeal, the taste of their architects was exhausted in erecting and adorning the habitations of their deities; and indeed in all ages and countries, the art seems to be principally indebted for its progress to the religious feelings of mankind.

In his description of Babylon, Herodotus speaks of houses being ranged on either side of the various streets into which the city was divided, and of others of a smaller character, on either side of the outer wall, so placed as to allow of a wide passage or roadway between the two ranges. The former are described as consisting of three or four stories, and the latter of only one story.

If we may form a judgment from the paintings of the ancient Egyptians, their domestic buildings were of very uniform character. Some houses were two or three stories in height, and these seem to have belonged to the more common sort, but the larger mansions were only of one story, but of considerable extent in plan. They consisted of one or more rectangular courts surrounded by chambers similar to the existing specimens of Roman construction; or sometimes a group of building was placed in the centre of such a court. The roofs, as in all Eastern buildings, were flat, and probably covered with an awning, as a protection from the heat.

According to Pliny, the Greeks originally dwelt in caves, and were taught the art of house-building by two brothers, Euryalus and Hyperbius, who were Tyrrhenians, from which nation buildings of all kinds are said to have been introduced into Greece. During their early history, up to the time of Aristides and Pericles, their dwellings were of a very simple description, nor did they arrive at any magnificence until the time of Alexander, when they had given themselves over to a luxurious mode of living. At this period their dwellings became of great extent, and were very highly embellished, being similar in form and arrangement to those of the Romans,—of which in all probability they afforded the idea—but far inferior to them in extent and magnificence. Ere, however, the Romans had become thus extravagant in the adornment of their villas, they had passed through the same stages as their predecessors, and it was not until by their conquests they had become acquainted with the luxury of Asia and Greece, that they began to erect such splendid mansions. The villa of Marcus Cato, we are told, was so rude, that the walls were not even plastered; nor did that of Scipio Africanus, or the Villa Publica, greatly excel in richness of decoration. The first houses of the Romans were nothing better than simple cottages thatched with straw; and when the city was rebuilt after it was burned by the Gauls, the houses were mostly constructed of wood and covered with shingles, although of so great a height as to become dangerous. This was the case, even in the reign of Augustus. The greater part of the city was again destroyed by fire in the time of Nero, and was rebuilt in a more substantial and elegant manner; but we can form only a remote idea of the houses, having no examples remaining.

The country seats or villas were the dwellings on which the higher classes expended the greatest care, and a full description of these will be found in Pliny's Letters, which we proceed to give, but, before doing so, insert some remarks and directions on the subject by Vitruvius.

Of the private and public Apartments of Houses, and of their Construction according to the different Ranks of People; (from Vitruvius.)

"These buildings being disposed to the proper aspects of the heavens, then the distribution of such places in private houses as are appropriated to the use of the master of the house, and those which are common for strangers, must be also considered: for into those that are thus appropriated, no one can enter unless invited; such as the cubiculum, the triclinium, the bath, and others of similar use. The common are those which the people unasked may legally enter; such are the vestibulum, cavædium, peristylium, and those that may answer the same purposes: but to persons of the common rank, the magnificent vestibulum, tablinum, or atrium, are not necessary, because such persons pay their court to those who are courted by others.

"People who deal in the produce of the country must have stalls and shops in their vestibules, and cryptæ, horreæ, and apothecæ, in their houses, which should be constructed in such a manner as may best preserve their goods rather than be elegant. The houses of bankers, and public offices, should be more commodious and handsome, and made secure from robbers; those of advocates and the learned, elegant and spacious, for the reception of company; but those of the nobles, who bear the honours of magistracy, and decide the affairs of the citizens, should have a princely vestibulum, lofty atrium, and ample peristylium, with groves and extensive ambulatories, erected in a majestic style; besides libraries, pinacotheeas, and basilicas, decorated in a manner similar to the magnificence of public buildings; for in these places, both public affairs and private causes are oftentimes determined. Houses therefore being thus adapted to the various degrees of people, according to the rules of decor, explained in the first book, will not be liable to censure, and will be convenient and suitable to all purposes. These rules also are applicable, not only to city houses, but likewise to those of the country; except that in those of the city the atrium is usually near the gate, whereas in the country pseudo-urbana, the peristylium is the first, and then the atrium; having a paved porticus around, looking to the palestra and ambulatories.

"I have, as well as I have been able, briefly written the rules relative to city houses, as I proposed. I shall now treat of those in the country, how they may be made convenient, and in what manner they should be disposed.

"*Of Country Houses, with the description and use of their several Parts.*

"In the first place, the country should be examined with regard to its salubrity, as written in the first book concerning the founding of a city, for in like manner villas are to be established. Their magnitude must be according to the quantity of land and its produce. The courts and their size must be determined by the number of cattle and yokes of oxen to be there employed. In the warmest part of the court, the kitchen is to be situated, and adjoining thereto the ox-house, with the stalls turned towards the fire and the eastern sky; for the cattle seeing the light and fire, are thereby rendered smooth-coated; even husbandmen, although ignorant of the nature of aspects, think that cattle should look to no other part of the heavens than to that where the sun rises. The breadth of the ox-house should not be less than ten feet, nor more than fifteen: the length should be so much as to allow no less than seventeen feet to each yoke.

"The bath also is to be adjoined to the kitchen, for thus the place of bathing will not be far from those of the husbandry occupations. The press-room should be near the kitchen, that it may be convenient for the olive business; and adjoining thereto the wine-cellar, having windows to the north; for, should they be toward any part which may be heated by the sun, the wine in that cellar would be disturbed by the heat, and become vapid. The oil-room is to be so situated as to have its light from the southern and hot aspects; for oil ought not to be congealed, but be attenuated by a gentle heat. The dimensions of these rooms are to be regulated by the quantity of fruit, and the number of the vessels; which, if they be cullearin, should in the middle occupy four feet. Also, if the press be not worked by screws, but by levers, the press room should not be less than forty feet long, that the pressers may have sufficient space; the breadth should not be less than sixteen feet, by which means there will be free room to turn, and to dispatch the work; but if there be two presses in the place, it ought to be twenty-four feet broad. The sheep and goat-houses should be so large, that not less than four feet and a half, nor more than six feet, may be allowed to each animal. The granary should be elevated from the ground, and look to the north or east, for thus the grain will not so soon be heated, but, being cooled by the air, will endure the longer; the other aspects generate worms and such vermin as usually destroy the grain.

"The stable, above all in the villa, should be built in the warmest place, and not look toward the fire, for if these cattle be stalled near the fire, they become rough-coated; nor are those stalls unuseful which are placed out of the kitchen, in the open air, toward the east; for in the winter time, when the weather is serene, the beasts, being led thither in the morning, may be cleaned while they are taking their food.

"The barn, hay-room, meal-room, and mill, are placed without the villa, that it may be more secure from the danger of fire.

"If the villa is to be built more elegantly, it must be constructed according to the symmetry of city houses, before described: but so as not to impede its use as a villa.

"Great care ought to be taken, that all buildings have sufficient light, which in villas is easily obtained; because there are no walls near to obstruct it. But in the city, either the height of the party-walls, or the narrowness of the streets, may occasion obscurity. It may, however, be thus tried: on the side where the light is to be received, let a line be extended from the top of the wall that seems to cause the obscurity, to that place to which the light is required; and if, when looking up along that line, an ample space of the clear sky may be seen, the light to that place will not be obstructed; but if beams, lintels, or floors, interfere, the upper parts must be opened, and thus the light be admitted. The upper rooms are thus to be managed; on whatsoever part of the heavens the prospect may lie, on that side the places of the windows are to be left, for thus the edifice will be best enlightened. As in tricliniums and such apartments, the light is highly necessary, so also is it in passages, ascents, and staircases, where people carrying burdens frequently meet each other.

"I have explained, as well as I have been able, the distribution of our buildings, that they may not be unknown to those who build; I shall now also briefly explain the distribution of houses, according to the custom of the Greeks, that they also may not be unknown.

"*Of the Disposition of the Houses of the Greeks.*

"The Greeks use no atrium, nor do they build in our manner; but from the gate of entrance they make a passage of no great breadth; on one side of which is the stable, on the other, the porters' rooms, and these are directly terminated by the inner gates. This place between the two gates is called by the Greeks *thyroreion.* After that, in entering, is the peristylium, which peristylium has porticos on three sides. On that side which looks to the south, are two antæ, at an ample distance from each other, supporting beams, and so much as is equal to the distance between the antæ, wanting a third part, is given to the space inwardly; this place is called by some *prostas*, by others *parastas.* From this place, more inwardly, the great œci are situated, in which the mistress of the family, with the workwomen, resides. On the right and left of the prostas, are cubiculæ, of which one is called *thalamus*, and the other *amphithalamus;* and in the surrounding porticos, the common tricliniums, cubiculums, and family rooms are erected. This part of the edifice is called *gynæconitis.*

"Adjoining to this is a larger house, having a more ample peristylium, in which are four porticos of equal height, or sometimes the one which looks towards the south has higher columns; and this peristylium, which has one portico higher than the rest, is termed *rhodian.* In these houses they have elegant vestibulums, magnificent gates, and the porticos of the peristyliums are ornamented with stucco, plaster, and lucunariæ, of inside work (wood.) In the porticos which look to the north, are the Cyzicene triclinium, and pinacothecæ: to the east are the libraries, to the west the exedræ, and in those looking to the south are the square œci, so large that they may easily contain four sets of dining couches, with the attendants, and a spacious place for the use of the games. In these œci are made the men's dining couches, for it is not their custom for the mothers of families to lie down to dine. This peristylium and part of the house is called *andronitides*, because here the men only are invited without being accompanied by the women.

"On the right and left also, small houses are erected, having proper gates, triclinæ, and convenient cubiculæ, that when strangers arrive, they may not enter the peristylium, but be received in this hospitalium; for when the Greeks were more refined and opulent, they prepared tricliniæ, cubiculæ, and provisions, for strangers; the first day inviting them to dinner, afterwards sending them poultry, eggs, herbs, fruits, and other productions of the country. Hence the pictures representing the sending of gifts to strangers, are by the painters called *zenia.* Masters of families, therefore, while they abode in the hospitium, seemed not to be from home, having the full retirement in these hospitaliums. Between the peristylium and hospitalium are passages, which are called *mesaulæ;* because they are situated between two *aulæ*; these are by us called *andronas;* but it is remarkable that the Greeks and Latins do not in this agree; for the Greeks give the name of *andronas* to the œcus where the men usually dine, and which the women do not enter.

"It is the same also with some other words, as *xystos*, *prothyrum*, *telamones*, and others; for *xystos* is the Greek appellation of those broad porticos, in which the athletæ exercise in winter time; whereas, we call the uncovered ambulatories *xystos;* and which the Greeks call *peridromidas.* The *vestibula*, which are before the gates, are by the Greeks called *prothyra;* whereas, we call *prothyra* that which the Greeks call *diathyra.* The statues of men bearing mutules or cornices we call *telamones*, for what reason is not to be found in history; but the Greeks call them *atlantes;* Atlas being in history represented as supporting the world; for he was the first who, by his ingenuity and diligence, discovered and taught mankind the course of the sun and moon, the rising and setting of all the planets, and the revolutions of the heavens; for which benefit the painters and statuaries represented him bearing the whole earth; and the Atlantides, his children, which we call *Vergilius*, and the Greeks *Pheïades*, are placed among the stars in the heavens. I have not, however, mentioned this in order to change the customary names or manner of discoursing, but only to explain them, that these things might not be unknown to the lovers of knowledge."

Extracts from Pliny's Letters.

Description of the villa at Laurentinum.

"You are surprised, it seems, that I am so fond of my Laurentinum, or (if you like the appellation better) my Laurens; but you will cease to wonder, when I acquaint you with the beauty of the villa, the advantages of its situation, and the extensive prospect of the sea-coast. It is but seventeen miles distant from Rome; so that, having finished my affairs in town, I can pass my evenings here, without breaking in upon the business of the day. There are two different roads to it: if you go by that of Laurentum, you must turn off at the fourteenth mile-stone; if by Ostia, at the eleventh. Both of them are, in some parts, sandy, which makes it somewhat heavy and tedious, if you travel in a carriage, but easy and pleasant to those who ride on horseback. The landscape, on all sides, is extremely diversified, the prospect, in some places, being confined by woods, in others extending over large and beautiful meadows, where numberless flocks of sheep and herds of cattle, which the severity of the winter has driven from the mountains, fatten in the vernal warmth of this rich pasturage. My villa is large enough to afford all desirable accommodations, without being extensive. The porch before it is plain, but not mean, through which you enter into a portico in the form of the letter D, which includes a small but agreeable area. This affords a very commodious retreat in bad weather, not only as it is enclosed with windows, but particularly as it is sheltered by an extraordinary projection of the roof. From the middle of this portico you pass into an inward court, extremely pleasant, and from thence into a handsome hall, which runs out towards the sea; so that when there is a south-west wind, it is gently washed with the waves, which spend themselves at the foot of it. On every side of this hall, there are either folding-doors, or windows equally large, by which means you have a view from the front and the two sides, as it were, of three different seas: from the back part, you see the middle court, the portico, and the area; and, by another view, you look through the portico, into the porch, from whence the prospect is terminated by the woods and mountains which are seen at a distance. On the left-hand of this hall, somewhat farther from the sea, lies a large drawing-room, and beyond that, a second of a smaller size, which has one window to the rising, and another to the setting sun: this has, likewise, a prospect of the sea, but being at a greater distance, is less incommoded by it. The angle which the projection of the hall forms with this drawing-room, retains and increases the warmth of the sun; and hither my family retreat in winter to perform their exercises: it is sheltered from all winds, except those which are generally attended with clouds, so that nothing can render this place useless, but what, at the same time, destroys the fair weather. Contiguous to this, is a room forming the segment of a circle, the windows of which are so placed, as to receive the sun the whole day: in the walls are contrived a sort of cases, which contain a collection of such authors whose works can never be read too often. From hence you pass into a bed-chamber through a passage, which, being boarded, and suspended, as it were, over a stove which runs underneath, tempers the heat which it receives, and conveys it to all parts of this room. The remainder of this side of the house is appropriated to the use of my slaves and freed-men: but most of the apartments, however, are neat enough to receive any of my friends. In the opposite wing, is a room ornamented in a very elegant taste; next to which lies another room, which, though large for a parlour, makes but a moderate dining-room; it is exceedingly warmed and enlightened, not only by the direct rays of the sun, but by their reflection from the sea. Beyond, is a bed-chamber, together with its ante-chamber, the height of which renders it cool in summer; as its being sheltered on all sides from the winds makes it warm in winter. To this apartment another of the same sort is joined by one common wall. From thence you enter into the grand and spacious cooling-room, belonging to the bath, from the opposite walls of which, two round basons project, sufficiently large to swim in. Contiguous to this is the perfuming-room, then the sweating-room, and next to that, the furnace which conveys the heat to the baths: adjoining, are two other little bathing-rooms, fitted up in an elegant rather than costly manner: annexed to this, is a warm bath of extraordinary workmanship, wherein one may swim, and have a prospect, at the same time, of the sea. Not far from hence, stands the tennis court, which lies open to the warmth of the afternoon sun. From thence you ascend a sort of turret, containing two entire apartments below; as there are the same number above, besides a dining-room which commands a very extensive prospect of the sea, together with the beautiful villas that stand interspersed upon the coast. At the other end, is a second turret, in which is a room that receives the rising and setting sun. Behind this is a large repository, near to which is a gallery of curiosities, and underneath a spacious dining-room, where the roaring of the sea, even in a storm, is heard but faintly: it looks upon the garden, and the *gestatio* which surrounds the garden. The gestatio is encompassed with a box-tree hedge, and where that is decayed, with rosemary; for the box, in those parts which are sheltered by the buildings, preserves its verdure perfectly well; but where, by an open situation, it lies exposed to the spray of the sea, though at a great distance, it entirely withers. Between the garden and this gestatio runs a shady plantation of vines, the alley of which is so soft, that you may walk bare-foot upon it without any injury. The garden is chiefly planted with fig and mulberry trees, to which this soil is as favourable, as it is averse from all others. In this place is a banqueting-room, which, though it stands remote from the sea, enjoys a prospect nothing inferior to that view: two apartments run round the back part of it, the windows whereof look upon the entrance of the villa, and into a very pleasant kitchen-ground. From hence an enclosed portico extends, which, by its great length, you might suppose erected for the use of the public. It has a range of windows on each side, but on that which looks towards the sea, they are double the number of those next the garden. When the weather is fair and serene, these are all thrown open; but if it blows, those on the side the wind sets are shut, while the others remain unclosed without any inconvenience. Before this portico lies a terrace, perfumed with violets, and warmed by the reflection of the sun from the portico, which, as it retains the rays, so it keeps off the north-east wind: and it is as warm on this side as it is cool on the opposite: in the same manner it proves a defence against the south-west; and thus, in short, by means of its several sides, breaks the force of the winds from what point soever they blow. These are some of its winter advantages: they are still more considerable in summer; for at that season it throws a shade upon the terrace during all the forenoon, as it defends the gestatio, and that part of the garden which lies contiguous to it, from the afternoon sun, and casts a greater or less shade, as the day either increases or decreases; but the portico itself is then coolest, when the sun is most scorching, that is, when its rays fall directly upon the roof. To these its benefits I must not forgot to add, that, by setting open the windows, the western breezes have a free draught, and, by that means, the enclosed air is prevented from stagnating. On the upper end of the terrace and portico stands a detached building in the garden, which I call my favourite; and indeed it is particularly so, having erected it myself. It contains a very warm winter-room, one side of which looks upon the terrace, the other has a view of the sea, and both lie exposed to the sun. Through the folding-doors you see the opposite chamber, and from the window is a prospect of the enclosed portico. On that side next the sea, and opposite to the middle wall, stands a little elegant recess, which, by means of glass-doors and a curtain, is either laid into the adjoining room, or separated from it. It contains a couch and two chairs. As you lie upon this couch, from the feet you have a prospect of the sea; if you look behind, you see the neighbouring villas; and from the head you have a view of the woods; these three views may be seen either distinctly from so many different windows in the room, or blended together in one confused prospect. Adjoining to this is a bed-chamber, which neither the voice of the servants, the murmuring of the sea, nor even the roaring of a tempest, can reach; not lightning nor the day itself can penetrate it, unless you open the windows. This profound tranquillity is occasioned by a passage, which separates the wall of this chamber from that of the garden; and thus, by means of that intervening space, every noise is precluded. Annexed to this is a small stove-room, which, by opening a little window, warms the bed-chamber to the degree of heat required. Beyond this lies a chamber and anti-chamber, which enjoys the sun, though obliquely indeed, from the time it rises, till the afternoon. When I retire to this garden-apartment, I fancy myself a hundred miles from my own house, and take particular pleasure in it at the feast of the Saturnalia, when, by the license of that season of festivity, every other part of my villa resounds with the mirth of my domestics: thus I neither interrupt their diversions, nor they my studies. Among the pleasures and conveniences of this situation, there is one disadvantage, and that is the want of a running stream; but this defect is, in a great measure, supplied by wells, or rather I should call them fountains, for they rise very near the surface. And, indeed, the quality of this coast is remarkable; for in what part soever you dig, you meet, upon the first turning up of the ground, with a spring of pure water, not in the least salt, though so near the sea. The neighbouring forests afford an abundant supply of fuel; as every other accommodation of life may be had from Ostia: to a moderate man, indeed, even the next village (between which and my house there is only one villa) would furnish all common necessaries. In that little place there are no less than three public baths; which is a great conveniency, if it happen that my friends come in unexpectedly, or make too short a stay to allow time for preparing my own. The whole coast is beautifully diversified by the contiguous or detached villas that are spread upon it, which, whether you view them from the sea or the shore, have the appearance of so many different cities. The strand is sometimes, after a long calm, perfectly smooth, though, in general, by the storms driving the waves upon it, it is rough and uneven. I cannot boast that our sea produces any very extraordinary fish; however, it supplies us with exceeding fine soles and prawns; but as to provisions of other kinds, my villa pretends to excel even inland countries, particularly in milk; for hither the cattle come from the meadows in great numbers, in pursuit of shade and water.

"Tell me now, have I not just cause to bestow my time and my affection upon this delightful retreat? Surely you are too fondly attached to the pleasures of the town, if you do not feel an inclination to take a view of this my favourite villa. I much wish, at least, you were so disposed, that to the many charms with which it abounds, it might have the very considerable addition of your company to recommend it. Farewell."

The following observations may tend to illustrate several of the obscure parts, in the foregoing description of Pliny's villa at Laurentinum.

Pliny had no estate round his seat at Laurentinum; his whole possessions there being included (as he informs us, n. 4. let. 3.) in the house and garden. It was merely a winter villa, in which he used to spend some of the cold months, whenever his business admitted of his absence from Rome; and, for this reason it is, that we find warmth is so much considered in the disposition of the several apartments, &c. And, indeed, he seems to have a principal view to its advantages as a winter house, throughout the whole description of it.

Scamozzi, in his *Architect. Univers.* lib. 3. 12. has given a plan and elevation of this villa. Mons. Felibien has also annexed a plan to his translation of this letter; as our own countryman, the ingenious Mr. Castel, has done in his *Villas of the Ancients illustrated.* But they differ extremely among themselves as to the disposition of the several parts of this building, and, perhaps, have rather pursued the idea of modern architecture, than that which is traced out in their original; at least, if the supposition advanced by one of the commentators upon this epistle be true; who contends that the villas of the ancients were not one uniform pile of building contained under the same roof, but that each apartment formed a distinct and separate member from the rest. The ruins of this villa are said to have been discovered some time about the year 1714, but whether any plan was ever taken of so valuable a remain of antiquity, or the reality of it ascertained, the translator has not been able to learn.

The Roman magnificence seems to have particularly displayed itself in the article of their baths. Seneca, dating one of his epistles from a villa which once belonged to Scipio Africanus, takes occasion, from thence, to draw a parallel between the simplicity of the earlier ages, and the luxury of his own times in that instance. By the idea he gives of the latter, they were works of the highest splendour and expense. The walls were composed of Alexandrine marble, the veins whereof were so artfully managed, as to have the appearance of a regular picture: the edges of the basons were set round with a most valuable kind of stone, found in Thasius, one of the Greek islands, variegated with veins of different colours, interspersed with streaks of gold; the water was conveyed through silver pipes, and fell, by several descents, in beautiful cascades. The floors were inlaid with precious gems, and an intermixture of statues and colonnades contributed to throw an air of elegance and grandeur upon the whole. *Vide* Sen. *Ep.* 86.

"The custom of bathing in hot water was become so habitual to the Romans, in Pliny's time, that they every day practised it before they lay down to eat, for which reason, in the city, the public baths were extremely numerous; in which Vitruvius gives us to understand, there were, for each sex, three rooms for bathing, one of cold water, one of warm, and one still warmer; and there were cells of three degrees of heat, for sweating: to the fore-mentioned members, were added others for anointing and bodily exercises. The last thing they did before they entered into the dining-room was to bathe; what preceded their washing was their exercise in the spheristerium, prior to which it was their custom to anoint themselves. As for their sweating-rooms, though they were, doubtless, in all their baths, we do not find them used but upon particular occasions." Castel's *Villas of the Ancients*, p. 31.

"The enclosed porticos in Pliny's description differed no otherwise from our present galleries, than that they had pillars in them: the use of this room was for walking." Castel's *Villas*, p. 44.

Mr. Castel observes, that though Pliny calls his house *Villula;* it appears that, after having described but part of it, yet, if every diæta or entire apartment may be supposed to contain three rooms, he has taken notice of no less than forty-six, besides all which, there remains near half the house undescribed, which was, as he says, allotted to the use of the servants; and it is very probable this part was made uniform with that he has already described. But it must be remembered, that diminutives in Latin do not always imply smallness of size, but are frequently used as words of endearment and approbation; and in this sense it seems most probable that Pliny here uses the word *Villula.*

The following is Pliny's description of his summer villa in Tuscany, book v. letter vi., addressed to Apollinaris.

"The kind concern you expressed when you heard of my design to pass the summer at my villa in Tuscany, and your obliging endeavours to dissuade me from going to a place which you think unhealthy, are extremely pleasing to me. I confess, the atmosphere of that part of Tuscany, which lies towards the coast, is thick and unwholesome: but my house is situated at a great distance from the sea, under one of the Apennine mountains, which, of all others, is most esteemed for the clearness of its air. But that you may be relieved from all apprehensions on my account, I will give you a description of the temperature of the climate, the situation of the country, and the beauty of my villa, which I am persuaded you will read with as much pleasure as I shall relate. The winters are severe and cold, so that myrtles, olives, and trees of that kind, which delight in constant warmth, will not flourish here: but it produces bay-trees in great perfection; yet, sometimes, though indeed not oftener than in the neighbourhood of Rome, they are killed by the severity of the seasons. The summers are exceedingly temperate, and continually attended with refreshing breezes, which are seldom interrupted by high winds. If you were to come here, and see the numbers of old men who have lived to be grandfathers and great-grandfathers, and hear the stories they can entertain you with of their ancestors, you would fancy yourself born in some former age. The disposition of the country is the most beautiful that can be imagined; figure to yourself an immense amphitheatre; but such as the hand of nature only could form. Before you lies a vast extended plain, bounded by a range of mountains, whose summits are covered with lofty and venerable woods, which supply variety of game: from thence, as the mountains decline, they are adorned with underwoods. Intermixed with these are little hills of so strong and fat a soil, that it would be difficult to find a single stone upon them; their fertility is nothing inferior to the lowest grounds; and though their harvest, indeed, is somewhat later, their crops are as well matured. At the foot of these hills the eye is presented, wherever it turns, with one unbroken view of numberless vineyards, terminated by a border, as it were, of shrubs. From thence you have a prospect of the adjoining fields and meadows below. The soil of the former is so extremely stiff, and, upon the first ploughing, turns up in such vast clods, that it is necessary to go over it nine several times, with the largest oxen and the strongest ploughs, before they can be thoroughly broken; whilst the enamelled meadows produce trefoil, and other kinds of herbage, as fine and tender as if it were but just sprung up, being continually refreshed by never failing rills. But though the country abounds with great plenty of water, there are no marshes; for, as it lies upon a rising ground, whatever water it receives without absorbing, runs off into the Tiber. This river, which winds through the middle of the meadows, is navigable only in the winter and spring, at which seasons it transports the produce of the lands to Rome; but its channel is so extremely low in summer, that it scarcely deserves the name of a river; towards the autumn, however, it begins again to renew its claim to that title.—You could not be more agreeably entertained, than by taking a view of the face of this country from the top of one of our neighbouring mountains: you would suppose that not a real, but some imaginary landscape, painted by the most exquisite pencil, lay before you: such an harmonious variety of beautiful objects meets the eye, which way soever it turns. My villa is so advantageously situated, that it commands a full view of all the country round; yet you approach it by so insensible a rise, that you find yourself upon an eminence, without perceiving you ascended. Behind, but at a great distance, stands the Apennine mountains. In the calmest day we are refreshed by the winds that blow from thence, but so spent, as it were, by the long tract of land they travel over, that they are entirely divested of all their strength and violence before they reach us. The exposition of the principal front of the house is full south, and seems to invite the afternoon sun in summer (but somewhat earlier in winter) into a spacious and well-proportioned portico, consisting of several members, particularly a porch built in the ancient manner. In the front of the portico is a sort of terrace, embellished with various figures, and bounded with a box-hedge, from whence you descend by an easy slope, adorned with the representation of divers animals, in box, answering alternately to each other, into a lawn overspread with the soft, I had almost said the liquid, acanthus: this is surrounded by a walk enclosed with tonsile evergreens, shaped into a variety of forms. Beyond it is the gestatio, laid out in the form of a circus, ornamented in the middle with box cut in numberless different figures, together with a plantation of shrubs, prevented by the shears from shooting up too high: the whole is fenced in with a wall covered by box, rising by different ranges to the top. On the outside of the wall lies a meadow that owes as many beauties to nature, as all I have been describing *within* does to art; at the end of which are several other meadows and fields interspersed with thickets. At the extremity of this portico stands a grand dining-room, which opens upon one end of the terrace; as from the windows there is a very extensive prospect over the meadows up into the country, from whence you also have a view of the terrace, and such parts of the house which project forward, together with the woods enclosing the adjacent hippodrome. Opposite almost to the centre of the portico, stands a square edifice, which encompasses a small area, shaded by four plane-trees, in the midst of which a fountain rises, from whence the water, running over the edges of a marble bason, gently refreshes the surrounding plane-trees, and the verdure underneath them. This apartment consists of a bed-chamber, secured from every kind of noise, and which the light itself cannot penetrate; together with a common dining-room, which I use when I have none but intimate friends with me. A second portico looks upon this little area, and has the same prospect with the former I just now described. There is, besides, another room, which, being situated close to the nearest plane-tree, enjoys a constant shade and verdure: its sides are incrusted half-way with carved marble; and from thence to the ceiling a foliage is painted with birds intermixed among the branches, which has an effect altogether as agreeable as that of the carving: at the basis a little fountain, playing through several small pipes into a vase, produces a most pleasing murmur. From a corner of this portico you enter into a very spacious chamber, opposite to the grand dining-room, which, from some of its windows, has a view of the terrace, and from others, of the meadow; as those in the front look upon a cascade, which entertains at once both the eye and the ear; for the water, dashing from a great height, foams over the marble bason that receives it below. This room is extremely warm in winter, being much exposed to the sun; and in a cloudy day, the heat of an adjoining stove very well supplies his absence. From hence you pass through a spacious and pleasant undressing-room into the cold-bath-room, in which is a large gloomy bath: but if you are disposed to swim more at large, or in warmer water, in the middle of the area is a wide bason for that purpose, and near it a reservoir from whence you may be supplied with cold water to brace yourself again, if you should perceive you are too much relaxed by the warm. Contiguous to the cold-bath is another of a moderate degree of heat, which enjoys the kindly warmth of the sun, but not so intensely as that of the hot-bath, which projects farther. This last consists of three divisions, each of different degrees of heat: the two former lie entirely open to the sun; the latter, though not so much exposed to its rays, receives an equal share of its light. Over the undressing-room is built the tennis-court, which, by means of particular circles, admits of different kinds of games. Not far from the baths, is the staircase leading to the enclosed portico, after you have first passed through three apartments: one of these looks upon the little area with the four plane-trees round it; the other has a sight of the meadows; and from the third you have a view of several vineyards: so that they have as many different prospects as expositions. At one end of the enclosed portico, and, indeed, taken off from it, is a chamber that looks upon the hippodrome, the vineyards, and the mountains; adjoining is a room which has a full exposure to the sun, especially in winter; and from whence runs an apartment that connects the hippodrome with the house: such is the form and aspect of the front. On the side, rises an enclosed summer portico, which has not only a prospect of the vineyards, but seems almost contiguous to them. From the middle of this portico you enter a dining-room, cooled by the salutary breezes from the Apennine valleys; from the windows in the back front, which are extremely large, there is a prospect of the vineyards; as you have also another view of them from the folding-doors, through the summer portico. Along that side of this dining-room, where there are no windows, runs a private staircase for the greater conveniency of serving at entertainments: at the farther end is a chamber from whence the eye is pleased with a view of the vineyards, and (what is not less agreeable) of the portico. Underneath this room is an enclosed portico, somewhat resembling a grotto, which, enjoying, in the midst of the summer heats, its own natural coolness, neither admits nor wants the refreshment of external breezes. After you have passed both these porticos, at the end of the dining-room stands a third, which, as the day is more or less advanced, serves either for winter or summer use. It leads to two different apartments, one containing four chambers, the other three; each enjoying, by turns, both sun and shade. In the front of these agreeable buildings, lies a very spacious hippodrome, entirely open in the middle, by which means the eye, upon your first entrance, takes in its whole extent at one glance. It is encompassed on every side with plane-trees, covered with ivy, so that while their heads flourish with their own foliage, their bodies enjoy a borrowed verdure; and thus, the ivy twining round the trunk and branches, spreads from tree to tree, and connects them together. Between each plane-tree are planted box-trees, and behind these, bay-trees, which blend their shade with that of the planes. This plantation, forming a straight boundary on both sides of the hippodrome, bends at the farther end into a semi-circle, which being set round and sheltered with cypress-trees, varies the prospect, and casts a deeper gloom; while the inward circular walks, (for there are several) enjoying an open exposure, are perfumed with roses, and connect, by a very pleasing contrast, the coolness of the shade with the warmth of the sun. Having passed through these several winding alleys, you enter a straight walk, which breaks out into a variety of others, divided by box edges. In one place you have a little meadow; in another, the box is cut into a thousand different forms; sometimes into letters, expressing the name of the master; sometimes that of the artificer; whilst here and there little obelisks rise intermixed alternately with fruit-trees: when, on a sudden, in the midst of this elegant regularity, you are surprised with an imitation of the negligent beauties of rural nature: in the centre of which lies a spot surrounded with a knot of dwarf plane-trees. Beyond these is a walk planted with the smooth and twining acanthus, where the trees are also cut into a variety of names and shapes. At the upper end is an alcove of white marble, shaded with vines, supported by four small Carystian pillars. From this bench, the water, gushing through several little pipes, as if it were pressed out by the weight of the persons who repose themselves upon it, falls into a stone cistern underneath, from whence it is received into a finely polished marble bason, so artfully contrived, that it is always full without ever overflowing. When I sup here, this bason serves for a table, the larger sort of dishes being placed round the margin, while the smaller ones swim about in the form of little vessels and water-fowl. Corresponding to this, is a fountain which is incessantly emptying and filling; for the water which it throws up a great height, falling back into it, is, by means of two openings, returned as fast as it is received. Fronting the alcove (and which reflects as great an ornament to it as it borrows from it) stands a summer-house of exquisite marble, the doors whereof project and open into a green enclosure; as from its upper and lower windows, the eye is presented with a variety of different verdures. Next to this is a little private recess (which, though it seems distinct, may be laid into the same room) furnished with a couch; and, notwithstanding it has windows on every side, yet it enjoys a very agreeable gloominess, by means of a spreading vine which climbs to the top, and entirely overshades it. Here you may recline and fancy yourself in a wood; with this difference only, that you are not exposed to the weather. In this place a fountain also rises, and instantly disappears: in different quarters are disposed several marble seats, which serve, no less than the summer-house, as so many reliefs after one is wearied with walking. Near each seat is a little fountain; and, throughout the whole hippodrome, several small rills run murmuring along, wheresoever the hand of art thought proper to conduct them, watering here and there different spots of verdure, and, in their progress, refreshing the whole.

"And now, I should not have hazarded the imputation of being too minute in this detail, if I had not proposed to lead you into every corner of my house and gardens. You will hardly, I imagine, think it a trouble to read the description of a place which, I am persuaded, would please you were you to see it; especially as you have it in your power to stop, and, by throwing aside my letter, sit down, as it were, and rest yourself as often as you think proper. I had, at the same time, a view to my own gratification; as, I confess, I have a very great affection for this villa, which was chiefly built or finished by myself. In a word (for why should I conceal from my friend my sentiments, whether right or wrong?) I look upon it as the first duty of every writer frequently to throw his eyes upon his title-page, and to consider well the subject he has proposed to himself; and he may be assured, if he precisely pursues his plan, he cannot justly be thought tedious; whereas, on the contrary, if he suffers himself to wander from it, he will most certainly incur that censure. Homer, you know, has employed many verses in the description of the arms of Achilles, as Virgil also has in those of Æneas; yet neither of them are prolix, because they each keep within the limits of their original design. Aratus, you see, is not deemed too circumstantial, though he traces and enumerates the minutest stars; for he does not go out of his way for that purpose, he only follows where his subject leads him. In the same manner (to compare small things with great) if endeavouring to give you an idea of my house, I have not deviated into any article foreign to the purpose, it is not my letter which describes, but my villa which is described, that is to be considered as large. But not to dwell any longer upon this digression, lest I should myself be condemned by the maxim I have just laid down; I have now informed you why I prefer my Tuscan villa to those which I possess at Tusculum, Tiber, and Præneste. Besides the advantages already mentioned, I here enjoy a more profound retirement, as I am at a further distance from the business of the town, and the interruption of troublesome avocations. All is calm and composed; circumstances which contribute, no less than its clear air and unclouded sky, to that health of body and cheerfulness of mind which I particularly enjoy in this place; both which I preserve by the exercise of study and hunting. Indeed, there is no place which agrees better with all my family in general; I am sure, at least, I have not yet lost one (and I speak it with the sentiments I ought) of all those I brought with me hither: may the gods continue that happiness to me, and that honour to my villa! Farewell!"

This villa in Tuscany was Pliny's principal seat, lying about 150 miles from Rome, and in which he usually resided during the summer season. The reader will observe, therefore, that he considers it in a very different manner from that of Laurentinum (his winter villa,) both with respect to the situation and the house itself. Cluver, in his geography, has placed this villa a little above *Tifernum Tiberium*, now called *Citta di Castello*, where our author built a temple at his own expense. This has given room to imagine that possibly there may be yet some remaining traces of this house to be discovered in Tuscany, near a town which the Italians call *Stintignano*, in the neighbourhood of *Ponte di San Stefano*, about ten miles north of an episcopal city now called *Borgo di San Sepulchro*.

Amongst the Jews, Greeks, and Romans, houses were flat at top, so that persons might walk upon them; and usually had stairs on the outside, by which they might ascend and descend without coming into the house. Each house, in fact, was so laid out that it enclosed a quadrangular area or court. This court was exposed to the weather, and being open to the sky, gave light to the house. This was the place where company was received, and for that purpose it was strewed with mats or carpets for their better accommodation. It was paved with marble or other materials, according to the owner's ability, and provided with an umbrella of vellum, to shelter them from the heat and inclemencies of the weather. This part of their houses, called by the Romans *impluvium* or *cava ædium*, was provided with channels to carry off the water into the common sewers. The top of the house was level, and covered with a strong plaster, by way of terrace. Hither, especially amongst the Jews, it was customary to retire for meditation, private converse, devotion, or the enjoyment of the evening breezes.

Some examples of the domestic buildings of the Romans still exist at Herculaneum and Pompeii, but they by no means equal those above described. At the former place the houses are small, and only one story in height; but at the latter we have a few on a somewhat grander scale. There are about 80 houses standing in this town, of which those of Diomedes, Sallust, and Pansa, are the finest; the second standing upon a plot of ground about 40 yards square; and the latter occupying, with its court and garden, a space of about 100 yards by 40.

Towards the close of the last, and commencement of the present century, some few examples have also been discovered in our own country. The most important is that at Woodchester, in Gloucestershire, which was discovered by Mr. Lysons in 1795, and consists of a large open court or atrium, an inner court, and a smaller one in the wing—the whole being surrounded with offices and apartments about sixty in number. The length of the apartments is about 25 feet. Another example in the same county was discovered in 1818, at Great Witcombe. Another example is that at Bignor, Sussex, discovered by Mr. Lysons in 1811, of which we give the following description, extracted from the original account, and partially from Stuart's Dictionary:—

"The first discovery of this villa occurred in 1811. A farmer who occupied the land, in removing the earth, discovered a fine mosaic pavement, which was afterwards found to have formed a part of the floor to one of the rooms. In the centre of this apartment was an hexagonal *piscina*, or cistern, formed of a hard white sort of stone, 4 feet in diameter and 1 foot 7¾ inches in depth, with a border of stone round it 9¼ inches wide, and a step within it, at nearly half its depth, 5½ inches wide; at the bottom is a round hole, 3 inches in diameter, from which a leaden pipe for carrying off the water was afterwards discovered on the outside of the south wall, running in a southern direction. The room appeared to have been heated by an hypocaust, and, in clearing away the earth, part of a small Doric column was found. In the next room discovered, the walls remained to the height of more than two feet at the north-east corner, where was a funnel above the pavement, communicating with the hypocaust below. The pavement was in good preservation; and the dimensions of the room were 40 feet 4 inches by 17 feet. The first room, 31 feet 11 inches by 19 feet. The walls on the east, west, and north sides, were 2 feet 6 inches thick; that on the south, 3 feet. This is conjectured to have been the *triclinium*, or grand banqueting room. Another pavement was found in a third room, at the end of which, opposite from the room last mentioned, was a doorway 3 feet 3½ inches wide, leading into another room, 22 feet by 10 feet 4 inches—the pavement formed of coarse red tesseræ. On the south side of the great pavement, the foundations of a cryptoporticus were discovered, which appears to have been of much larger dimensions than any one hitherto discovered in this island; it was 10 feet wide, and 157 feet 6 inches long. Its tessellated pavement was destroyed, except at the west end; on the north side of this gallery the foundation-walls of a range of rooms was discovered, running eastward, in a line with the great room first discovered. The one which adjoined that room on the east side was 19 feet 2 inches by 18 feet 9 inches, and had a floor of terras of a light red colour. The next room to the eastward was nearly of the same dimensions, and had a coarse tessellated pavement. Adjoining the two last-mentioned rooms on the north side, were the foundations of one 16 feet square, containing a mosaic pavement. The *præfurnium* of the hypocaust, by which the great room and others had been heated, was discovered on the north side of the north wall of the third-mentioned room, and consisted of two walls 18 inches thick and 18 inches asunder, projecting 16 inches from the wall of the building; between them was a kind of arch formed by bricks projecting beyond each other, and communicating with the flues under the different pavements; about 30 feet north of the room, marked 5, in Mr. Lysons' plan, a very fine mosaic pavement was discovered, and a magnificent apartment, marked 3, was traced, to which 5 was found to have served as an ante-room. The wall on the north side of this room was found to continue 32 feet towards the west, where it terminated with a projection or buttress of two feet, forming two sides of what appeared to have been a kind of court, enclosing an area of 30 feet, filled with great quantities of stones, bricks, and tiles. At a small distance from the west wall of the great room, last described, the base and part of the shaft of a small column were discovered. At the west end of the ante-room, 5, was a very small room, 4, (9 feet by 12 feet,) having two doorways, one on the east, opening into 5, and the other on the north, communicating with the square area marked 1. The continuation of the east wall of the room 11, at the west end, or rather the continuation of the cryptoporticus, was next explored to the southward, and traces of it were found to the extent of 100 feet. The room 27, adjoining 26, had its walls still remaining on the east, north, and south sides, to about two feet high, which were covered with stucco two inches thick, painted red, with a skirting of plaster at two inches high, projecting two inches and a half from the wall. On the east side was found, in good preservation, a fireplace 21½ inches wide in front, 17 at the back, and 8 deep, with a hearth formed of 8 bricks, each about 7 inches square. The fireplace was formed by two brick tiles on each side, which had been cramped together with iron, and were placed on the sides of the stove introduced by Count Rumford. I am not aware, Mr. Lysons observes, of any open fireplace of this kind having been discovered elsewhere in the remains of a Roman building, though it is certain, from various passages in the Roman writers, that other means were employed by the ancients for warming their apartments, besides hypocausts. The *caminus* is mentioned by Cicero, Horace, Vitruvius, and others; but the learned commentators on these authors are by no means agreed as to its form or situation, and it has been much questioned by some of them, on the authority of several passages in ancient writers, and from none having been discovered in Roman buildings, whether there was any chimney, or other means of conveying away the smoke, though it is hardly to be conceived that a room could have been habitable under such circumstances at times, when it was necessary to close the doors and windows.

This room was 14½ by 17; the room 29 was 16 feet 5 inches by 15 feet 6 inches, and against the wall was another fireplace resembling the one described. The range of rooms running eastward from the great triclinium, were found to extend the whole length of the cryptoporticus 10.11. On the south side of the building, another cryptoporticus was discovered, marked 45; which communicated with a range of 12 rooms, containing nothing remarkable except those at the east end, which furnished many interesting remains of baths. The room 56 is nearly a square of 25 feet, and contained a finely preserved mosaic pavement. Beyond this mosaic pavement were three rows of black and red tiles, 6 inches square, laid chequer-wise; and next to the wall a row of bricks, each 11 inches by 15½. Great part of a small stone column was found on the pavement, in the same style as the fragment first discovered, being a sort of irregular Doric, the tori of the base being both of the same size. The adjoining room 55 was 30 feet by 25; the floor formed of black and white stones, and next to the wall a row of bricks. Nearly in the middle, was a cold bath 18 feet from east to west, and 3 feet 2 inches deep; it had 3 steps on the east, north, and west sides. On the west side of this room appeared the remains of an extensive hypocaust marked 53 54; and from the frequency of the brick piers, it appeared that the apartment over it must have been a sudatory, probably divided into several smaller rooms. The præfurnium was on the outside of the wall, on the south end; the piers were 2 feet 9 inches high, and 7½ inches square, and consisted of 18 layers of bricks, with a larger one 10½ inches square, laid at the top and bottom. In room 52 adjoining, was another hypocaust, communicating with a larger one by an arch of brick. The area No. 1 was in another examination found to be surrounded by an inner wall, which appeared to have formed a kind of portico; and an entire column was found resembling the fragments found before, which showed that it had been surrounded by a colonnade. A cold bath was also found in the apartment marked 21. Mr. Lysons thinks the villas to have been the residence of a *proprætor*, or at least of the legate or governor of the province. At the time Mr. Lysons first communicated an account of this villa to the Archæologia, the discovery was confined to the rooms marked No. 1 to 26. During the years 1816 and 1817, by tracing the foundations of the walls on the east and west sides of the great court, it was discovered that the cryptoporticus extended all round. The western cryptoporticus 46, was 8 feet wide and 108 long, including a small room 45, at the north end, which had a mosaic pavement. Several rooms, No. 27, 51, 52, 53, 54, 55, 56 and 57. besides the cryptoporticus and passages, were discovered on the western side of the great court, most of them extending into an arable field belonging to the rector of Bignor. No remains of pavements were discovered in this division of the building, except those in the cryptoporticus above mentioned, and some fragments of the coarser kind in the rooms No. 28 and 29. Many large tesseræ were found among the rubbish in the passage No. 50. By digging further to the eastward of the single wall mentioned in the former account, that wall was ascertained to be part of an Eastern cryptoporticus. Nos. 60 and 61, which completed the enclosure of the great court, and the foundations of the buildings, were discovered in a field called the Loure-field, extending 181 feet eastward. Nos. 62 to 71.; several of these buildings were of large dimensions, and they were enclosed within a boundary wall of considerable thickness, not built at right angles with the eastern side of the principal court, but in a very irregular manner, the following being the dimensions of the several sides of this court, viz.: the eastern side 277 feet 4 inches; the west side 385 feet 5 inches; the north side 286 feet; and the south side 322 feet 8 inches.

It would appear reasonable to suppose that the Britons must have advanced considerably in the civilized arts of life, by such examples of Roman luxury as were afforded in their larger residences, such as that above described, for although not equal to those in Rome, it is evident that they were of considerable dimensions, and decorated with taste and skill, in proof of which we have only to refer to the mosaics and paintings. Whether, however, the Britons did not profit by such examples; or whether they were prevented by external circumstances from turning their increased skill and knowledge to practical account, it is tolerably certain that they did not improve so much in these matters as they might reasonably be expected to have done.

It is true, that after the departure of the Romans, they were fully employed in resisting the attacks of their rougher neighbours, and probably had but little time for cultivating the arts of peace. They cannot have made much progress in house-building before the arrival and successful invasion of the Saxons; for had they, we should certainly look for some proof of it in the erections of their invaders, and this we do not find. Most of their churches and cathedrals, or at least of the earlier ones, seem to have been constructed of timber, and we cannot therefore suppose that their domestic buildings were erected in a more durable or costly manner. William of Malmsbury speaks of them as "low and mean dwellings;" they were probably constructed of wood, and roofed with reeds and straw. But even in Norman times, and for some period after the Conquest, there seems to have been but little progress made in this respect. The principal buildings erected for habitation immediately after the conquest of the Normans, consisted of small round towers raised on a mound, and designed with an eye to security rather than convenience. Located in an enemy's country, and in the midst of men who, although conquered in battle, were nevertheless impatient of their victors' control, and unsubdued in courage, it became a matter of necessity to secure themselves against the contingency of a sudden attack, and William found it a matter of policy to promote the erection of fortified residences by his followers. The earliest buildings of this kind were simple towers, either round, rectangular, or polygonal in plan, and of small size, but of considerable strength, the walls being sometimes as much as 12 feet in thickness, while the external diameter of the entire building did not measure more than from 40 to 50 feet. The windows and apertures were very narrow, and the entrance raised several feet above the ground, and approached by a steep flight of steps. Such a building is the keep at Conisborough, erected about this time. It is circular in plan, about 90 feet in height, which is divided into three stories, the lowermost, which is lighted only from the interior, being used probably as a dungeon; the next, in which is the entrance, as a storeroom; and the upper ones, for residence. The interior diameter, in this instance, is about 23 feet, and the thickness of the walls from 10 to 13 feet. At a somewhat later period, such towers or keeps were surrounded by a court enclosed within a strong wall and ditch, the former being strengthened by towers at intervals, and the latter crossed at the entrance by a drawbridge, which was defended by an advanced outwork or watch-tower, termed the barbacan. In such castles the keep was not used as a place of residence, except in cases of danger or emergency, more convenient and roomy apartments being provided in the towers or court-yard.

We next arrive at the Edwardian castles, which present an improved appearance. The keep was now dispensed with, the castle being still strongly fortified by an outer wall, with towers at intervals; but greater attention seems to have been paid to convenience and domestic comfort; and the buildings begin to assume the character of a fortified residence rather than of a mere stronghold: strength is evidently not the only property considered, although still a necessary qualification. Caernarvon castle is a good example of this date.

During the fourteenth century, the sterner features of castles were considerably modified, and assumed a lighter and more peaceful appearance. The apartments were enlarged, and rendered at once more commodious and agreeable. The apertures of the windows also were considerably enlarged, and, late in the period, filled with tracery in the heads. Examples exist at Windsor, Warwick, and Kenilworth.

It must not be forgotten, however, that during all this time there was in existence a different class of dwellings of a less imposing character, but perhaps more strictly entitled to the appellation of domestic buildings. They are included under the general term of *manor houses.*

Previous to the thirteenth century, houses were built of timber, and at first only of one story, being somewhat in the form of the inverted hull of a ship, formed of timber frame-work, the intervals being filled in with horizontal planks. Afterwards, this hull was raised on walls, likewise of timber frame-work filled up with clay, stones, and plaster. Stowe says that the houses in London of this period were not more than 16 feet in height; built of wood, and covered with reeds and straw. The general plan seems to have been that of a parallelogram, and where there were two stories, the approach to the upper was by an external staircase. The lower story was vaulted, and lighted by small windows; but there does not appear to have been any convenience for warming, except in the upper floor, where there is a hearth in the middle of the floor with smoke-hole above: the windows also of the upper floor were larger than those below. In some instances, the building was surrounded by a moat. An example of this kind exists at Boothby Pagnel, Lincolnshire. In some houses of the same date, the principal feature was the hall, which extends the whole height of the building, and is sometimes divided into aisles similar to those of a church, as in the palace of the bishop of Hereford.

In the thirteenth century the same general plan was preserved; but at its close, some little differences occur, as at Little Wenham Hall, Suffolk, where, above the general range of building, which is two-storied, one portion is carried up an additional story, so as to present externally the appearance of a tower. In this example, the lower portion of the building is constructed of flint and stone, and the upper part of brick—a material not found in any previous example, and not generally used for a considerable time afterwards. Square towers were common additions to the houses of the next century, the plans of which were more varied than those of preceding periods. The Mote, Ightam, Kent, is an example of this date; it is square on plan, and surrounded by a moat. Timber houses of this date exist at York and Salisbury, with ornamental barge-boards, which appear to have been introduced about this time, as were also dormer windows and chimney-shafts.

In the fifteenth century, the erection of castles, as distinguished from manor-houses, may be said to have ceased; the two were merged together, as it were; for although the dwellings were still fortified, they were incapable of a regular siege, as comfort was no less considered than security. Houses were erected of all shapes and materials, and often considerably oramented. The square plan, amongst others, was still in use, as was also the surrounding moat, although the latter was not so frequent as formerly. Chimneys became common at this period, and several shafts were often connected into one stack. Panelled ceilings were now introduced, both of wood and plaster; and the windows became large, and highly ornamented; bay and oriel windows were common. The internal walls of large mansions were often painted, or hung with tapestry, and, towards the close of the century, lined with wainscot. Examples of this date are

Eton College, Eltham and Hampton-Court palaces, and Crosby-Hall. Timber houses, which have the spaces between the timbers filled with ornamented plaster, are also of this date. Brick came into very general use during this century.

During the commencement of the next century, the houses retained much the same character, although perhaps somewhat more enriched, and occasionally with some introduction of Italian work. Ere the close, however, the Italian style had become predominant, which gives a vast difference in the buildings of the sixteenth century. The ceilings of this last style were entirely of plaster, which is often highly enriched with carving. Ornamental staircases and galleries were first introduced at this period, but open balusters were not common at the first, the space below the hand-rail being filled up with plaster. Timber houses are still common, and often of good design, the intervals between the quartering being filled with bricks or plaster. Examples of this date are Wollaston-Hall, Nottinghamshire; Longleat, Wiltshire; the Quarries, Rochester; and Little Charlton House, Kent.

During the next century, the Italian style of building continued to prevail, the Gothic features gradually disappearing until they were entirely lost in the works of Inigo Jones, Vanbrugh, &c. Amongst the earlier works may be mentioned Audley End, Essex; Hatfield House, Herts; and Holland House, near London; and amongst the latter, the spacious mansions of Blenheim and Castle Howard.

In the earlier Domestic buildings of this country but little attention was given to comfort. For a very long period the houses were constructed of a timber framing, either covered with planks, or having the intervals between the parts of the framing filled in with clay. Such materials of course rendered the houses subject to frequent conflagrations; and in cities where the houses were closely packed together in narrow streets, such accidents were most destructive. A law was enacted by Richard I., that all houses in the city should be built to a certain height of stone, and covered with slate or tiles; and after the fire, which consumed the greater part of Oxford in 1190, the same precaution was adopted in that city; and in cases where the people were too poor to effect this, a high stone wall, built up between every fourth or fifth house, was deemed sufficient. In these cases, however, the stonework was only rough rubble-work. Brick was introduced from Flanders, and we do not find any instance of its employment in this country until the close of the thirteenth century at Wenham-Hall, where the lower part is of stone, and the upper story of brick. This material did not come into general use until the reign of Henry VI., at the early part of the fifteenth century, but before its close it was very much employed.

In the interiors, the walls were, in most cases, left bare, or sometimes painted or hung with arras or tapestry suspended on hooks three or four inches from the wall. This ornamentation, however, was seldom introduced but in regal mansions, or such as vied with them in splendour; they were by no means of frequent or common use, nor were probably employed at all till the fourteenth century. There was a splendid specimen of tapestry in Warwick Castle in 1344, and Chaucer, who lived a few years later, in describing his chamber, says—

> "All the walls with colours fine,
> Were paint both text and glose;"

The floors were either of earth or stone, but at a later period were rough-cast with plaster and pebbles, and the dais, or upper end of the hall, planked. They were strewed with straw, or leaves, even in royal residences, for we hear of parties holding lands of Edward I., on condition of providing straw for strewing the king's chamber in winter, and herbs in summer; and Fitzstephen tells us, that Thomas à Becket, when chancellor to Henry II., "had his hall strewed every day in the winter, with fresh straw or hay, and in the summer with rushes and green leaves fresh gathered, that such knights as the benches could not contain, might not dirty their fine clothes when they sat on the floor." From this we learn that such litter served for a seat even in great houses; it also served for a bed amongst a lower class of persons.

The fireplace was in the centre of the hall, where logs of wood were supported on dogs, the smoke being allowed to find its way as best it could, through an opening in the roof, which was usually covered with a small turret or lantern, the sides being left open, or filled with louvre-boards. There does not seem to have been any means of warming the smaller chambers, except by pans of charcoal. It is true, we find chimneys in Winwall House, which is supposed to belong to the twelfth century, but this is an unique specimen, and it is certain that they were not in use for a considerable period after that. At Rochester and Hedingham Castles also, we have examples, but the flues are carried up only a very short distance in the wall, and then turned out. Early examples of chimneys are found at Conway Castle, built by Edward I. in the middle of the thirteenth century, and at Kenilworth of about the same date. These, however, are but exceptions; chimney flues were not common in the fourteenth century.

Glass for windows does not seem to have been in use in any other than ecclesiastical buildings, until the time of Edward I., and then it was of very rare occurrence, to be found only in the halls of princes. The common practice adopted for the admission of light consisted in the insertion of louvre-boards in apertures at the upper part of the apartment, but these, although effectual to exclude the rain, were but little adapted to exclude the wind also. To this end another expedient was resorted to—oiled canvas or linen was stretched over the apertures, which was to a certain extent effectual for all requirements, and certainly a great improvement upon louvre-boarding. Glass did not come into general use for gentlemen's houses before the reign of Henry VIII., and we find Sir Thomas More, in his "Utopia," alluding to this circumstance, when he says, that they keep the wind off their houses with glass, for it is there much used, and some also with very fine linen dipped in oil or amber. That it was occasionally in use some time previous to this period, is evident from Chaucer's description of his chamber, for he says:—

> "With glas
> Were all the windowes well yglazed;
> Full clere, with not a hole ycrased;"

They were also beautifully painted, for he goes on—

> "That to behold it was great joy;
> For holly all the story of Troy
> Was in the glaising wrought."

Such were the comforts of our ancestors; we should scarcely call them by that name now-a-days, when the regal luxuries of former times are looked upon as necessaries even by our poorer classes. From the time of the Reformation, however, domestic convenience and comfort made rapid progress; we fear we might say too rapid, for the real happiness and welfare of the people. Belonging to the olden times, we find ecclesiastical structures, which, even in their present state of neglect and decay, rival the resources of modern taste and skill, while their domestic buildings were mean and cheerless: we have lived to see the tables turned—churches mean, cold, and neglected; nay, even our old structures, the bequests of our ancestors, allowed to fall to ruin and decay, while our own dwellings are loaded with luxuries, and over-crowded with ornament. But this scandal is passing away, and we are glad to see some slight return to the principles of our forefathers.

For a further elucidation of this subject, as regards the Domestic buildings of Old England, we refer to the article on Tudor Architecture.

The dwelling-houses of the metropolis are divided by act of parliament into three classes, each of which is subject to certain regulations as regards the building, as is shown in the following table:—

If in height	If in area	If containing	The Raters.	The thickness of external walls must be		The thickness of party-walls must be		
more than 70 ft., and not more than 85 ft.	more than 10 sqrs., and not more than 14 sqrs.	7 stories	1st class	21½ in. from top of footing to underside of floor next but 3 below topmost floor,	and 13 in. thence to top of wall.	21½ in. from top of footing to underside of floor next but three below topmost floor,	and 17½ in. thence to underside of floor next below topmost floor,	and 13 in. thence to top of wall.
more than 85 ft.	more than 14 sqrs.	more than 7 stories.	extra 1st.	21½ in. from top of footing to underside of floor next but 2 below topmost floor,	and 17½ in. thence to top of wall.	21½ in. from top of footing to underside of floor next but three below topmost floor.	and 17½ in. thence to underside of topmost floor,	and 13 in. thence to top of wall.
more than 52 ft., and not more than 70 ft.	more than 6 sqrs., and not more than 10 sqrs.	6 stories.	2nd.	17½ in. from top of footing to underside of floor next but 1 below topmost floor,	and 13 in. thence to top of wall.	17½ in. from top of footing to underside of floor next but one below topmost floor:	13 in. thence to top of wall.	
more than 38 ft., and not more than 52 feet.	more than 4 sqrs., and not more than 6 sqrs.	5 stories.	3rd.	17½ in. from top of footing to underside of floor next but 2 below topmost floor,	and 13 in. thence to top of wall.	17½ in. from top of footing to underside of floor next but two below topmost floor:	13 in. thence to underside of topmost floor,	and 8½ in. thence to top of wall.
not more than 38 feet.	not more than 4 sqrs.	not more than 4 stories.	4th.	13 in. from top of footing to underside of floor next below topmost floor,	and 8½ in. thence to top of wall.	13 in. from top of footing to underside of floor next but one below topmost floor.	and 8½ thence to top of wall.	

HOUSING, the space excavated out of a body, for the insertion of some part of the extremity of another, in order to fasten the two together: thus the string-board of a stair is most frequently excavated, or notched-out for the reception of the steps. The term is also applied to a niche for containing a statue.

HOVELLING, a method adopted for the prevention of smoky chimneys by carrying up the two sides which are the most obnoxious to currents of air, above the others; or by leaving apertures on all sides for the escape of the smoke.

HUE (from the Saxon) in painting, any degree of strength or vividness of colour, from its greatest or deepest, to its weakest tint.

HUMERI, the angles of a temple formed by the longitudinal and transverse walls of the cella.

HUNDRED OF LIME, a denomination of measure, in some places denoting 35, and in others 25 heaped bushels or bags.

Hundred, *Great* or *Standard*, = 112lb. avoirdupoise = 4 quarters = 7 stone (of 16lb.) = 14 cloves (8lb.) = 16 cloves (7lb.) = 1,792 ounces = 20,972 drachms avoirdupoise = .93333 long cwt. (120lb.) = 103lb. 2½ oz. Dutch, or Scottish weight. This is the legal hundred-weight of the custom-house of London, and in all the southern parts of England.

Hundred, *Long*, or *Northern*, = 120lb. = $8\frac{4}{7}$ stones (14lb.) = 12 rationes (10lb.) = 1.0714286 great cwt. (112lb.) This weight is legalized on all or most of the canals and navigable rivers in the north of England and of the midland counties, by their acts for collecting tolls, &c.

Hundred is also used as a measure to express a certain quantity or number of things.

Deal boards are sold at six score to the hundred, called *the long hundred*. Pales and laths are counted at five score to the hundred if five feet long, and six score if three feet long.

HUNG, *Double*, see Double Hung.

HUNTING TOWERS, ancient buildings erected, as is supposed, for the purpose of giving ladies an opportunity of viewing the progress of the chase. Examples remain at Chatsworth, and at Tibbermuir near Perth, in Scotland.

HURLERS, a name given to a rude erection of stones existing near St. Clare, Cornwall. They are of Druidical origin. *See* Celtic Architecture.

HURRIES, in engineering, is sometimes applied, at Newcastle and other places, to the strong stages of wood erected on the sides of navigable rivers and harbours, to which the railways are conducted from the coal pits; by which means the load is emptied at once, by the help of a spout, from the railway waggons into the holds of ships.

HUT (from the Saxon *hutte*) a small cottage or hovel. It is also used for the soldiers' lodges in the field, otherwise called *barracks* or *caserns*.

HUT, in rural economy, a low sort of building, of the cottage kind, generally constructed of earthy materials, as strong loamy clay, &c. A number of huts of this description have been built on the borders of the South Esk, in Scotland, which have a very neat and rural appearance, affording the idea at a distance of their being formed of a kind of brown brick-work. The materials employed consist of a sort of muddy clay, blended with the roots of aquatic plants, which are dug beyond the flood-mark of the river, in such sizes and shapes as are suitable for the intended purpose. The pieces, or peats, as they are called, are generally cut out in the form of bricks, but somewhat larger, being prepared in every respect in the manner of peat-fuel. It is useful in some cases to build huts with lime-mortar, but more commonly with clay only.

These huts are generally preferred by the cottagers to such as are built of stone, being warmer, and nearly as durable.

It seems not improbable but that a similar sort of material for building this kind of cottages may be met with in many situations where it has not yet been discovered, and be made use of in this way, as well as for various fences of the wall kind.

HYPÆTHRAL TEMPLE, see the following article.

HYPÆTHRON, or Hypæthros (from the Greek, *open above*) a temple with ten columns on the pronaos and posticus, in external appearance similar to the dipteral; but within, it had a double tier of columns on each side, detached from the wall, and the middle area was open to the sky. The cell was approached from both front and rear. From the description given by Vitruvius, it appears, that Rome did not afford any example of this species; and he points out the temple of Jupiter Olympus at Athens as one.

HYPERBOLA (from ὑπερ and βάλλω) one of the conic sections, being that which is made by a plane cutting the opposite side of the cone produced above the vertex, or, by a plane which makes a greater angle with the base than the opposite side of the cone makes. In this figure the squares of the ordinates are greater than, or exceed, the rectangles under the parameters and abscissas, whence the name *hyperbola.*

A few useful properties of the hyperbola.—1. The squares of the ordinates of any diameter are to each other, as the rectangles of their abscissas.

2. As the square of any diameter is to the square of its conjugate, so is the rectangle of two abscissas to the square of their ordinate.

3. The distance between the centre and the focus, is equal to the distance between the extremities of the transverse and conjugate axes.

4. The difference of two lines drawn from the foci to meet in any point of the curve, is equal to the transverse axis.

5. All the parallelograms inscribed between the four conjugate hyperbolas, are equal to each other, and each is equal to the rectangle of the two axes.

6. The rectangles of the parts of two parallel lines, terminated by the curve, are to each other as the rectangles of the parts of any other two parallel lines, anywhere cutting the former. Or, the rectangles of the parts of two intersecting lines are as the squares of their parallel diameters, or squares of their parallel tangents.

7. All the parallelograms are equal which are formed between the asymptotes and curve, by lines parallel to the asymptotes.

For other properties, see the articles CONE, and CONIC SECTION.

HYPERBOLA, *Acute*, one whose asymptotes make an acute angle.

HYPERBOLA, *Ambigenal*, that which has one of its infinite legs falling within an angle formed by the asymptotes, and the other falling without that angle.

HYPERBOLA, *Apollonian*, the common hyperbola, as derived from the cone. See HYPERBOLA.

HYPERBOLA, *Deficient*, a curve having only one asymptote, though two hyperbolic legs running out infinitely by the side of the asymptote, but contrary ways.

HYPERBOLA, *Equilateral*, has its asymptotes equal to each other.

HYPERBOLAS, *Infinite*, or HYPERBOLAS OF THE HIGHER KINDS, are expressed or defined by general equations similar to that of the conic or common hyperbola, only having general exponents, instead of the particular numeral ones, but so that the sum of those on one side of the question is equal to the sum of those on the other side. Such as $a\, y^{m+n} = b\, x^m (d + x)^n$, where x and y are the abscissa and ordinate to the axis or diameter of the curve; or $x^m y^n = a^{m+n}$, where the abscissa x is taken on one asymptote, and the ordinate y parallel to the other.

HYPERBOLIC CONOID, a solid formed by the revolution of an hyperbola about its axis; it is otherwise called HYPERBOLOID, which see.

HYPERBOLIC CURVE, the same as the hyperbola. To draw a tangent to any point in the hyperbolic curve, draw a semi-diameter to the given point, and find its conjugate; then through the given point, draw a straight line, parallel to the conjugate diameter; which line will be a tangent to the curve.

To find the focus of the hyperbolic curve, take the distance between the extremities of the transverse and conjugate axes, and apply it from the centre upon the axis, and the remote extremity of the distance gives the focus.

HYPERBOLIC CYLINDROID, a solid formed by the revolution of an hyperbola about its conjugate axis, or line through the centre perpendicular to the transverse axis.

HYPERBOLOID, a conoid formed by the revolution of an hyperbola about its axis. It is otherwise called an *hyperbolic conoid.*

To find the solidity of an hyperboloid, or the frustum of an hyperboloid.—To the areas of the two ends, add four times the area of the middle section parallel thereto, and multiply the sum by one-sixth part of the axis or height, and the product is the solidity. In the complete hyperboloid, the area of the end at the apex being nothing, the rule will be similar to what is laid down under the article CONOID.

An hyperboloid is to a paraboloid of the same base and altitude as $t + \frac{2x}{3}$ is to $t + x$.

Let $t =$ the transverse, $c =$ the congugate } axes of the generating hyperbola.
$x =$ the abscissa or altitude of the solid.
$y =$ the ordinate or radius of the base.
$p = 3.1416$.

Then $y^2 = c^2 \times \frac{tx + x^2}{t^2}$, by the property of the solid;

and $p\, y^2 \dot{x} = p\, c^2 \dot{x} \times \frac{tx + x^2}{t^2}$, the fluxion of the solid;

$p\, y^2 x = p\, c^2 x^2 \times \frac{\frac{1}{2} t + \frac{2}{3} x}{t^2}$, the fluent of the solid;

but because $y^2 = c^2 \times \frac{tx + x^2}{t^2}$, we obtain $c^2 = \frac{y^2 t^2}{tx + x^2}$

Therefore, substituting $\frac{y^2 t^2}{tx + x^2}$ for c^2 in the fluent $p\, c^2 x^2 \times \frac{\frac{1}{2} t + \frac{2}{3} x}{t^2}$ we obtain $\frac{p\, y^2 x}{2} \times \frac{t + \frac{2}{3} x}{t + x} =$ half the area of the base multiplied into the altitude, $\times \frac{t + \frac{2}{3} x}{t + x}$, for the solidity of the solid. But the paraboloidal area is half the area of the base multiplied into the altitude; that is, $\frac{p\, y^2 x}{2}$; now $\frac{p\, y^2 x}{2} \times \frac{t + \frac{2}{3} x}{t + x} : \frac{p\, y^2 x}{2} : : t + \frac{2}{3} x : t + x$; and hence the proposition is manifest.

HYPERTHYRUM, the lintel of a doorway, or that part of the frame which stands over the supercilium. In Grecian buildings it consisted of a frieze and cornice, the latter supported by a console at each extremity.

HYPOCAUSTUM, (from ὑπο *under*, and καυςον *to burn*,) among the Greeks and Romans, a subterraneous place, in which was a furnace for heating the baths. Another kind of hypocaustum was a sort of kiln to heat their winter parlours.

Several hypocausts have been found amongst the Roman remains still existing in Britain. About three years since, the remains of a portion of a Roman villa were laid open in Lower Thames-street, London, and beneath the floor of one of the rooms was discovered a hypocaust formed of columns about two feet in height, each consisting of fourteen tiles about twelve inches square. These were connected at the top by larger tiles, which formed the superstructure of the floor. Flue-tiles, with varied patterns incised on their surfaces, were likewise found amongst the ruins, which originally conveyed warm air up the sides of the building.

More recently, a hypocaust was discovered at Cirencester, and in a most perfect condition, the furnace, which was in existence, still containing some portion of the fuel. In this case, the columns were of two kinds, square and circular, the former being composed of tiles laid one upon the other to the number of ten, and the latter being formed of blocks of stone. Resting upon these pillars were large square tiles, as in the preceding example, and above these a layer of concrete six inches in thickness, on which the pavement was laid. The room above the hypocaust measured twenty-five feet square, and it is remarkable that the hypocaust extended only half-way underneath, the remaining half of the pavement being laid solid.

Still more recently, the remains of some apartments have been found within a Roman camp at Lymne, Kent. An extensive hypocaust was discovered under the floor of these apartments, formed entirely of layers of large tiles placed at regular intervals, but the pavement had been totally destroyed. Several hollow flue-tiles were also discovered of a similar description to those above alluded to. These, in all probability, were connected with the hypocaust, and served to convey the hot air from the furnace through the principal apartments of the villa, the hypocausts being used not only for baths, as is by some supposed, but also in the place of fires, and answered an exactly similar purpose to our modern hot-air pipes.

In a hypocaust discovered at Lincoln some few years since, the piers supporting the pavement were all of the circular form.

HYPODROMUS, (Greek ὑπὸ, *under*, and δρομος, *from* τρεχέιν, *to run*,) amongst the Romans, a shady or covered walk or ambulatory.

HYPOGÆUM, (from ὑπο, *under*, and γῆ *the earth*,) in ancient architecture, a name given to all parts of a building that were underground.

The term was more particularly applied to the common sort of sepulchres used by the Romans; they were built underground, whence their name, and are now known under the name of catacombs. The urns containing the ashes of the deceased were placed round the chamber in niches cut out in the walls, which, from their resemblance to the niches of a pigeon-house, were called columbaria.

Montfaucon has given descriptions and illustrations of several such hypogæa in his *Antiquitè Expliquée.* In many examples, especially in those of later date, the chambers are highly ornamented.

HYPOPODIUM, (from ὑπο, *under*, and πȣς, *foot*,) a piece of furniture in the ancient baths, on which the feet rested.

HYPOSCENIUM, (from ὑπο, *under*, and σκηνῆ, *a scene*,) a partition under the logium appointed for the music.

HYPOTRACHELIUM, (from ὑπο, *under*, and τραχήλιον, *the neck*,) the lower part of the Tuscan and Doric capitals, comprehended between the astragal at the top of the shaft, and the fillet or annulets under the ovolo. This description applies only to the Roman Doric; for the Grecian, instead of an astragal, had from one to three horizontal grooves circumscribing the column.

END OF VOL. I.

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ICE-HOUSE, a repository for the preservation of ice during the summer months.

The aspect of an ice-house ought to be towards the south-east, on account of the advantage of the morning sun in expelling the damp air, which is far more prejudicial to it than warmth. The best soil on which such a house can be erected is a chalk-hill, or declivity, as it will conduct the waste water without the aid of any artificial drain; but where such land cannot be procured, a loose stony earth, or gravelly soil on a descent, is preferable to any other.

For the construction of an ice-house, a spot should be selected at a convenient distance from the dwelling-house. A cavity is then to be dug in the form of an inverted cone, the bottom being concave, so as to form a reservoir for the reception of waste water. Should the soil render it necessary to construct a drain, it will be advisable to extend it to a considerable length, or, at least, so far as to open at the side of the hill or declivity, or into a well. An air-trap should likewise be formed in the drain, by sinking the latter so much lower in that opening as it is high, and by fixing a partition from the top, for the depth of an inch or two into the water of the drain, by which means the air will be completely excluded from the well. A sufficient number of brick-piers must now be formed in the sides of the ice-house, for the support of a cart-wheel, which should be laid with its convex side upwards, for the purpose of receiving the ice; and which ought to be covered with hurdles and straw, to afford a drain for the melted ice.

The sides and dome of the cone should be about nine inches thick, the former being constructed of brick-work, without mortar, and with the bricks placed at right angles to the face of the work. The vacant space behind ought to be filled with gravel, or loose stones, in order that the water oozing through the sides may the more easily be conducted into the well. The doors of the ice-house should likewise be made to shut closely; and bundles of straw put before them, more effectually to exclude the air.

The ice to be put in should be collected during the frost, broken into small pieces, and rammed down hard in strata of not more than a foot, in order to make it one complete body; the care in putting it in, and well ramming it, tends much to its preservation. In a season when ice is not to be had in sufficient quantities, snow may be substituted.

ICHNOGRAPHY, (from ιχνος, *footstep*, and γραφω, *to describe*,) an orthographical projection of an object on a horizontal plane, or the description of an object on a plane representing the horizon, by straight lines from all points of the object perpendicular to the plane. This term is used only in reference to a projection of the same nature with another, on which it is made perpendicular to the former, by lines from all points of the object falling perpendicular to such plane, and consequently parallel, to that of the ichnography.

ICOSAHEDRON, (from the Greek, εἰκοσαεδρον,) in geometry, a regular solid, consisting of twenty triangular pyramids, whose vertices meet in the centre of a sphere, supposed to circumscribe it; and therefore have their height and bases equal; wherefore the solidity of one of those pyramids multiplied by twenty, the number of bases, gives the solid content of the icosahedron.

To form or make the icosahedron.—Describe upon a card paper, or some other such like substance, twenty equilateral triangles; cut it out by the extreme edges, and cut all the other lines half through, then fold the sides up by these edges half cut through, and the solid will be formed.

The linear edge or side of the icosahedron being A, then will the surface be

$$5\,A^2\sqrt{3} = 8.6602540A^2,$$

and the solidity $= \frac{5}{6}\,A^3\sqrt{\frac{7 + 3\sqrt{5}}{2}} = 2.1816950A^3.$

IMAGE, (from the Latin, *imago*,) the scenographic or perspective representation of an object. See PERSPECTIVE.

IMAGERY, painted or carved work.

IMBOW, (from *bow*,) to arch over, to vault.

IMBOWMENT, an arch, or vault.

IMPAGES, (Latin,) in ancient joinery, is supposed to mean the rails of a door, as appears from Vitruvius, book iv. chap 6. "The doors are so framed, that the cardinal scapi may be the twelfth part of the whole height of the aperture. Out of twelve parts between the two scapi, the tympans have three parts. The impages are so distributed, that the height being divided into five parts, two superior and three inferior are disposed. Upon the middle, the middle impages are placed; of the rest some are framed at top, and some at bottom; the breadth of the impage is a third part of the tympan; the cymatium is a sixth part of the impage; the breadth of the scapi is the half of the impage; the replum is the half and a sixth part of the impage."

IMPETUS (Latin) the span of a building, roof, or arch.

IMPLUVIUM, the cistern in the centre of the atria of Roman houses, to receive the rain, the atria being uncovered.

IMPOST (French) the upper part of a pier or pillar, which sustains an arch; or the collection of mouldings under an arch, forming a cornice of small projection as a finishing to the pier.

INBAND JAMBSTONE, a stone laid in the jamb of an aperture for the purpose of bond: its length being inserted in the thickness of the wall, and showing only its end in the face of it.

INCERTAIN WALL. *See* WALL.

INCH (*ince*, Saxon, *uncia*, Latin) a measure of length, supposed equal to three grains of barley laid end to end; the twelfth part of a foot.

INCLINATION (from the Latin) a word frequently used by mathematicians to signify the mutual approach of a line and a plane, or of two planes, to each other, so as to constitute an angle. In this sense we speak of the inclination of the meridians, the inclination of the sun's rays, &c.

The inclination of a line to a plane, is measured on a second plane, by supposing the second to pass along or through a line perpendicular to the first, and forming an intersection with it: then the angle comprehended on the second plane, between the line and the intersection, is called *the inclination of the line to the plane.*

The inclination of one plane to another, is measured on a third plane drawn perpendicular to the common intersection of the two first, till it intersect them: then the angle contained between the lines of section is *the inclination of the planes.*

INCLINED PLANE, in mechanics, a plane forming an oblique angle with the horizon, or placed at a given angle to another: so that when an inclined plane is spoken of absolutely, another is always to be understood, which is the primitive or first plane, from which the inclined plane rises. When a force, in a given direction, supports a weight upon an inclined plane, such force is to the weight as the sine of the angle made by the line in which the force acts with the line perpendicular to the plane.

Given, the heights of any three points in an inclined plane, and their seats in position upon the primitive plane, to determine the inclination of the planes.—Join the seat of the greatest height to that of the least height, and take the least height from the other two: then say, As the greatest difference is to the least difference, so is the whole length of the line joining the two seats to the portion of it between the seat of the least height and that of the greatest; join the intermediate point to the seat of the mean height by a straight line, which call A B; draw a straight line, C D, perpendicular to A B; through the seats of the greatest and least heights draw two lines, C E and D F, parallel to A B; make C E equal to the greatest height, and D F equal to the least; join E F, and produce C D and E F to meet in O; then the angle C O E is the inclination of the planes.

INCRUSTATION (French) an adherent covering. This term is frequently applied to plaster, or other tenacious materials employed in building.

INDEFINITE (from the Latin *indefinitus*, not limited) is sometimes used to express something that has but one extreme; as a line drawn from any given point, while the other extremity is extended infinitely, or to any given distance, without affecting its use.

INDENTED (from the Latin *in*, and *dens*, a tooth) in architecture, toothed together.

INDIAN ARCHITECTURE, the style which was practised by the inhabitants of India. Although what relates to India was anciently but very imperfectly known to the western world, yet such is the change in human affairs, and the eagerness with which every matter relating to India has of late been investigated, that we are now furnished with accounts fully as ample as those relating to Egypt or Persia. In the following brief relations we shall be guided by some excellent papers, by Sir William Jones and others, in the *Asiatic Researches;* Robertson's *Disquisitions respecting Ancient India;* the learned and laborious work of Maurice on *Indian Antiquities;* and several other authorities quoted for particular descriptions.

In India, the cities and palaces were on a scale with its great wealth and population. They were generally indebted for their origin to the favour of powerful princes, and successively became the centre of the riches and traffic of the East. In the historical poem, called the *Mahabbarit* (or History of the Great War) translated by Abul Fazel, the secretary or minister of the great Akbar, it is said, that Oude, the capital of a province of that name, to the north-east of Bengal, was the first regular imperial city of Hindoostan, and that it was built in the reign of Krishen, one of the most ancient rajahs. The *Ayeen Akbery* (vol. ii. p. 41) represents Oude to have anciently been 148 coss (or about 259 miles) in length, and 36 coss (or about 53 miles) in breadth; but this bears more resemblance to a province than a city. "This city," says Sir W. Jones, "extended, if we may believe the brahmins, over a line of ten yojans (or 40 miles.) It is supposed to have been the birth-place of Rama." According to the *Mahabbarit*, Oude continued the imperial city 1,500 years, until about the year 1,000 before the Christian era, when a prince of the dynasty of the Surajas, who boasted their descent from the sun, erected Canouge upon the banks of the Ganges, and made the circumference of its walls 50 coss, or about 87 miles. Strabo, from Megasthenes, who had seen Canouge, says it was situated at the confluence of another stream with the Ganges; that its form was quadrangular, the length 80 stadia, breadth 15, or, taking the mean stadium of the ancients, about 8 miles by 1½; that it had wooden fortifications, with turrets for archers to shoot from, and was surrounded by a vast ditch.—Strabo, lib. xv. p. 667. Arrian calls it the greatest city amongst the Indians; he says that it was situated at the junction of the Erannaboa with the Ganges: he gives the same dimensions as Strabo; and says, that there were 570 towers on the walls, and 65 gates. Diodorus Siculus, lib. xvii. says, that when Alexander passed the Hyphasis, he was informed, that on the banks of the Ganges he would meet the most formidable sovereign of India, called Xambranes, king of the Gangarides, at the head of 20,000 horse, 200,000 foot, 2,000 war-chariots, and 4,000 fighting elephants. The *Mahabbarit* states that Sinkol, a native of Canouge, brought into the field, against Affrasiah, king of Persia, 4,000 elephants, 100,000 horse, and 400,000 foot. But that after Delu had founded Delhi, and established his court there, Canouge declined, and was involved in civil discord;—still we learn from the same authority, that Sinsarchand, or Sandrocottus, the successor of Porus, restored Canouge to its ancient splendour; and that here, about the year 300 before Christ, he entertained the ambassadors from Seleucus, the successor of Alexander, and that Megasthenes was amongst the number. In the beginning of the fifth century, Ramdeo Rhator (or the Mahratta) entered Canouge in triumph, and reigned there 54 years. The last king under whom this city may be considered as the metropolis of a great empire, was Maldeo, who, about the beginning of the sixth century, added Delhi to his dominions. At this time, Canouge was said to contain 30,000 shops in which areca was sold. Although not the metropolis, it long after continued of great consequence. About the year 1,000, when Sultan Mahmed invested it, it is represented as a city which, in strength, has no equal. It became an appendage to the empire established by Mahmed.—*Ferishta*, vol. i. p. 27.

Major Rennell is of opinion that Canouge and Palibrothra were the same. Others endeavour to prove the contrary; and that both may have existed at the same time capitals of the Prasii, as Delhi and Agra have done in later times.

The precise period of the origin of Delhi is not correctly ascertained: according to the *Ferishta*, it was founded by Delu, who usurped the throne about 300 years before Christ. The *Ayeen Akbery* fixes it about the commencement of this æra, and informs us, that twenty princes of the name of Bal, or Paul, followed in regular succession for 437 years; that the last of its native princes was Pithoura, when it was conquered by the Mahomedan slave Cattub, named by Herbelot, Cathbaddin Ibek, who made Delhi the capital of the vast empire he established in Hindoostan; and that each successive monarch of the Mahomedan dynasty adorned it with splendid edifices, appropriated to the purposes of religion and commerce. At the invasion of Timur Beck, it had arrived at the highest distinction for commerce and wealth, being then the centre of the traffic carried on between Persia, Arabia, and China. Timur entered it on the 4th July, 1399; and on the 13th of the same month, this celebrated city was destroyed. Sherifedden, the Persian historian, says, that old Delhi was celebrated for a mosque and palace, built by an ancient Indian king, in which were a thousand marble columns. Under the dynasty which succeeded Timur, it recovered its original splendour, and was again ornamented with mosques, baths, caravanseras, and sepulchres.

The great Akbar, the glory of the Timur house, having fixed his residence at Agra, Delhi, of course, experienced a partial eclipse; but in 1647, according to Fraser, Ischaim Shah, the grandson of Akbar, restored Delhi under the name of Ischaimbad, where he built a magnificent palace, formed extensive gardens, and constructed a throne in the shape of a peacock, whose expanded tail was entirely composed of diamonds, and other precious stones. It continued the capital of Hindoostan till 1738, when it was sacked by Nadir; and afterwards repeatedly by Ahmed Abdallah, from 1756 to 1760, when it was totally destroyed. During the reign of Aurungzebe, it was said to contain two millions of inhabitants.

Lahore is situated to the north-west of Delhi, on the banks of the Rauvee, the ancient Hydraotes: it appears to have been the Bucephalus of Alexander. Jeipal, the rajah of Lahore, during the incursions of Subuitagi, and his son Mahmud, defended his possessions with great bravery, and so great were his riches, that, when taken prisoner, around his neck alone were suspended sixteen strings of jewels, each of which was valued at 180,000 rupees, and the whole at £320,000. Lahore continued to flourish under the sultan of Cosro, and was the imperial seat of Cuttub before he removed it to Delhi; even afterwards it remained the general storehouse for the traffic of Persia, Arabia, India, and China. It was restored by Homaion, who amongst other magnificent buildings, erected a palace, which was completed by Ischaim Geer, the son of Akbar. This palace, according to Mr. Finch, who visited it in 1609, had twelve gates, nine towards the land side and three towards the river. He says, the rarities were too numerous and glorious to be represented in a description; that the mahls, courts, galleries, and rooms of state, were almost endless; and that, in the king's lodgings, the walls and ceilings were overlaid with plates of gold. M. Bernier, who was in this city in the suite of Aurungzebe, speaks of this place as a high and magnificent building, but then hastening to ruin.

Agra, the Agara of Ptolemy, situated in 27° 15′ north latitude on the banks of the Jumna, we have already observed, was raised to splendour by the great Akbar. He caused the earthen wall, by which the city had been enclosed by the Patan monarchs, to be taken away and replaced by one of hewn stone, brought from the quarries of Fettipore. He collected the most skilful artificers from every part of his dominions; and the palace alone employed above 1,000 workmen for twelve years. The castle was built in the form of a crescent, upon the banks of the Jumna; and in a line with it were ranged the palaces of the princes and great rajahs, intersected with canals and beautiful gardens. Akbar also erected many caravanseras and mosques. He invited foreigners of all nations; he built them factories; and permitted to all the free use of their religion. It was soon crowded with Persian, Arabian, and Chinese merchants, besides those immediately from European settlements. But when Ischaim removed the imperial insignia and treasures to Delhi, and made it the residence of his court, Agra sunk rapidly to decay.

These five imperial cities seem, with regard to extent, splendour, and wealth, to have exceeded the greatest cities of the western world; and, besides these, many others were almost of equal magnificence; for Chundery is said to have contained 384 markets, and 360 caravanseras; and Ahmedabad was once so large as to require to be divided into 360 quarters.—Maurice, *Ind. Antiq.* vol. i. p. 118–124.

These extensive and proud cities were evidently the symbols of temporary policy and power, and have passed away, like so many splendid scenes on the great theatre of the East. But as the religion of India has been more permanent than their political relations, it is from the sacred edifices we are to trace most distinctly the characters of Indian architecture, and be enabled to judge how far they have any affinity with those of other nations. Of their large temples, (pagodas) we find accounts of five different forms.

1. Simple pyramids constructed of large stones, and diminished by regular recesses or steps, as at Deogur and Tanjore; the exterior rude, and the interior having only light from without by a small entrance door; illuminated by a profusion of lamps, with the exception of a chamber in the middle, which has only a single lamp. Aquetil says, that to him one of the mountains of Canara seemed hewn to a point by human art.

2. The second kind were formed by excavations in the sides of rocky mountains. Abul Fazul (*Ayeen Akbery*, vol. ii. p. 208) says, that in the soobah of Cashmere, in the middle of the mountains, 12,000 recesses were cut out of the solid rock. From Captain Wilford's paper on Caucasus, inserted in the sixth volume of the *Asiatic Researches*, we learn that an extensive branch of the Caucasus was called by the Greeks Parapamis, obviously derived from Para Vami, the pure and excellent city of Vami, commonly called Bamiyan. It is situated on the road between Balkh and Cabul, and like Thebes in Egypt, consists of vast numbers of apartments and recesses cut out of the rock; some of which, on account of their extraordinary dimensions, are supposed to be temples. There are also, at that place, two colossal statues, one of a man eighty ells high, and another of a woman fifty ells high, erect and adhering to the mountain from which they are cut. At Salsette, Elephanta, and Vellore or Ellora, the excavations were not only extensive, but were divided into separate apartments, with regular ranges of sculptured pillars and

entablatures, and the walls and ceilings covered with multitudes of figures of their genii, deutah, men, and women; and various animals, such as elephants, horses, lions, &c. all of the most excellent workmanship. See *Plates* I. and II.

3. A third set was composed of square or oblong courts of vast extent. The circumference of the outward wall of that in the island of Seringham, adjacent to Trichinopoly, is said to extend nearly four miles. The whole edifice consists of seven square enclosures, the walls being 350 feet distant from each other. In the innermost spacious square are the chapels. In the middle of each side of each enclosure-wall there is a gateway under a lofty tower: that in the outward wall, which faces the south, is ornamented with pillars of single stones, thirty-three feet long, and five in diameter.—*Voyages de M. Sonnerat*, tom. i. p. 217; and Robertson's *India*, p. 268. Tavernier describes the pagoda of Santidos, in the Guzerat, as consisting of three courts paved with marble, and surrounded with a portico supported by marble columns; the inside of the roof and walls formed of mosaic work and agates, and all the portico covered with female figures cast in marble. Aurungzebe profaned this temple by killing a cow within its precincts, and converting it into a Turkish mosque. At Chittambrum, on the coast of Coromandel, there is only one court, 1,332 feet in one direction, and 936 in another, with an entrance gateway under a pyramid 120 feet high, and the ornamental parts finished with great delicacy.—John Call, *Phil. Trans.* vol. lxii. p. 354. Orme's *Hist.* vol. i. p. 178.

4. A fourth sort, as Benares pagoda, in the city of Casi, which from the earliest times was devoted to Indian religion and science. The temple is in the form of a cross, with a cupola terminated by a pyramid in the centre, and having also a tower at each extremity of the cross. From the gate of the pagoda to the Ganges, there is a flight of steps.—*Tavernier*, tom. iv. p. 149. Rouen edit.

5. A fifth are made in a circular form, as the celebrated pagoda of Juggernaut, which Hamilton compares to an immense butt set on end. Juggernaut is only another name of the god Mahadeo, who is represented by the vast bull which juts out of the eastern aspect of the building. It is the seat of the arch-brahmin of all India, and its sacred domains are said to afford pasturage for 20,000 cows.

Besides these general terms, if our limits permitted us to trace those interesting structures through the various districts of this extensive country, many different arrangements might be described; but, for the present, we must be satisfied with mentioning the pagoda of Bezoara, (or Buswara of Major Rennell,) now a fort upon the Kistna river: it was not enclosed with walls, but erected upon 52 lofty columns with statues of Indian deities standing between the columns. It was situated in the midst of an oblong court, around which there was a gallery raised on sixty-six pillars, like a cloister.—*Voy. des. Ind.* tom. iii. p. 226. Rouen Ed. 1713. Near this, on a hill ascended by one hundred and ninety-three steps, was another pagoda of a quadrangular form, terminated by a cupola.

These temples were generally erected on the banks of the Ganges, Kistna, and other sacred rivers, for ablution. Where there was no river, a tank or reservoir of a quadrangular form was constructed, and lined with free-stone or marble, with steps descending into them. Crawford observed many 300 or 400 feet in breadth.—Crawford's *Sketches*, vol. i. p. 106. At the entrance of the principal pagodas, there is a portico supported by rows of lofty columns, and ascended, as in the case of Tripetty, by more than one hundred steps; under these porticos, and in the courts which generally enclose the buildings, multitudes attend at the rising of the sun, and having bathed, and left their sandals at the border of the tank, impatiently await the unfolding of the gates by the ministering brahmin.—*Thevenot.*

We must reserve, until we come to treat of the detail of Indian architecture, many particulars relative to those splendid edifices, which, with the plates accompanying them, will afford a more distinct view of the nature of their arrangements and appropriations; but it will be proper in this place to notice some leading circumstances respecting the Indian sculptures, with a view to ascertain what affinity they had to those in Egypt. From the *Ayeen Akbery*, and Captain Wilson's paper on Caucasus, we find, that in the Soubah of Cashmere, between Balkh and Cabul, in the numerous excavations, there were 700 places where the figure of a serpent was carved; and that near these excavations, there were sculptured in rock, on the side of the mountain, figures of 15, 50, and 80 ells high; that in the great temple of the sun, which was near Juggernaut, and said, by the *Ayeen Akbery*, to have consumed, in the expense of building, the whole revenue of the Orissa for twelve years; that in front of the gate, there was a pillar of black stone, of an octagon form, 50 cubits high; that at the eastern gate, there were two elephants, each with a man on his trunk; at the western gate were figures of horsemen, completely armed; and at the northern gate two tigers, who had killed two elephants, and were sitting upon them. That in one extensive apartment, there was a large dome constructed of stone, upon which was carved the sun and stars, and around them a border of human figures. In the pagoda at Juggernaut, Hamilton describes the idol as a huge black stone, of a pyramidal form; and there was a bull, representing the god Mahadeo, jutting from the wall of the eastern aspect. Tavernier observed a conspicuous idol of black stone in the temple of Benares; and that the statue of Creeshna, in his celebrated temple of Mathura, was of black marble. In the great pagoda at Elephanta, the bust of the triple-headed deity measures 15 feet from the base to the top of the cap, the face is five feet long, and it is 20 feet across the shoulders. Along the sides of the cavern are colossal statues, to the number of forty or fifty, from 12 to 15 feet high; some have a sort of helmet of a pyramidal form; others a crown with devices; others display bushy ringlets, some with curled, and others with flowing hair; many have four hands, some six; with sceptres, shields, weapons of war, and symbols of peace. At the west end of the pagoda, there is a great dark recess, 20 feet square, totally destitute of ornaments, except the altar in the centre, and the gigantic figures which guard the several doors which lead into it. Niebuhr says these figures are eight in number; they are naked, and 13½ feet high; their heads, decorated like the other statues, have rich collars round their necks, and jewels of great size in their ears. In the before-mentioned recess, the Lingam divinity is represented. The pagoda at Salsette exceeds that at Elephanta; the two colossal statues immediately before the entrance of the grand temple are 27 feet high; they have caps and ear-rings. There are here two hundred figures of idols; ninety of which are in and about the great pagoda. In the interior spaces, which recede from the apartments, the Lingam is represented. Many of the sculptures in these grand temples have reference to the astronomical, as well as mythological notions prevalent in India.

At Vellore, Ellore, or Ellora, (*Plates* I. and II.) the sculptures, &c. are still more extraordinary; and all are dedicated to the Lingam or Mahdew. The height of the grand pyramid is here 90 feet; the smaller ones 50 feet; the obelisk 38 feet. The elephants on each side of the court are larger than life; and there is an apartment for the bull Nundee. See Sir C. W. Mallet's paper. *Asiatic Researches*, vol. vi. p. 383.

Sir W. Jones (*As. Res.* vol. i. p. 253) is of opinion, that the Eswara and Isi of the Hindoos are the Osiris and Isis of Egypt. He says, that the word Misr, the native appellation of Egypt, is familiar in India; that Tirhoot was the country, asserted by a learned brahmin to be that in which an Egyptian colony of priests have come from the Nile to the Ganges and Yamma (Jumna). And again, in his third annual discourse, the remains of architecture and sculpture in India, prove an early connection between this country and Africa; the pyramids of Egypt, the colossal statues of the Sphinx, and the Hermis Canis, which last bears a great resemblance to the Varahavatu, or the incarnation of Vishnu, indicate the style and mythology of the same indefatigable workmen, who formed the vast excavations of Canarah, the various temples and images of Buddha, and the idols which are continually dug up at Gaya.

Kempfer asserts, that the great Indian saint, Buddha, was a priest of Memphis, and having fled to India, introduced the worship of Apis.—Kempfer's *Hist. Japan.* vol. i. p. 38, ed. 1738.

Athanasius Kircher is of opinion, that after Cambyses had murdered Apis, the most revered of the Egyptian deities, he committed wanton cruelties on the priests, and destroyed their magnificent temples, as related by Herodotus, and that the priests flying into the neighbouring countries of Asia, there propagated the superstitions of Egypt.

The lotus was anciently in Egypt, and is still in India, held sacred. Herodotus calls it the lily of the Nile. The Egyptian priests had a sacred language; so have the brahmins. The Egyptians, according to Diodorus Siculus, were divided into five tribes, of which the first was sacerdotal; the Indians are separated into four tribes, besides an inferior one, named Buzzer Sunker.

Father Loubere, who went ambassador from the king of France to the king of Siam, in 1687, thinks the superstition of Boodh no other than the Sommonacodom, or stone deity of the Siamese, originally from Egypt. He says, that their astronomers have fixed the death of Sommonacodom to the year B.C. 545, and that it was then their first grand astronomical epocha commenced. Now, according to Usher, Cambyses invaded Egypt in 525 B.C. Loubere adds, that the Siamese priests live in convents, which consist of many cells ranged within a large enclosure; that in the middle of the enclosure stands the temple; that pyramids stand near to, and quite round the temple, all within four walls.—See Loubere's *Hist. of Siam*, in Harris's *Coll. of Voy.* vol. ii. p. 482.

Sir W. Jones thinks that the great statue of Narrayen, or the Spirit of God, who at the beginning floated on the waters, as that statue is now to be seen in the great reservoir of Catmander, the capital of Nepaul, is the same as the Cneph of Egypt, under a different appellation; both statues are made of blue marble.—See *Asiatic Researches*, vol. i. p. 261.

Mr. Call has published a drawing of the signs of the zodiac, which he found in the ceiling of a choultry at Verdapettah, in the Medurah country, viz., Brahma, painted in pagodas, in the act of creation, floating over the watery abyss, reclining upon the expanded leaf of lotus; and Osiris is found in the same attitude, recumbent on the same plant, in the Egyptian monuments.—Mauriee, vol. ii. p. 394.

In the Hindoostan edifices, although many parts of the general arrangement and principal features resemble those of Egypt, yet simplicity has been more departed from, and circular outlines similar to those of pagodas have been introduced. The most splendid of the Indian edifices being wholly formed by excavation, may most properly be denominated sculptures; but even for this mode, abundance of originals exist in Egypt. The numerous sculptured tombs adjacent to the principal cities in the Thebaïd, are perfect examples, as far as regards excavations within the natural rock; and the gigantic colossal statues are equally so as to isolated forms.

Detail of Indian Architecture.—The city of Agra was built in the form of a crescent along the banks of the Jumna; its walls were constructed with stones of great size, hard, and of a reddish colour resembling jasper. It was four miles in extent, and consisted of three courts, with many stately porticoes, galleries, and turrets, all richly painted and gilt, and some overlaid with plates of gold. The first court was built round with arches, which afforded shade; the second was for the great omrahs and ministers of state, who had here their apartments for transacting public business; and the third court, within which was the seraglio, consisted entirely of state apartments of the emperor, hung round with the richest silks of Persia. Behind these were the royal gardens. In front of the palace, towards the river, a large area was left for the exercise of the royal elephants, and for battles of the wild beasts; and in a square which separated the palace from the city, a numerous army lay constantly encamped. Mandesto, who visited Agra in 1638, then in the zenith of its glory, says, it was surrounded by a wall of freestone and a broad ditch, with a drawbridge at each of its gates. He states, that at the farther end of the third court, under a piazza, were a row of silver pillars; that beyond this was the presence-chamber, with golden pillars; that within a balustrade was the royal throne of massy gold, almost incrusted with diamonds, pearls, and other precious stones; that above this throne was a gallery, where the Mogul appeared every day at a certain hour, to hear and redress the complaints of his subjects; and that no person but the king's sons were admitted behind these golden pillars. He mentions also an apartment remarkable for its tower, which was covered with massy gold, and for the treasure it contained, having eight large vaults filled with gold, silver, and precious stones. Tavernier, who visited the Agra near the end of the 17th century, and in the absence of the court had permission to examine the inside, describes a gallery, the ceiling of which was decorated with branched work of gold and azure, and the walls hung with rich tapestry. The gallery which fronted the river, the monarch had proposed to cover over with a sort of lattice-work of emeralds and rubies to represent grapes with their leaves when they are green, and when they begin to grow red; but this design then remained imperfect, there being only three stocks of a vine in gold, with their leaves enamelled with emeralds, and rubies representing grapes; being a specimen of what was intended for the whole.

We have been thus minute in the description of the palace of Agra, because, having been built by one of the most enlightened princes of the East, it affords a perfect specimen of the scale upon which the monarchs of those extensive and rich countries acted. And it will be allowed, that the establishments of Akbar and his great rajahs, occupying four miles along the banks of the Jumna, and connected with a handsome and prosperous city, must have produced a picture sufficiently splendid, and emblematic of the wealth and power of the prince who erected it.

At Cuttek, or Cuttack, the capital of Orissa, there is a fine palace. It consists of nine distinct buildings:—1. for elephants, camels, and horses; 2. for artillery, military stores, and quarters for the guards; 3. for porters and watchmen; 4. for artificers; 5. for kitchens; 6. for the rajah's public apartments; 7. for the transaction of private business; 8. where the women reside; 9. the rajah's sleeping apartments.

The specimens here selected being the most noted, will, we trust, convey an idea of the nature of the Indian cities and palaces; and we shall therefore proceed to consider their sacred edifices.

We have already stated, that these were of five different sorts; that is, 1. pyramids; 2. excavations; 3. square or oblong courts; 4. in the form of a cross; and 5. perfectly circular.

1. We are here at a loss to determine whether or not the construction of Indian pyramids preceded that of their excavations. To construct a pyramid of rude stones, is certainly a much simpler operation than forming a cavern ornamented with sculpture; so that although it may be conceived that mankind might, for the purposes of worship, make use of the simple plain cavern, either natural or artificial, previous to the construction of buildings of great magnitude on the surface: yet it is not very probable that the splendid excavations of Elephanta and Vellore, in which were rich sculptures, and even pyramids cut out of the solid rock, could have preceded a rude pyramid on the surface. But as the purposes to which the pyramids of Deogur and Tanjore are appropriated partake very much of the nature of the cavern, their entrance-doors being very small, their interior being lighted by means of lamps, and the middle chamber by one lamp only; there is some reason for supposing, that in places where rocky eminences were not conveniently situated, or from motives now unknown, some change of ideas taking place, these pyramids might be constructed for purposes similar to the original cavern or grotto, in the same manner as the Egyptian pyramids are considered to have been done with regard to the tombs of the Thebaïd. The external faces of the pyramids of Deogur and Tanjore are very rude.

2. In regard to excavations, they are numerous and extensive. In some instances, they are very simple and plain; in others, highly ornamented with architectural forms and sculptures. From Captain Wilson's paper in the 6th volume of the *Asiatic Researches*, we learn, that an extensive branch of the Caucasus was named by the Greeks, Parapamis, from *Para Vami*, the pure and excellent city of Vami, commonly called Bamaiya. It is situated on the road between Balkh and Cabul, where vast numbers of apartments are cut out of the rocks, some of them so large that they are supposed to have been temples. And Abul Fazel says, that in the soubah of Cashmere, in the middle of the mountains, 12,000 apartments were cut in the solid rock. At this place there were 700 places where the figure of a serpent was sculptured.

Although neither the precise form nor dimensions are given, yet from the great number of excavations, and the place being noticed by the Greeks, it must, in former ages, have been of importance, at least, for its sanctity; and its situation between India and Persia renders it still an interesting subject of inquiry.

In other parts of India, the excavated temples have fallen more frequently under the observation of well-informed scientific persons, who have, with laudable industry, furnished the public with exact representations, and full details respecting them. The three principal ones, and which our limits will only enable us to notice, are Elephanta, Salsette, and Vellore or Ellora.

Elephanta is situated near Bombay, in an island so named from the figure of an elephant being cut upon the rocks on the south shore. The grand temple is 120 feet square, and supported by four rows of pillars; along the side of the cavern are from forty to fifty colossal statues, from 12 to 15 feet high, of good symmetry, and, though not quite detached from the rock, boldly relieved; some have a helmet of pyramidal form, others a crown, decorated with jewels and devices, and others have only bushy ringlets of flowing hair; many of them have four hands, some six, holding sceptres, shields, symbols of justice and religion, warlike weapons and trophies of peace, some inspire horror, others have aspects of benignity. The face of the great bust is 5 feet long, and the breadth across the shoulders 20 feet. At the west end of this great pagoda is a dark recess, 20 feet square, totally destitute of ornament; the altar is in the centre, and there are two gigantic statues at each of the four doors by which it is entered. Niebuhr represents these statues as naked, 13½ feet high, and the sculpture good; their heads are dressed like the other statues, and they have each rich collars round their necks, and jewels in their ears. Hunter states, that, on entering Elephanta, there is a veranda or piazza, which extends from east to west 60 feet, that its breadth is 16 feet, and that the body of the cavern is on every side surrounded by similar verandas.—*Archæologia*, vol. vii. p. 287.

Canara, in the island of Salsette, which is also situated near Bombay, is represented by Linshotten, who visited it in 1759, as being like a town. He describes the front as hewn out of the rock, in four stories or galleries, in which there are 300 apartments: these apartments have generally an interior recess, or sanctuary, and a small tank for ablution. In these recesses, as at Elephanta, are representations of the Lingan deity. The grand pagoda is 40 feet high to the soffit of the arch or dome; it is 84 feet long, and 46 broad. The portico has fine columns, decorated with bases and capitals: immediately before the entrance to the grand temple are two colossal statues, 27 feet high, which have mitre caps and ear-rings. Thirty-five pillars, of an octagonal form, about 5 feet diameter, support the arched roof of the temple; their bases and capitals are composed of elephants, horses, and tigers, carved with great exactness. Round the walls, two rows of cavities are placed with great regularity, for receiving lamps. At the farther end is an altar of a convex shape, 27 feet high, and 20 in diameter; round this are also recesses for lamps, and directly over it is a large concave dome cut out of the rock. Immediately about this grand pagoda, there are said to be 90 figures of idols, and not less than 600 within the precincts of the excavations.

Mr. Grose, who visited India in 1750, seems to be of opinion, that the labour required to construct Elephanta and Salsette, must have been equal to that of erecting the pyramids of Egypt; and though it is not mentioned which of the many pyramids he refers to, the remark sufficiently expresses his admiration of the greatness of these Indian works. He observes (p. 92) that the roof of Elephanta was flat; that of Salsette of an arch-form, supported by rows of pillars, of great thickness, arranged with much regularity; that the walls are crowded with figures of men and women, engaged in various actions, in different attitudes; that along the cornice there are figures of elephants, horses, and lions, in bold relief; and above, as in a sky, genii and dewtah are seen floating in multitudes.

But magnificent as the excavations at Elephanta and Salsette must appear, they are still surpassed by those near Vellore, Ellore, or Ellora, which is situated 18 miles from Aurungabad, capital of the province of Balagate, N. lat. 19° 20′, E. long. 75° 30′.

Sir C. Mallet, in a paper he transmitted to the president of the Asiatic Society, and published in the sixth volume of their *Researches*, gives a detailed account of sixteen of them:—

1. Jagnath Subba.
2. Adnaut Subba.
3. Indur Subba.
4. Pursuram Subba.
5. Doomar Lyna.
6. Jun Wassa.
7. Comar Wana.
8. Chana, or Oil Shop.
9. Neelkunt Mahdew.
10. Ramish Wur.
11. Kylas, or Paradise.
12. Dus Outar.
13. Tee Tal.
14. Bhurt Chutturghun.
15. Biskurma, or Carpenter's Hovel.
16. Dehr Wanar, or Hallulcore's quarters.

Of these we must, of course, confine ourselves to such parts as are calculated to convey a general idea of their architecture; with this view, we have selected for engravings (*see Plates* I. and II.) the ground-plan of Kylas, the entrance and section of Bĭskurma, the elegant entrance to the cave of Jugnath Subba, the temple of Indur Subba, and a singularly-beautiful piece of sculpture at the door of Jun Wassa. We shall also give the description and dimensions of the Kylas and the Biskurma.

Kylas, alias *Paradise*, (aspect, west.)—This wonderful place is approached more handsomely than any of the foregoing, and exhibits a very fine front in an area cut through the rock. On the right-hand side of the entrance is a cistern of very fine water. On each side of the gateway there is a projection reaching to the first story, with much sculpture and handsome battlements, which, however, have suffered much from the corroding hand of time. The gateway is very spacious and fine, furnished with apartments on each side, that are now usually added to the dewries of the eastern palaces. Over the gate is a balcony, which seems intended for the Nobut Khanneh. On the outside of the upper story of the gateway, are pillars that have much the appearance of a Grecian order. The passage through the gateway below is richly adorned with sculpture, in which appear Bouannee Ushtbooza on the right, and Gunnes on the left. From the gateway you enter a vast area, cut down through the solid rock of the mountain, to make room for an immense temple of the complex pyramidal form, whose wonderful structure, variety, profusion, and minuteness of ornament, are too elaborate for description. This temple, which is excavated from the upper region of the rocks, and appears like a grand building, is connected with a gateway by a bridge left out of the rock as the mass of the mountain was excavated. Beneath this bridge, at the end opposite the entrance, there is a figure of Bouannee sitting on a lotus, and two elephants with their trunks joined as though fighting, over her head. On each side of the passage under the bridge, is an elephant marked (*a*) in the plan, one of which has lost its head, the other its trunk, and both are much shortened of their height by earth. There are likewise ranges of apartments on each side behind the elephants, of which those on the left are much the finest, being handsomely decorated with figures. Advanced in the area, beyond the elephants, are two obelisks (*b*) of a square form, handsomely graduated to the commencement of the capitals, which seem to have been crowned with ornaments, but they are not extant, though, from the remains of the left-hand one, I judge them to have been a single lion on each.

To preserve some order, and thereby render easier the description of this great and complex work, we shall, after mentioning, that on each side of the gateway within there is an abundance of sculpture, all damaged by time, proceed to describe the parts of the centre structure; and then, returning to the right side, enumerate its parts; when, taking the left hand, we shall terminate the whole in a description of the end of the area opposite the gateway, and behind the grand temple, exemplifying the whole by reference to the annexed plan.

Centre below.—Passing through the gateway (1) below, you enter the area (2), and, proceeding under a small bridge, pass a solid square mass (3), which supports the bull Nundee stationed above; the sides of this recess are profusely sculptured with pillars and figures of various forms. Having passed it, you come to the passage under another small bridge, beneath which there is, on one side, a gigantic figure of the Rajah Bhoj, surrounded by a group of other figures, opposite to which is a gigantic figure Guttordhuj, with his ten hands. At each end of this short passage commences the body of the grand temple (4), the excavation of which is in the upper story, that is here ascended by flights of steps on each side (5).

Right and left-hand sides of the temple below.—The right-hand side is adorned with a very full and complex sculpture of the battle of Ram and Rouon, in which Hunomaun makes a very conspicuous figure. Proceeding from this field of battle, the heads of elephants, lions, and some imaginary animals, are projected, as though supporting the temple, till you come to a projection (6), in the side of which, sunk in the rock, is a large group of figures, but much mutilated. This projection was connected with the apartments on the right-hand side of the area by a bridge (7), which has given way, and the ruins of it now fill up the sides of the area. It is said to be upwards of a hundred years since it fell.

Passing the projection of the main body of the temple, it lessens for a few paces, then again projects (8); and after a very small space on a line of the body of the temple, the length of this wonderful structure, if what is fabricated downwards out of a solid mass can be so called, terminates in a smaller degree of projection than the former. The whole length is supported in the manner above mentioned, by figures of elephants, lions, &c., projecting from the bases, to give, it should seem, the whole vast mass the appearance of movability by those mighty animals. The hindmost, or eastern extremity of the temple, is composed of three distinct temples, elaborately adorned with sculpture, and supported, like the sides, by elephants, &c., many of which are mutilated. The left-hand side (from the entrance) differs so little from the right, that it is unnecessary to be particular in mentioning anything, except, that, opposite the description of the battle of Ram and Rouon, is that of Keyso Pando, in which the warriors consist of footmen, and others mounted on elephants, and cars drawn by horses, though none are mounted on horses. The principal weapon seems the bow, though maces and straight swords are discoverable.

Centre above.—The gateway consists of three centre rooms (9), and one on each side (9). From the centre rooms, crossing the bridge (10), the ascent is by seven steps (11) into a square room (12), in which is the bull Nundee. This room has two doors and two windows. Opposite the windows are the obelisks (*b*) before mentioned.

From the station of Nundee we cross over the second bridge (13), and ascend by three steps (14) into a handsome open portico (15), supported by two pillars (above each of which, on the outside, is the figure of a lion, that, though mutilated, has the remains of great beauty; and, on the inside, two figures resembling sphinxes) towards the bridge, and two pilasters that join it to the body of the temple, the grand apartments of which (16) are entered from the portico by four handsome steps and a doorway, on each side of which are gigantic figures. Advancing a few paces into the temple, which is supported by two rows of pillars, besides the walls that are decorated with pilasters, there is an intermission of one pillar on each side, leading to the right and left to an open portico (17), projecting from the body of the temple; from the right-hand one of which, the bridge, already mentioned as broken, connected the main temple with the side apartments, to which there is now no visible access but by putting a ladder for the purpose; though I was told there is a hole in the mountain above, that leads to it, which I had not time nor strength to explore. The access from the opposite is by stairs from below. The recess (18) of the Ling (19) of Mahdew, to which there is an ascent of five steps, forms the termination of this fine saloon, on each side of the door of which is a profusion of sculpture. The whole of the ceiling has been chunamed and painted, great part of which is in good preservation.

A door (20) of each side of this recess of the Ling of Mahdew leads to an open platform (21), having, on each side of the grand centre pyramid that is over the recess of the Ling, two other recesses (22), one on each side, formed also pyramidically, but containing no image. Three other pyramidical recesses (23), having no images within them, terminate the platform, all of them elaborately ornamented with numerous figures of the Hindoo mythology. Many of the outer, as well as the inner parts of this grand temple, are chunamed and painted. The people here attribute the smoky blackness of the painting within to Aurungzebe having caused the different apartments to be filled with straw and set on fire, which can be reconciled on no other ground than that he meant to efface obscenities, as there are many in the sculptures. Upon the whole, this temple has the appearance of a magnificent fabric, the pyramidal parts of which seem to be exactly in the same style as that of the modern Hindoo temples.

Right-hand side of the area.—This side of the rock has a continuance of excavations, as marked in the plan; but all those below, except the veranda, which I shall quit for the present, are of little note; and those above of three stories, called Lunka (24), which appear much more worthy of attention, are inaccessible but by a ladder, from the fall of the bridge. We shall, therefore, proceed to the

Left-hand side of the area.—In this side there are excavations of some consideration below, from which we ascend to an upper story, called Par Lunka, by an indifferent staircase, into a fine temple (25); at the extremity of which is a recess, containing the Ling of Mahdew; and opposite thereto, near the entrance from the staircase, is the bull Nundee, with two large fine figures, resting on maces, on each side of the recess in which he sits. The ceiling of this temple is, I think, lower than any of the foregoing. The whole of this temple is in fine preservation, strongly supported by very massy pillars, and richly ornamented with mythological figures, the sculpture of which is very fine. The ceiling, like the others, has the remains of painting visible through the dusky appearance of smoke with which it is obscured. Descending from Par Lunka, we pass through a considerable ensculptured excavation (26), to a veranda (27), which seems allotted to the personages of the Hindoo mythology (a kind of pantheon) in open compartments. These figures commence on the left hand with, 1. The Ling of Mahdew, surrounded by nine heads, and supported by Rouon. 2. Goura Parwuttee, and beneath Rouon, writing. 3. Mahdew, Parwuttee, and beneath Nundee. 4. Ditto, ditto. 5. Vishnu. 6. Goura and Parwuttee. 7. A Bukta (votary) of Vishnu, with his legs chained. 8. Goura and Parwuttee. 9. Ditto. These representations of Goura and Parwuttee all differ from each other. 10. Ditto. 11. Vishnu and Luchmee. 12. Bal Budder issuing from the Pind, or Ling of Mahdew. Here ends the left-hand side, and commences the east extremity, or end of the area (28), in which the figures are continued, *viz.*, 13. Goura and Parwuttee. 14. Behroo, with Govin Raj transfixed on his spear. 15. Dytasere on a chariot, drawing a bow. 16. Goura and Parwuttee. 17. Kal Behroo. 18. Nursing Outar, issuing from the pillar. 19. Kal Behroo. 20. Bal Behroo. 21. Vishnu. 22. Govin. 23. Brimha. 24. Luchmedass. 25. Mahmund. 26. Nunain. 27. Behroo. 28. Govin. 29. Bal Behroo. 30. Govin Raj and Luchmee. 31. Kissundass. Here ends the veranda of the eastern extremity: and we now proceed with that on the right hand (29), having in our description of that side, stopped at the commencement of this extraordinary veranda, for the purpose of preserving the enumeration of the figures uninterrupted, *viz.*, 32. Mahdew. 33. Ittuldass. 34. Dhurm Raj embracing Uggar Kaum. 35. Nursing destroying Hurn Kushb. 36. Vishnu sleeping on Seys Naug, the kummul (lotus) issuing from his navel, and Brimha sitting on the flower. 37. Goverdhun. 38. Mahdew Bullee, with six hands. 39. Krishna sitting on Gunoor. 40. Bharra Outar. 41. Krishna Chitterbooz trampling on Callea Naug. 42. Ballaju. 43. Anna Pooma. It is to be observed, that almost all the principal figures are accompanied in their respective panels by others, explanatory of the history of the idol in which it is represented.

Dimensions of the Kylas.

	Ft.	In.
Outer area, broad	138	0
Ditto, deep	88	0
Greatest height of the rock, through which the outer area is cut	47	0
Gateway, height	14	0
Ditto, breadth, without the modern building	14	4
Passage of the gateway, having on each side rooms, 15 feet by 9	42	0
Inner area or court, length from gateway to the opposite scarp	247	0
Ditto, breadth	150	0
Greatest height of the rock, out of which the court is excavated	100	0
Left Side of the Court, lower Story, viz.		
A small cave, in front two pillars, and a pilaster at each end, with three female figures buried up to the knees with rubbish, length	22	6
Ditto, breadth	8	0
Ditto, height	9	8
Another excavation, in front five pillars, two pilasters, length	57	9
Ditto, breadth, within the benches that are round this cave	6	0
Ditto, height, at the end of this is a staircase to the upper story	10	4
Interval unexcavated	20	0
Another excavation, having two large plain square pillars, and two pilasters in front, with a bench round the inside, the rock projecting beyond the pillars, length	54	6
Ditto, breadth	12	6
Ditto, height	16	0
Doorway, leading to a gallery, or veranda, 5 feet 11 inches high, by 2 feet 9 inches wide. Gallery containing figures. Length from doorway to the extreme depth of the whole excavation	117	8
Ditto, breadth	13	0
N.B. In this length are eleven pillars, each 2 feet 8 inches square.		
Ditto, height within the pillars (the projecting rock is about 3 feet lower, extending irregularly in the course of the length, from 7 to 13 feet beyond the pillars)	14	8
End of the Area, opposite the Gateway, behind the Temple.		
Whole breadth from side to side, measuring from the inner wall of the gallery on each side	186	6
Breadth of the gallery, including the pillars, there being 17 in this range	13	4
N.B. The rock projects beyond the pillars along this range, and the right hand one irregularly, from 15 to 22 feet, and is lower than the ceiling.		

Right-hand of the Court, lower Story, viz.

	Ft.	In.
Figure gallery, or veranda, of the same dimensions as the preceding parts of the same gallery, for the space of ten pillars, the angle of one being included in the foregoing; three of which were broken, it is said, to make trial of the power of the deity of the place; and when it was found that the superincumbent rock did not sink, the tempter, said to be Aurungzebe, forbore farther trial.		
Doorway, 2 feet 4 inches broad, by 5 feet high, leads to a veranda; within this veranda is a room of 60 feet by 22, and 11 feet 4 inches high. Right end unfinished: length	60	0
Ditto, breadth	17	0
Ditto, height	13	0
A small projecting room, 15 feet by 13, and 6 feet high, being choked with several finely-sculptured figures. An excavation raised 12 feet from the surface of the court, length	36	10
Ditto, depth	14	9
Ditto, height	12	0
There is a multiplicity of figures in this apartment, detached from the wall. Amongst the rest, a large skeleton figure, with a smaller one on each side. The principal is sitting, with each foot on a prostrate naked figure.		
An excavation, which has a small recess, opposite the entrance, of 6 feet by 7, and 8 high, length	24	0
Ditto, breadth	18	0
Ditto, height	10	0
An excavation terminating the lower story on the side, length	24	0
Ditto, depth	10	0
Ditto, height	11	6

Except between the two pillars, where the roof is arched, and is there 14 feet 8 inches high. This is the first instance I have seen of the arch.

Left hand Side, upper Story, viz.

	Ft.	In.
A small unfinished excavation, the dimensions of which were not worthy taking.		
Par Lunka is a fine large excavation, ascended by a flight of 25 steps, and a doorway of 3 feet 8 inches broad, by 7 feet 7 inches high; length, exclusive of the recess, in which is the temple of Mahdew	70	7
Ditto, breadth	61	9
Ditto, height	14	6
Recess, in which stands the temple of Mahdew, depth	26	0
Ditto, breadth, (the temple on the outside is 26 by 20 feet)	39	0

N.B. The whole of this apartment is full of figures, some very finely sculptured; and the centre floor is raised one foot, and the ceiling in proportion.

Right-hand Side, first Story.

	Ft.	In.
A large room, formerly connected with the grand temple by a bridge, now broken down	60	0
Ditto, depth	18	0
Ditto, height	16	0
Another room within the foregoing, entered by a door from it, having a bench all round. This inner room is very dark, having no light but from the doorway; length	36	0
Ditto, depth	29	0
Ditto, height	11	0

Right-hand Side, second Story.

	Ft.	In.
Entered by a staircase from the right side of the foregoing, of 24 steps. A large room, of the same dimensions as a correspondent one below, except two feet less in the height.		
Another room within the foregoing, depth	35	0
Ditto, length	37	0
Ditto, height	14	0
The rock seems to have given way in the centre of this room, and the rubbish has fallen in.		

Centre.

Balcony over the gateway, 14 feet by 8, and 8 high. A room within it 9 feet square, and about 9 feet high. Another within it, same dimensions. One on each side from the centre, 22 × 15 each. Bridge 20 feet × 18, with a parapet 3 feet 6 inches high. Ascent by nine steps from the bridge into a distinct room, in which is the bull Nundee, 16 feet 3 inches square. Another bridge, 21 feet × 23 broad, leading to the upper portico of the temple. This portico, with the parapet wall, is 18 feet × 15 feet 2 inches, and 17 high; within a bench that is rounded, of 4 feet high, by 3 feet 7 inches broad. This portico may be entered from the gateway, by a passage that the filling up of the rubbish has afforded; but the proper passage is by flights of steps on each side, of 36 steps each, leading up on each side the body of the temple.

Grand Temple.

	Ft.	In.
Door of the portico 12 feet high × 6 feet broad; length from the door of the portico entering the temple to the back wall of the temple	103	6
Length from the same place to the end of the raised platform behind the temple	142	6
Greatest breadth of the inner part of the temple	61	0
Height of the ceiling	17	10
Two porches on each side, measured without, 34 feet 10 inches × 15 feet 4 inches.		

The particulars of the intricate measurement of this fine temple will be best understood from the plan formed on the spot.

Height of the grand steeple or pyramid computed about 90 feet from the floor of the court, and of the smaller ones about 50; height of the obelisks about 38 feet; base 11 feet square, being 11 feet distant from each side of the room in which is the bull Nundee. The shaft above the pedestal is 7 feet square. The two elephants on each side the court or entry are larger than life." *Bishurma or Viswakurma ka Joompree.—The Carpenter's Hovel.* (Front W. 5 S.)—According to the legend, Bishurma (creator of the world, but allegorically artificer of Ram) was the artist who fabricated the whole of these wonderful works in a night of six months; but the cock crowing before they were finished, they remained imperfect, and he retired, having wounded his finger, to this hovel, in which state, the figure in front (1) of the entrance of this beautiful excavation, is said to be a representation of him holding the wounded finger; but it is more probable, that the figure is in the act of devout meditation, as many figures, with similar positions of the hands, occur. But, quitting the fable for the fact, this excavation is, in beauty, inferior to none. In form it is unique, and in design elegant. The portico is light, and striking to the beholder. On the right hand of the entrance is a fine cistern of water Above the gateway, II, which is richly sculptured on the outside, is a balcony, which seems well suited, if not intended, for a music-gallery to the interior temple, I, which has the appearance of an elegant chapel, with an arched roof, and is exactly in the style of a similar excavation at Canara, on the island of Salsette, and another at Ekvera, near the top of Bhore Ghaut, first explored by Mr. Wales the painter. At the upper end is the figure (I) above mentioned. From the ceiling are projected stone ribs, following the curvature of the arch to the capitals of the pillars on each side, through the whole length of the excavation. Beside the grand aisle, or body of the excavation, there is a small passage formed by the row of pillars on each side round the altar; but it is dark and narrow. This singular form of a cave, wherever it has been met with, has conveyed the same impression of its being a place of congregation and adoration, rather than of residence or habitation, and has given rise to an idea, from the orbicular ceiling, and the name and attitude of its inhabitant, that it may be meant to represent the Almighty, meditating the creation of the world, under the arch or canopy of unlimited space. It is necessary, however, to accompany this idea with an acknowledgment, that the similar caves of Ekvera and Canara are not inhabited by Bishurma, they having only a very high altar, the top of which is circular, and situated, as represented in the annexed drawing, at the back of Bishurma.

Dimensions.

	Ft.	In.
Area, square	49	0
Veranda below, in front, and each side, having 12 pillars, and two pilasters, breadth	14	0
Ditto roof, height	10	4
Doorway, 4 feet broad × 8 feet four inches high; gallery above the door, square	14	0
Length of the temple from the entrance to the opposite wall behind the altar	79	0
Breadth of ditto from wall to wall	43	5
Height of ditto from the centre of the arch to the floor	35	0
N.B. The height between the pillars and wall where the ceiling is flat, is	14	10
Breadth between the pillars and wall	7	8
Circumference of pillars (two square, and 28 octagon ones)	8	1
Altar at the end, about 24 feet high.		

3. The third kind of temples are those composed of square enclosures; the largest is that of Seringham, situated near Trichinopoli. The pagoda is composed of seven square enclosures, one within another; each side of the outermost is a mile in length, making the whole four miles in circumference. The walls of each enclosure are 350 feet from those of the others; they are 25 feet high, and four feet thick. Each enclosure has four gateways, that is, one in the middle of each side, opposite the cardinal points. In the outward wall, the gateway which fronts the south is ornamented with pillars, several of the single stones 33 feet long, and five feet diameter; those of which the roof is composed are still larger. All the gateways are covered with figures emblematical of their divinities. In the innermost enclosures are the chapels. Into the last, which is 1,024 feet square, and contains the sanctuary of Vishnu, no European is willingly admitted; but during the wars between the English and French, it was alternately occupied by each of the belligerents. The pagoda of Chittambrum, which consists of one square only, 1,332 feet by 396, entered by a pyramid 122 feet high, has already been described.

The pagoda Ahmed-Abad, in Guzerat, or pagoda of Santidus, consists of three courts surrounded with marble columns, and paved with marble. No person is admitted into the innermost court with sandals on. All the porticos are covered with female figures, of excellent workmanship; the inside of the roof and walls are decorated with mosaic and precious stones.—*See Tavernier* and *Thevenot's Travels.* This pagoda was converted into a Turkish mosque by Aurungzebe.

The Jumna Mesgid is quadrangular, 140 paces by 120; round the inside of the enclosing wall runs a gallery, having its roof supported by 34 pillars. The temple itself stands upon 44 pillars, ranged in couples; the pavement is marble; in the middle of the front are three large gateways. On the sides are two gateways; each gate has a sort of pilasters; the minarets are Mahometan.

The pagoda of Baswara, or Bezora, now a fort, on the Vistnu river, is not enclosed by walls, but stands upon 52 lofty columns, with statues of Indian deities standing between them; it was placed in the midst of an oblong court, and surrounded by a gallery, supported by 66 pillars.—*See Tavernier.*

4. The fourth kind are in the form of a cross. The most noted is that of Benares, in the city of Casi, on the banks of the Ganges, down to which there is a flight of steps. This, from the earliest period of history, has been devoted to Hindoo religion and science. The form of the temple is that of a great cross, with a cupola in the centre, which, towards the top, takes a pyramidal form. At the extremity of each branch of the cross, which are of equal length, there is a tower with balconies, to which the access is on the outside. Within the temple, immediately under the central cupola, there is an altar, eight feet in length, and six in breadth, covered sometimes with tapestry, sometimes with cloth of gold and silver. Tavernier saw several idols, one, in particular, six feet high, having its neck decorated with a chain of precious stones; the head and neck only were visible; the body was covered with a robe. On the right of the altar was a golden figure, composed of an elephant, a horse, and a mule; upon this the deity journeyed on his guardian care of mankind. In this pagoda was also an idol of black stone, or Sammenacodom. Aurungzebe polluted this temple.

Mattra, the Methora of Pliny, eighteen miles from Agra, on the road to Delhi, is the birth-place of the beneficent god, Chreeshna. The pagoda is constructed of the same stone as Delhi, and stands upon a very extensive octagonal platform of hewn stone. This platform is ascended by two flights of stone steps, which lead to the grand portal, composed of pillars with the usual sculptures. The pagoda is in the form of a cross with a lofty cupola in the centre, and two others nearly similar on each side. The sanctuary is separated by a balustrade, behind which only priests are admitted. In the sanctuary is a square altar, 16 feet in height, covered with gold and silver brocade, and here stands the god Ram Ram; the head only is visible, and appears of black marble, with two large rubies for eyes; the body is covered with a robe of purple velvet.

5. Of those which are of a circular form, Sonnerat thinks that Juggernaut is the most ancient in India, and says that the brahmins attribute it to the first king on the coast of Orissa, 4,800 years. Its plan is a perfect circle, of immense size. Juggernaut is said to be only another name for the god Mahadeo, who is represented by the figure of a large bull, which projects out of the eastern side of the edifice; the image of Juggernaut stands in the centre of the building,

upon an elevated altar, surrounded by an iron railing. Mr. Hamilton describes the idol as being an irregular pyramidal black stone, and the temple deriving light only from one hundred lamps. He compares the edifice to a great butt set on end. This place is the residence of the arch-brahmin of all India, and the sacred dominions are said to yield pasturage for 20,000 cows.—See Buchanan's *Christian Researches.*

Besides these, which are offered as specimens of the different forms of Hindoo temples, there is one more which our general views of the matter require to be noticed. The *Ayeen Akbery* relates, that near to Juggernaut is the temple of the sun, in constructing which, the whole revenue of the Orissa was, for twelve years, wholly expended; that the wall which surrounds the whole is 150 cubits high, and 19 cubits thick; that there are three entrances: at the eastern gate are two elephants, each with a man on his trunk; on the west, are two figures of horsemen, completely armed; and over the northern gate, are two tigers sitting upon two dead elephants. In front of the gate is a pillar of black stone, of an octagonal form, 50 cubits high. After ascending nine flights of steps, there is an extensive enclosure with a large cupola, constructed of stone, and decorated with sculptures of the sun and stars, surrounded by a border, composed of a variety of human figures, some kneeling, some prostrate with their faces on the earth, and some representing minstrels, also a number of imaginary animals. But of this splendid temple, so minutely described in the *Ayeen Akbery*, not a vestige is now to be found.

It may be observed generally, that these temples, for the sake of ablution, are usually placed on the banks of the Ganges, Vistnu, or some sacred river; or where that is not the case, artificial tanks or reservoirs are constructed, generally of a quadrangular form, lined with free-stone or marble, and having steps to descend into them. Crawford mentions several tanks from 300 to 400 feet in breadth.—Crawford's *Sketches*, vol. i. p. 106. Some of these tanks cover eight or ten acres, have steps of masonry 50 or 60 feet long, are faced with brickwork, and plastered substantially and neatly. The corners of the tank are generally ornamented with round or octagonal pavilions.—*Oriental Sports*, vol. ii. page 116.

In the Birman empire, which, for situation and various circumstances connected with its history, is one of the most interesting districts of the East, the temples of Godama are of a pyramidal form, of solid brick-work, placed upon an elevated terrace; and the base of the great pyramid is frequently encompassed by a double row of small ones, having its summit terminated by an umbrella made of iron bars into a sort of filligree work, and adorned with bells; many of these pyramids are from 300 to 500 feet high. In the larger temples, the umbrella, with at least the upper part, sometimes the whole, of the pyramid, is entirely gilt. Other temples, of similar shape, are hollow, and have images of Godama within them; but the images are more frequently placed in chapels, which encompass the pyramid. Dr. Buchanan saw at Ava an image made of one block of pure alabaster, of so large a size, that one of its fingers appeared about the length and thickness of a large man's thigh and leg. The whole statue must therefore have been about fifty feet high.

At one village, Colonel Symes saw 30 or 40 yards full of statuaries, all employed in making images of the god Godama, and all in the same position, that is, sitting crossed-legged upon a pedestal: the smallest exceeded the human stature. The price of this size was 100 tackals, or 12 or 13 pounds sterling. They work the marble with a chisel and mallet, and polish with three stones of different fineness; and, lastly, by rubbing with the hand, which gives a great degree of brightness and smoothness.

At Ummapoora were spires, turrets, and lofty obelisks. The fort is an exact square, with public granaries and store-rooms, and a gilded temple at each angle, upwards of 100 feet high. In the centre of the front stands the royal palace, with a wide court in the front, beyond which is the council-hall, supported by eighty pillars, on eleven roods. The royal library is a brick building, raised on a terrace, and covered with a roof of very compound structure; it consists of one square room, with an enclosed veranda or gallery round it.—See Colonel Symes's *Embassy to Ava*, 1795.

With regard to the present practice of Hindoo architecture, we learn that in Benares, their holy city, situated on the north bank of the Ganges, 460 miles N. W. of Calcutta, the streets are so narrow as not to admit of two carriages to pass one another. The houses are built with large stones, accurately joined. Some of them are six stories high, with terraces on the summits; a band or string-course, decorated with sculpture tolerably well executed, serves to mark externally the division of each story. The windows are very small. The houses on the opposite side of the streets sometimes communicate by galleries. The number of houses built of stone and brick are reckoned at 12,000; those with mud walls 16,000. In this city there is an observatory of immense magnitude, a great number of Hindoo temples, and a spacious mosque, built by Aurungzebe, from the minarets of which, the whole city may be seen.

By the kindness of a gentleman, whose opportunities and disposition for accurate observation have qualified him to afford the most authentic information, we are enabled to give the following account of the modes pursued by the Hindoos in the construction of their dwelling-houses: "The houses of the opulent are substantially built of stone and brick, with lime mortar, generally terraced with small bricks, about four inches square, and one inch in thickness; the beams are laid about 12 feet apart, and the joints 10 inches. The masons begin to form the terrace at one angle of the building, sitting upon a plank, which is supported on the brickwork as they proceed, until they finish at the angle opposite to that at which they commenced. They have no planks upon the beams or joists to support the work below; but as the middle of the terrace (generally about 18 feet wide) is from five to six inches higher than the sides, an arch is thereby formed and supported by the surrounding walls, which are 20 inches in thickness, and have a parapet placed upon them, both for ornament and adding to the security. Over this brick arch is laid a coat or layer of jelly or gravel, or broken bricks, about the size of a large pea, mixed with quick-lime and Jaggury water; this is beat down hard with small hand mallets. Over this first coat is laid a second, composed of rough lime-mortar, which is scored across. The third and last coat is a fine chunars; and this, altogether, forms so strong and firm a body, that a whole terrace sometimes falls down entire and unbroken. Many houses are built with pointed roofs, covered with flat tiles, four inches square, and three-quarters of an inch in thickness; others have a slight coat of lime, with pantiles, which are seldom above seven inches by four; they are semicircular nearly. The houses of the middling class are usually built in a square, and covered with tiles, with a seat round the inside of the square, about three feet high, and three feet in width, protected by a veranda; it is here the inhabitants sit to receive their guests. There are no windows in the external walls, but to each house there is a small door, and frequently a window; the latter placed as high as the veranda will admit. In the open square there is generally a well, with a water-course below the house, for domestic purposes. The houses of the poor are miserable: a few bamboos stuck in the ground, in a circular form, are collected, bent, and tied at the top, so as to represent an egg with the end cut off. They are seldom 10 feet in diameter, with a hole about three feet high to creep in at; this is shut with a leaf, tied on a simple wicker frame. The towns are generally a long street, with others at right angles, but seldom built with much regularity: some are large, some small; some are thatched, and others tiled. Those in the interior parts of the country are inferior to those near the sea-coast towns, where Europeans are settled."

From the account of Colonel Symes's embassy to Ava, we learn, that in the Birman empire, in private houses, the use of brick and stone is prohibited, and they are therefore all constructed of wood. They are raised from the ground by wooden posts or bamboos, according to the size of the building, and made tolerably convenient. The roofs are slightly covered, and at every door stands a long bamboo, with an iron hook at the end, to pull off the thatch, and another with an iron grating, to stifle the flame by pressure. Firemen constantly patrol the streets at night.

INDIAN INK, a black pigment brought principally from China, and much used in architectural drawing for lining, as well as colouring. Indian Ink should be free from grit, and readily fixed, so that when used for outlines, it may not be disturbed, or run, when washed over with any other colour. A good test of the former quality is afforded by cutting the cake, or rubbing it over the teeth; but the latter can only be discovered by use.

INDIAN RED, a pigment introduced from India, composed of peroxide of iron. It is of a russet hue, and forms a good colour for representation of brickwork.

INDIAN YELLOW, another Indian colour, produced from the urine of the camel. It is an excellent tint, and has the property of resisting the action of light to a greater extent than other similar colours.

INDIAN RUBBER, the substance known by the names Indian rubber, elastic gum, Cayenne resin, cautchoc, and by the French *caoutchouc*, is prepared from the milky juice which occurs in several plants, such as the *siphonia cahuca*, *jatropha elastica*, &c. It is, however, extracted chiefly from the first plant, which grows in South America and Java. The manner of obtaining this juice, is by making incisions through the bark of the lower part of the trunk of the tree, from which the fluid resin issues in great abundance, appearing of a milky whiteness as it flows into the vessel placed to receive it, and into which it is conducted by means of a tube or leaf, fixed in the incision, and supported with clay. On exposure to the air, this milky juice gradually inspissates into a soft, reddish, elastic resin. It is moulded by the Indians in South America into various figures, but is commonly brought to Europe in that of sphere-shaped bottles, which are said to be formed by spreading the juice of the siphonia over a proper mould of clay; as soon as one layer is dry, another is added, until the bottle is of the thickness desired. It is then exposed to a thick dense smoke, or to a fire, until it becomes so dry as not to stick to the fingers, when, by means of certain instruments of iron or wood, it is ornamented on the outside with various figures. This being done, it remains only to pick out the mould, which is easily effected by softening it with water. Indian rubber may be subjected to the action of some of the most powerful menstrua, without suffering the least change, while its pliability and elasticity are eminently peculiar to itself.

INDURATING, (from the Latin *induro*, to harden) a term applied to such things as give a harder or firmer consistence to others, either by the greater solidity of their particles, or by dissipating the thinner parts of their matter, so as to leave the remainder harder.

INFIRMARY, a hospital, or house for the reception and cure of invalids.

INLAYING. *See* MARQUETRY, MOSAIC, and VENEERING.

INN, a public tavern, or lodging-house, for the entertainment of travellers, &c.

INNER PLATE, the wall-plate in a double-plated roof, which lies nearest the centre of the roof, the side of the other wall-plate, called the *outer plate*, being laid in the inner surface of the wall.

INNER SQUARE, the edges forming the internal right angle of the implement called a *square*.

INSCRIBED, (from the Latin *inscribo*, to write) in geometry, is said of a figure when all its angles touch either the angles, sides, or planes of another figure within which it is contained.

INSCRIBED FIGURE, a figure placed within another figure or solid, so that all its angles may touch either the angles or sides of it, or both.

INSERTED COLUMN, one that is let into a wall.

INSTRUMENTS, *Mathematical*, a set of implements for describing mathematical diagrams and drawings of every description, when the figures or elementary parts are composed of straight lines, circles, or arcs of circles. The most useful drawing instruments are the following:

A drawing-pen—a pair of plain compasses, commonly called *dividers*—a pair of drawing compasses, with a pen and pencil foot—a pair of bow-compasses—a pair of triangular compasses—a pair of proportional compasses—a set of spring-bows for small work, consisting of spring-dividers, spring-bow pen and bow-pencil—a protractor, in the form of a semicircle, or of a rectangle—a plain scale—a sector—and a parallel rule.

Figure 1. *Plate* I.—The *drawing-pen*. No. 1, the steel pen. No. 2, the same with a pointer, which is screwed into the upper end of the drawing-pen, and has its point enclosed in it, as in a case. The end which contains the ink consists of two thin plates, adjusted by a screw; one of the plates is movable on a joint, for the purpose of being cleaned.

Figure 12. *Plate* II.—The *dividers*. The common sort.

Figure 9, No. 2, hair dividers, in which, by means of a screw, at *a*, the slighest alteration may be made in the extent, by turning it, one way or the other, as the distance requires to be shortened or extended.

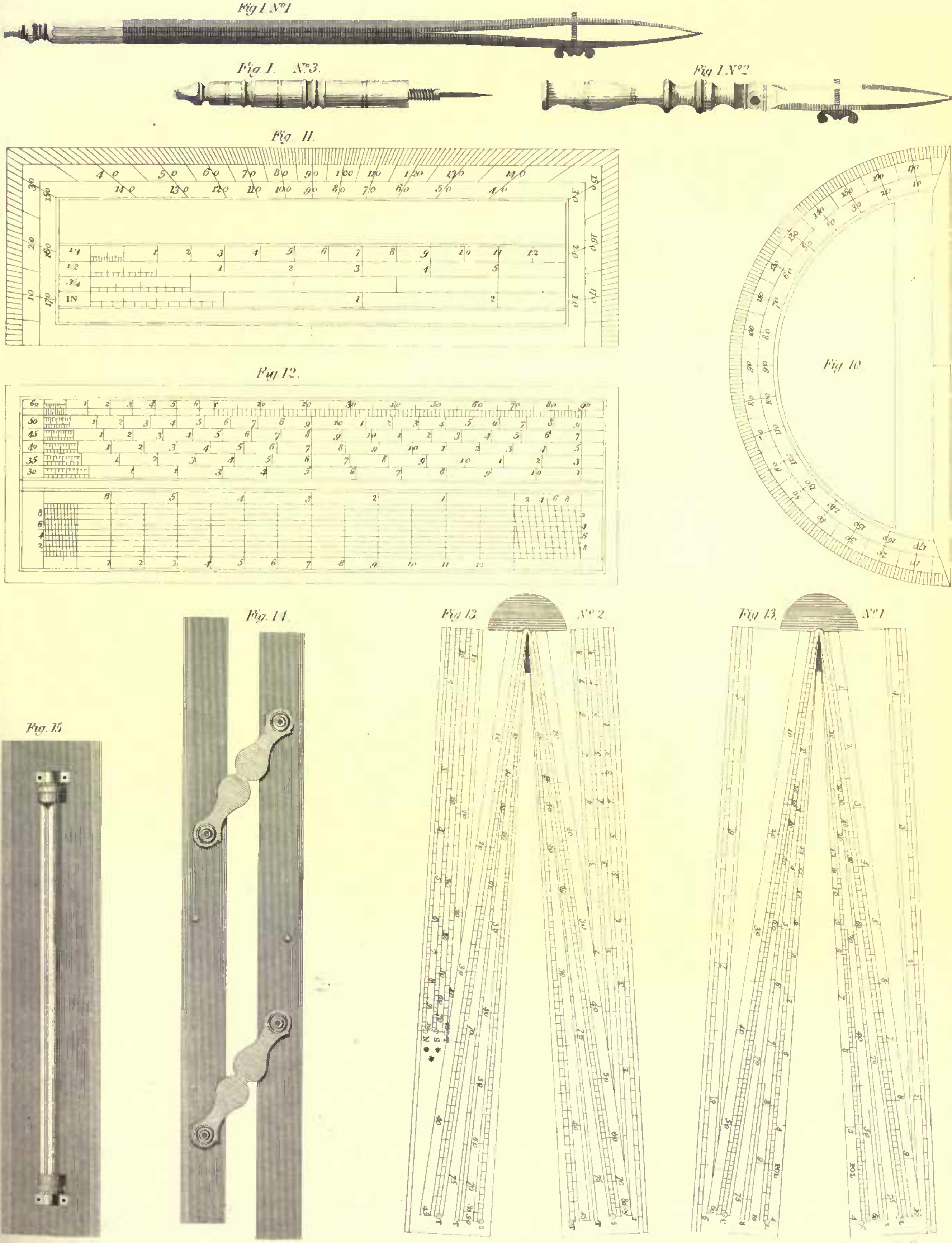
Figure 12.—The *drawing compasses*. No. 1, the crayon foot. No. 2, the ink foot. Both these feet are movable upon a joint, so that when fitted in for use, they may be brought perpendicular to the surface of the paper, and thereby perform with greater accuracy. One leg of these compasses has a cylindrical socket, with a parallel slit on the outer side, into which the upper end of each foot is closely fitted: the slit permits the leg of the compass to expand at the socket, and thereby retains the foot with the greater force, in consequence of the spring acquired by the surrounding parts of the socket in forcing in the foot.

Bow-Compasses, one of small dimensions, and were so called from the handling point in the original construction being made in the form of a bow; but which being found inconvenient for the fingers, has been altered to the present shape.

Figure 11.—A pair of *triangular compasses;* consisting of three legs, two of which are movable at the head, in the same manner as the dividers or the drawing-compasses; the third leg, which is made of steel, is fitted into a socket, through a knob projected from the side of the head, by which means

INSTRUMENTS
FOR DRAWING.

PLATE



Drawn by P. Nicholson

Engd by R. Thew.

INSTRUMENTS.

PLAT

Drawn by M. A. Nicholson. Engd. by R. Thew.

it is movable in almost any direction, while the other two remain stationary. Sometimes there is a joint in one of the legs, which permits its being lengthened or shortened at pleasure, so as to answer the expansion of the other two.

The *plain proportionol compasses* are made in the form of a cross, having a parallel slit cut down the middle of each part, and a centre piece fitted to each, so as to be movable round a pin, and to slide from one end of the slit to the other, or to any intermediate distance, to admit of the two points at one end being set in any ratio to the two points at the other. The centre piece is fastened by means of a nut and screw.

Figure 10.—The *improved proportional compasses.* In these, the method of construction is in all respects the same as in the plain proportional compasses; but the adjusting screw is an addition, which admits of its being set with greater accuracy. The parts of the proportional compasses, when shut, mutually cover each other. Scales of different gradations are engraved on the margin of each part, and on both sides of the compasses, for certain uses, which will be afterwards shown.

The common *protractor* is in a semicircular form, with a scale upon one side;

Figure 11, *Plate* I.—The best kind of *protractor*, in the form of a rectangle.

Figure 12.—A *plain scale;* consisting of lines divided into equal parts, of various proportions.

Figure 13.—A *sector*, in the form of a joint rule. The figure represented is of the best kind, having a French joint.

Figure 14.—The common *parallel rule.*

Figure 15.—The rolling *parallel rule.*

The *drawing pen* is used in making ink lines by the edge of a ruler; the cavity between the plates receives the ink, which is supplied from a common quill-pen, or a camel-hair pencil; or, what is perhaps better than either, by wetting the inside of the nibs, and taking up the ink or colour with the point of the pen, by which means the ink will rise without difficulty, and free from sediment. In performing this operation, the plane of the inside of the plate should be parallel to the edge of the rule, and in a plane perpendicular to the surface of the paper.

The use of *the dividers* is to take the extent of any line or surface from one point to another, in order to transfer it to some other line; to repeat any extension upon a straight line in an equimultiple; to divide a straight line, or the circumference of a circle, or any arc thereof, into equal parts; to proportion the parts of a drawing by a scale, in any desired ratio to each other; to construct a drawing similar to one already drawn, either greater or less, by an appropriate scale to each; to construct an angle of any number of degrees; to measure the quantity of any given angle in degrees.

The *drawing compasses* are used either in describing temporary arcs, or whole circumferences, with black-lead pencil, or permanently in ink. If the diagram or drawing consist of many circles, and is to be finished in ink, the circumferences must be first drawn with a pencil, and when afterwards inked must be cleaned with Indian rubber.

The *bow compasses* are used in the description of small circles, in which the legs of the larger kind would be apt to vibrate, and thereby make the arc or circumference ragged.

The *triangular compasses* are used in transferring a given angle from one place to another; or in taking the three points of a triangle at once, and transferring them to any required place, where the figure may be completed by joining the points. These compasses, though exceedingly useful, are but little known: they are serviceable in copying all kinds of drawings, as from two fixed points the position of a third may always be ascertained.

The *proportional compasses* are used in making one drawing similar to another, without the use of scales or triangular lines; in graduating the radii of spirals; in dividing circles into any number of parts between two limits, generally from six to twenty; in dividing a straight line into any number of equal parts, from two to a certain other limit, which is generally about ten.

Some general uses of the proportional compasses may be obtained from the following examples, which, though made to particular numbers in the cases of the planes and solids, will show the application of the principle to any other number contained in the margin of the instrument.

To divide a straight line into any number of equal parts. —Set the index marked upon the centre to the number on the line of lines; then take the extent of the given line with the longer points of the instrument, and the shorter points will divide the line as required. Thus, let it be required to divide three inches, or any distance within the reach of the compasses, into five equal parts: set the index to five on the line of lines: then take three inches, or the distance required by the longer points of the compass, and the shorter points will divide the line into five equal parts.

To divide a circle into any number of equal parts, from six to twenty, that the length of the compasses will admit of. —Set the index upon the number in the line of circles, and with the longer points take the radius of the circle; then the distance between the shorter ends being repeated as chords round the circumference, the circle will be divided as required. Should it be required to divide the circle into ten parts, set the index to ten on the scale of circles, and with the longer points of the compasses take the radius of the circle, and the shorter points will divide the circumference into ten equal parts. And thus any regular polygon, from six to twenty sides, may be inscribed in a circle.

Line of Lines exemplified.

To divide a line of 5 *inches into three equal parts.*—Set the index to three on the scale of lines, then from any scale of equal parts take the extent of 5 between the longer legs, and the distance between the shorter will be one-third of that between the longer.

Line of Circles exemplified.

To inscribe an enneagon, or regular polygon of nine sides, in a circle.—Let the radius of a circle be 3 inches, it is required to inscribe therein an enneagon. Set the index to the ninth division, open the compasses and take the extent of the radius, 3 inches, between the longer legs; then will the distance between the shorter be a side of the required polygon. And thus for any other number marked on these compasses.

Line of Planes exemplified.

To find the square root of a given number by the proportional compasses; say, that of four.—Shut the compasses and unscrew the nut, slide the centre along the groove till the index points to the number 4 upon the line of planes. Open the compasses, and from any scale of equal parts on the plane scale, or elsewhere, take 4 between the points of the longer legs; apply the points of the shorter legs upon the same scale, and the distance between them will be equal to the square root of the distance between the points of the longer legs, which in this case is 2, the square root of the given number 4.

Likewise, if the index be set to 9, the root of 9 will be 3.

To find a mean proportion between two given numbers.— Required the mean proportion between 2 and 4½. The way to find a mean proportion between two numbers is, to multiply them together, and extract the square root of the product. Therefore open the compasses with the index set against 9, the product of the two given numbers, till the distance of the longer legs be equal to 9, taken from some scale of equal parts; then the distance between the points of the shorter legs will be equal to 3 of those parts, which is the mean proportion to 2 and $4\frac{1}{2}$. For as $2 : 3 :: 3 : 4\frac{1}{2}$.

The use of the Line of Solids exemplified.

To extract the cube root of a given number.—To find the cube root of 8 by the line of solids, shut the compasses, unscrew the nut, move the centre along the groove till the index points to 8 on the line of solids; open the compasses, and take 8 between the long points from any scale of equal parts; then the distance between the shorter legs will be the cube root of the given number, which in this example is 2.

Again, by reversion, if the index is set to 2 on the line of lines, take 2 by the shorter legs of the compass, then apply the longer legs to the scale, and it will be found that they extend to 4. Then suppose the square of 3 to be wanted; fix the index to 3 on the line of lines, take 3 by the shorter points, and by applying the longer points to the scale, it will be found that 9 parts will be contained between them, which is the square of 3.

The same may be also pointed out by the index itself, without referring to any scale, not only with respect to the squares, but also of the cubes. Thus let it be required to find the square of 3: set the index to 3 on the line of lines, and turn the other side of the compasses, where the index will be found, against 9. Again, if the index be set to 2 on the line of lines, it will stand against 4 on the line of planes, and against 8 on the line of solids. This is the foundation of the construction of the line of planes and the line of solids: the line of lines being first constructed, the others will easily follow; since the planes are only the squares, and the solids the cubes, of the distances or numbers on the line of lines. The proportional compasses might therefore be made a very useful arithmetical instrument, provided each of the distances were graduated, and the compasses sufficiently long to give the operation correctness.

The use of the *protractor* is to lay down an angle of any number of degrees. Thus, let it be required to lay down an angle of 25 degrees on the line A B, *Figure* 16: supposing the angular point to commence at A, lay the centre of the semicircle, which is shown by a short line, to the point A, and bring the diameter or edge upon the line; then mark the paper at 25 in the circumference, at C; then a line drawn from A to C will form an angle C A B, or B A C, of 25 degrees, generally marked thus 25°. Again, let it be required to make an angle with A B, *Figure* 17, equal to 90°, or to constitute a right angle at the point B: bring the diameter or straight edge of the instrument upon the line A B, and the centre upon the point A; then at the point 90, in the middle of the semi-circumference, make a mark upon the paper at C, and join C B; then will A B C be the right angle required. Lastly, let it be required to find the quantity of any given angle: lay the centre of the instrument upon the angular point, and the straight edge upon one of the lines, and the number against the other line will show the degrees contained in both.

The *rectangular protractor* is used in the same manner; the edge which is not graduated answers to the straight edge, and the other three sides to the graduated semi-circumference, and are numbered round in the same order; the only advantage which this form can have over the semicircular, is, that when fitted into a case, the points at the extremities of the gradations, being more removed from the centre, gives the position of the line to be drawn more accurately, for a small error in any distance will be repeated proportionally to such distance: for example, supposing the line to be continued two, three, or four times as long, the error will be two, three, or four times as great as at first; whereas, if the instrument were four times as long, the error would be the same on the circumference of a circle four times the radius, as it would on the circumference of a circle once that radius, and consequently bear a greater proportion to the circumference of the latter circle than to that of the former.

The *parallel rule*, as its name implies, is an instrument by which straight lines are drawn parallel to each other. Of the two kinds in use, we should prefer the rolling one, as it moves more easily and steadily upon a surface which is not exactly a plane. When the common parallel rule is used upon a round board, it is very apt to revolve; and if the board be hollow, it moves very heavily. With respect to the rolling parallel rule in drawing lines in pencil, it performs its office with the greatest rapidity; but in drawing a series of lines in ink, as the friction is less than in the parallelogramic rule, it is apt to roll away. To remedy this inconvenience, the author would suggest the following alterations: instead of the axle and wheels being in the middle of the rule, it would be much better to place them as nearly as possible to the remote edge from that by which the lines are drawn, as it would give a greater command of leverage from the force exerted upon the drawing edge, and thereby require much less pressure, and consequently would make it much easier for the fingers. Another improvement would be, to insert a convex piece of brass, made exactly as a portion of the wheel on the lower side, as near to the drawing edge as possible, exactly opposite to each wheel; this addition would increase the friction, and keep the edge from the paper at the same time, which would be rather a convenience. These two pieces of brass should be notched the same as the wheel, otherwise no advantage would accrue from them. The rolling parallel rule has also this convenience; that any point in the drawing edge, when the rule is in motion, describes a line perpendicular to the edge of the rule, from which property it becomes easy to raise a perpendicular.

To draw a straight line parallel to a given line through any given point.—Place the edge of the rule upon the line, and then roll it to the point given, where a new line drawn will be parallel to the one given, and will also pass through the point, as required.

To draw a straight line perpendicular to a given line, from a given point.—Let a small line be made on the edge of the rule as an index; place the edge of the rule upon the line, so that the index may be brought to the given point; then move the rule to any parallel distance required, and mark the paper at the index with a point, from which draw a line to the given point, and it will be perpendicular to the given line, as required. Or, instead of a fixed index, the edge of the rule may be marked with a pencil, or the perpendicular may be drawn by the end of the rule.

From a given point out of a straight line, to draw a perpendicular to the straight line.—Place the edge of the rule upon the line, and move it forward to the point; then mark a short line, as nearly perpendicular from the point as the eye can judge, upon the bevel edge of the rule, with a pencil, and roll the rule backwards till the edge comes to the line, where mark the paper at the pencil line on the edge of the rule, and draw a straight line between this mark and the given point, which will be perpendicular to the line given, and pass through the given point.

From the perpendicular motion of the rolling parallel rule, its place can be depended upon at any distance. Whereas, in the parallelogramic rule, as it is opened by so many steps, and the motion at each point is in the arc of a circle, and made towards the same end of the rule, the line drawn from any point in the first line of the parallel, to the same point in the edge of the rule at the remote parallel, will be exceedingly oblique, and frequently so much so, as not to reach the place where the line is intended to be drawn : consequently the rule must be brought back towards the side which it is intended to reach; an operation not only troublesome, but also attended with much uncertainty.

From a given point to make an angle equal to, and in the same position as a given one.—Place the edge of the parallel rule upon one of the legs of the given angle, roll it to the given point, and draw a straight line ; then bring the edge of the rule to the other leg, roll it to the given point and draw another line, which will complete the angle required.

This operation might also be performed by the common parallel rule, though not so handily.

In lieu of the parallel rule, some use a T-square, which consists of a thin parallelogramic blade mortised into a rectangular prismatic piece, at right angles to one of its narrow sides or planes, in the form of the letter T, and a set-square, drawing both parallel and perpendicular lines by means of a thin board, and the straight edge of the T-square; the board is made up in the form of a right-angled triangle, and is termed a set-square. Any straight edge may be used with the set-square, but in most instances the T-square is most convenient, as, when moved along the side of a drawing board, it will give any horizontal line, and the set-square any perpendicular. To use this with any straight edge, place one of the legs of the triangle, which forms the right angle, upon the line; place the straight edge upon the hypothenuse of the triangle, and if it be required to draw another line parallel, slide the triangle along the edge of the rule till the edge that was upon the line comes to the given point, then draw a line by this edge, and it will be the co-parallel of the given line, but if the line be required to be perpendicular to the given line, place the triangle as before, then slide it along, till the other edge, (that is, the one at right angles, that was placed to the line,) comes to the point required, and draw a line by it, which will be perpendicular to the given line.

From the hypothenuse being placed upon the straight edge, the triangle is not liable to turn, as the pressure exerted in drawing the lines is everywhere perpendicular to the hypothenuse ; but in drawing any parallel or perpendicular lines at a great distance, the same inconvenience would occur which attends the common parallel ruler ; that is, the lines could not be drawn within a rectangle to the full length of the first line, which is a side thereof.

In this case, to draw one line parallel to another, place one of the perpendicular edges of the triangle upon the line, as before, but instead of applying the straight edge to the hypothenuse, apply it to the other leg of the right angle, and the motion of the drawing edge will be the same as in the rolling parallel rule.

If, however, the difference be considerable between the two sides of the right angle, and if the shorter side be that which is applied to the straight edge, the pressure of the hand at the extremity will be liable to turn round the triangle ; this inconvenience may be remedied to a great degree by making the two sides of the triangle which contain the right angle equal to each other, and the angle made by either side, which forms the right angle, and the hypothenuse, will be 45° or half a right angle. Though this equality of the legs makes the triangle more clumsy, it has its advantages not only in the case here described, but also in bisecting a right angle, which is an operation frequently wanted.

The *plain scale*, in common cases of instruments, has the following lines or scales upon it, viz., a line of 6 inches ; a line of 50 equal parts ; a diagonal scale : these are put on one side. On the other side are, a line of chords, marked C ; and seven particular scales of equal parts, or decimal scales, of different sizes ; the numbers at the beginning of each denote how many of the small divisions at the beginning are contained in one inch, viz., 10, 15, 20, 25, 30, 35, 40.

The use of the line of inches is the same in this as in all other rules, viz., to take the length or dimensions of bodies in inches and tenths of an inch, in order to compute their contents.

The line of 50 equal parts, being equal to 6 inches, shows the foot to be divided into 100 of the same equal parts, and the divisions of this line are placed by those of the inches, that it may be easily seen what number in one is equal to a given number of the other ; thus 3 inches is equal to 25 parts of the 100 ; and 30 of these latter are equal to 3 inches and 6 tenths. This line is therefore often useful in practical mathematics.

The *diagonal scale* is probably a *centesimal scale*, because by it an unit may be divided into 100 equal parts; and therefore any number, to the 100th part of an unit, may be expressed, which is an exactness generally sufficient in practical business. How this is done will be easy to understand, as follows: let A B, *Figure* 18, *Plate* III., be 1, or an unit, and divide it into 10 equal parts at 1, 2, 3, 4, &c. At a proper distance, B C, draw the line C D, equal and parallel to A B, and divide it also into 10 equal parts at *a*, *b*, *c*, *d*, &c : then join the points A *a*, 1 *b*, 2 *c*, 3 *d*, &c., and these will be the ten diagonal lines. Lastly, divide B C into ten equal parts also, and number them 1, 2, 3, 4, &c., to 10 at C ; then, through each of these divisions, draw lines parallel to A B, through the length of the scale, and the construction is completed.

In this diagonal scale, A B is one inch ; then if it be required to take off $1\frac{73}{100}$ inches, or 1.73, set one foot of the compasses in the third parallel under 1, at *e*, and extend the other foot or point to the seventh diagonal in that parallel, at *g* ; and the distance *e g* is that required ; for *e f* is one inch, and *f g* is 73 parts of 100.

Again, suppose it required to set off upon any line 2.37 inches ; then place one point of the compasses on the seventh parallel under 2, at *h*, and extend the other to the third diagonal in the same parallel at *i* ; and the distance *h i* is that required. Or, if A B be 10, the distance *e g* is 17.3, and *h i* is 23.7. Also, if A B be 100, then *e g* is 173, *h i* is 237 ; and so on.

This diagonal scale has the centesimal division at each end, and the unit in one is just the double of that of the other : thus, if A B be one inch at one end, it is half an inch at the other ; or if it be half an inch in the larger, it is one quarter in the lesser divisions, as is the case upon most of the common plain scales.

This unit, A B, may also be one foot, one yard, one rod, one mile, &c. So that every unit in every kind of measure is hereby estimated in hundredth parts of the whole, which shows the diagonal scale to be a most useful invention.

On the other side of the plain scale are the seven decimal lines, which are usually called *plotting scales*, because, their divisions of an unit into ten parts being different in the proportion of 4 to 1, the surveyor may vary the scale of his plot or plan of an estate, &c., in that ratio, in seven different drawings ; and the superficies or sizes of the greatest and least plans, will be as 16 to 1. Or, that drawn by scale No. 10, will be sixteen times larger than the plan laid down from scale No. 40.

The same variety is also to be had in the construction of all other geometrical figures, whether superficies or solids ; and with respect to the latter, the greatest will be the least as 64 to 1; that is, the architect can vary the size of his structure in the ratio of 64 to 1, in seven different elevations.

The last line on the common plain scale is that of chords; and is much more used than the protractor for laying off or measuring any proposed angle. Thus, let it be required to draw the line B C, *Figure* 19, to make an angle of 35° with the line A C. To do this, set one point of the compasses in the beginning of the line of chords, and extend the other to 60; with that extent, as a radius, place one foot in C, and with the other describe the arc A B; then take from the chords 35° in the compasses, and set them on the arc from A B; then through C and D draw C B, and it is done.

Again.—If it be required to measure any angle, as A B C, *Figure* 20, produce B A, if necessary; take 60° from the chords in the compasses, and with one foot in B describe the arc A C, cutting the leg B A at A, and B C at C; then take the arc A C in the compasses, and applying it upon the beginning of the line of chords it will reach to 30°, the quantity of the angle required. But the line of chords is more useful on the sector, to which we now proceed.

N.B.—The construction of this line is shown in the next article.

The *sector* is a most useful instrument, as forming a universal plane scale.

The lines commonly laid down upon the sector, are—a line of equal parts, marked L at the end; a line of chords to 60°, marked C; a line of sines, to 90°, marked S; a line of tangents, to 45°, marked T; another line of tangents from 45 to 75 or upwards, marked *t a*; a line of secants, marked *s e*; a line of polygons marked P O L.

Besides these, when the sector is quite opened, there are placed on one side—a Gunter's line of artificial numbers, *n*; a line of artificial sines, *s*; and a line of artificial tangents, *t*. Likewise a line of 12 inches, and another of the foot divided into 1000 equal parts, placed by it, for the purposes already mentioned.

Before a proper idea can be formed of these sectoral lines, and their uses, their construction must be shown from the circle. Therefore, let A C D, *Figure* 21, be a quarter of a circle, divided into 90°, described with the radius C A, on the centre C; let A E and C F be perpendicular to A C, at A and C; then if the radius A C be divided into 10, 100, 1000, &c., equal parts, it will be the line so called upon the sector.

If from A, a line be drawn to any part or division of the quadrant, as G, at 60°, then that line A G is the chord of that arc, or of 60°. And if the line A B be drawn, it will be the chord of 90°; and by setting one foot of the compasses in A, and extending the other to the several divisions, 10, 20, 30, 40, &c., they may be transferred from the circle to the line A B, which will then be properly divided into a line of chords in 10, 20, 30, 40, &c., to 90 as on the plane scale.

If from any point, G, in the quadrant, you let fall a perpendicular, G I, to the radius A C, or G H to the radius C B, then the line G I is called the sine of the arc A G; and the line G H is the sine of the arc G B, the complement of A G to 90°. And if all the divisions of the quadrant were transferred to C B by lines parallel to A B; then the line C B will be divided as a line of sines in the points, 10, 20, 30, 40, &c., to 90°.

By laying a rule from the centre, C, to the several divisions of the quadrant, 10, 20, 30, &c., it will cut the line A E in the points 10, 20, 30, &c., which will be thereby divided into a line of tangents; and here it must be observed, that the line of tangents, T, on the sector, extends but to 45°, equal to C A or C B radius; and that the line of lesser tangents, *t*, are projected from a lesser radius, and begin from 45° at the distance of its radius from the centre of the sector.

By drawing the line C L through the division 60° to the line A E, it makes A L the tangent of 60°, and C L the secant of 60°, or of the angle A C L. And if one foot of the compasses in C, the other is extended to the several divisions in the line A E, and transfer them to the line C F, then will the part B F be thus divided into a line of secants; being placed at the distance of the radius C B, from the centre of the sector, and beginning at E, where the radius ends.

It may be of use in many cases to observe, that the chord 60°, A G, is equal to the radius C A or C G; that the sine 60°, G I, besects the radius A C in I, and therefore the sine G H of 30° is equal to half the radius, or C I. Therefore the secant, C L, of 60° is equal to twice the radius, A C; for C I is to C G as C A to C L, and consequently the cosine is to radius as radius to the secant. Also, the tangent A L is to radius A C as radius B C is to the co-tangent B K.

From what has been said, the reason appears why the line of lines (or equal parts L) terminates upon the sector at 10; the line of chords, C, at 60°; the line of sines, S, at 90°; the larger tangents, T, at 45°; and that the lesser tangents, and also the secants are, of indefinite lengths.

From the nature of the sector, consisting of two pairs, or legs, movable upon a central joint, it is requisite that the lines should be laid on the sector by pairs, *viz.*, one of a sort on each leg, and all of them issuing from the centre—all of the same length, and every two containing the same angle. We shall now illustrate the nature of working problems by the sector, as follows, by the lines of lines, or equal parts L L.

Figure 22.—Let C L, C L, be the two lines of lines upon the sector, opened to an angle, L C L; join the divisions 4 and 4, 7 and 7, 10 and 10, by the dotted lines *a b*, *c d*, L L. Then by the nature of similar triangles, C L is to C *b* as L L to *a b*; and C L is to C *d* as L L to *c d*; therefore *a b* is the same part of L L as C *b* is of C L. Consequently, if L L be 10, then *a b* will be 4, and *c d* will be 7, of the same parts.

And hence, though the lateral scale C L be fixed, yet a parallel scale, L L, is obtainable at pleasure; and therefore, though the lateral radius is of a determined length in the lines of chords, sines, tangents, and secants, yet the parallel radius may be had of any size required, by means of the sector, as far as its length will admit; and all the parallel sines, &c. peculiar to it; as will be evident by the following examples in each pair of lines.

Example I.—*In the lines of equal parts. Figure* 22. Having three numbers given, 4, 7, 16, to find out a fourth proportional. To do this, take the lateral extent of 16 in the line C L, and apply it parallel-wise, from 4 to 4, by a proper opening of the sector; then take the parallel distance from 7 to 7 in the compasses; and applying one foot in C, the other will fall on 28 in the line of lines, C L, and is the number required; for as 4 is to 7 so is 16 to 28.

Example II.—*In the line of chords. Figure* 23. Suppose it required to lay off an angle, A C B, equal to 35°; then with any convenient opening of the sector, take the extent from 60 to 60 and with it, as radius, on the point C describe the arc A D indefinitely; then in the same opening of the sector take the parallel distance from 35° to 35°, and set it from A to B in the arc A D, and draw A B, which will make the angle at C as required.

Example III.—*In the lines of sines. Figure* 24. The lines of sines, tangents, and secants, are used in conjunction with the lines of lines in the solution of all the cases of plain trigonometry; thus let there be given in the triangle A B C, the side A B = 230, and the angle A B C = 36° 30′, to find the side A C. Here the angle at C is 35° 30′; then take the lateral distance 230 from the line of lines, and make it a parallel from 53° 30′ to 53° 30′ in the line of sines; then the

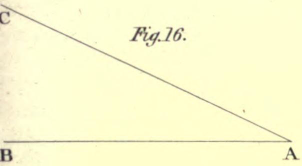


Fig. 16.

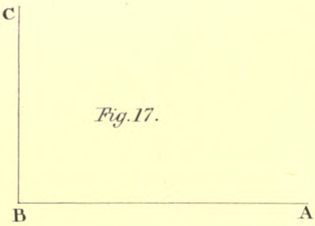


Fig. 17.

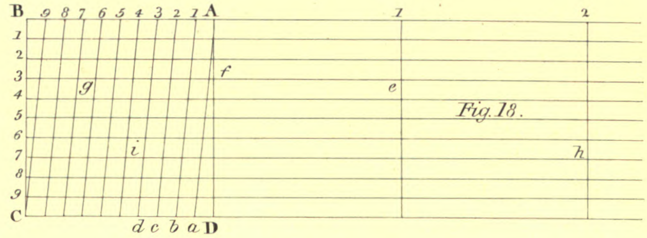


Fig. 18.

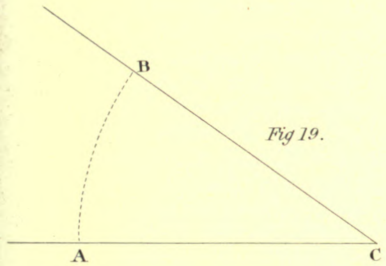


Fig. 19.

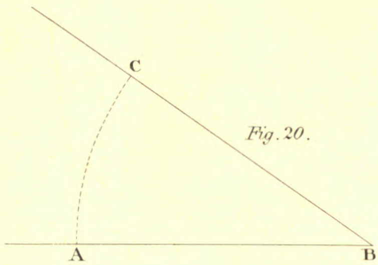


Fig. 20.

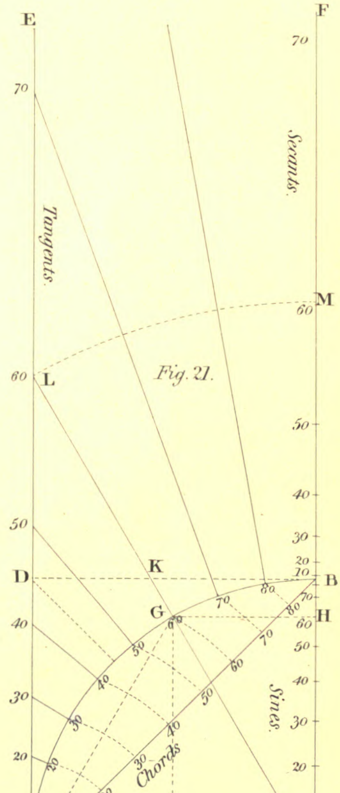


Fig. 21.

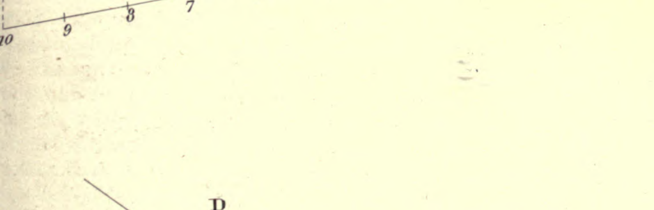


Fig. 22.

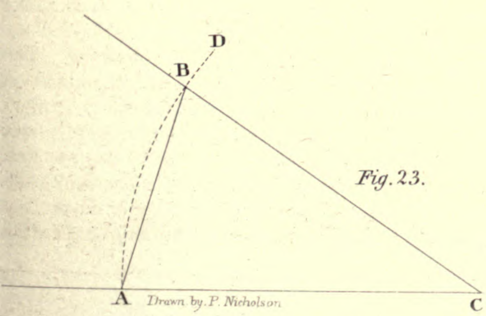


Fig. 23.

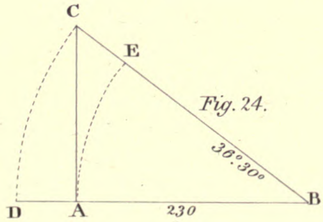


Fig. 24.

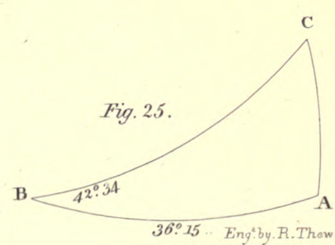


Fig. 25.

Drawn by P. Nicholson

Engd. by R. Thew.

parallel distance between 36° 30′ in the same lines, will reach laterally from the centre to 170.19 in the line of lines for the side A C required.

Example IV.—*In the lines of tangents.* If, instead of making the side B C radius, as before, A B be made radius; then A C, which before was a sine, will be the tangent of the angle B; and, therefore, to find it, the lines of tangents must be used thus:—Take the lateral distance, 230, from the line of lines, and make it a parallel distance on the tangent radius, *viz.*, from 45° to 45°; then the parallel tangent from 36° 30′ to 36° 30′, will measure laterally on the line of lines, 170.19, as before, for the side A C.

Example V.—*In the lines of secants.* In the same triangle, in the base A B, and the angles at B and C given, as before, to find the side or hypothenuse B C. Here B C is the secant of the angle B. Take the lateral distance 230 on the line of lines, make it a parallel distance at the radius, or beginning of the lines of secants; then the parallel secant of 60° 30′ will measure laterally on the line of lines 287.12, for the length of B C, as required.

Example VI.—*In the lines of sines and tangents conjointly. Figure* 25. In the solution of spherical triangles, use the line of sines and tangents only, as in the following example. In the spherical triangle A B C, right-angled at A, there is given the side A B = 36° 15′ and the adjacent angle B = 42° 34′ to find the side A C. The analogy is, as radius is to sine of A B, so is tangent of B to tangent of A C; therefore make the lateral sign of 36° 15′ a parallel at radius, or between 90 and 90; then the parallel tangent of 42° 34′ will give the lateral tangent of 28° 30′ for the side A C.

Example VII.—*In the lines of polygons. Figure* 24. It has been observed, that the chord of 60° is equal to radius, and 60° is the sixth part of 360°; therefore, such a chord is the side of a hexagon, inscribed in a circle. So that in the line of polygons, if the parallel distance between 6 and 6 be made the radius of a circle, as A C, and the parallel distance between 5 and 5 be taken and placed from A to B, the line A B will be the side of a pentagon A B D E F, inscribed in the circle. In the same manner may any other polygon, from 4 to 12 sides, be inscribed in a circle, or upon any given line A B.

Of Gunter's lines.—Having thus shown the use of all that are properly called *sectoral lines*, or that are to be used sectorwise, it only remains to describe another set of lines usually put upon the sector, which will in a more ready and simple manner give the answers to the questions in the above examples; these are called *artificial lines* of numbers, sines, and tangents, because they are only the logarithms of the natural numbers, sines, and tangents, laid upon lines of scales; this method was first invented by Mr. Edmund Gunter, and the lines are called *Gunter's lines*, or *the Gunter*. Logarithms are a set of numbers, so contrived, that, by addition and subtraction, the answers to all questions in multiplication, division, proportion, and the analogies of plain and spherical trigonometry, are found. Therefore, in the compasses, the extent, or ratio, between the first and second terms will always be equal to the extent, or ratio, between the third and fourth terms; consequently, if with the extent between the first and second terms, one foot of the compasses be placed on the third term, the other foot, on turning the compasses about, will fall on the fourth term sought.

Thus, in *Example* I., of the three given numbers 4, 7, and 16, take the extent from 4 to 7 in the compasses, then place one foot in 16, and the other will fall on 28, the answer, in the line of numbers, marked *n*.

Again, the artificial line of numbers and sines are used together in plain trigonometry, as in *Example* III., where the two angles B and C, and the side A B, are given; for here, if the extent of the two angles 53° 30′ and 36° 30′ be taken in the line of sines, marked *s*, and one foot be placed upon 230 in the line of numbers, *n*, the other will reach to 170.19, the answer.

Also, the line of numbers and tangents are used conjointly, as in *Example* IV.; thus, take in the line of tangents, *t*, the extent from 45°, radius, to 36° 30′, and it will reach from 230 to 170.19, the answer, as before.

Lastly, the artificial lines of sines and tangents are used together in the solution of spherical triangles.

Thus, *Example* VI. is solved by taking in the line of sines, *s*, the extent from 90°, radius, to 36° 15′, and in the line of tangents, *t*, it will reach from 42° 34′ to 28° 30′, the answer required.

It may be farther observed, that each pair of sectoral lines contains the same angle, viz., six degrees in the common six-inch sector; therefore, to open these lines to any given angle, as 35°, for instance, take 35° laterally from the line of chords, and apply it parallel-wise from 60° to 60° in the same lines, and they will all be opened to the given angle 35°.

If to the angle 35° be added the angle 6°, which they contain, the sum is 41°; then take 41° laterally from the line of chords, and apply it parallel from 60 to 60, then will the sides or edges of the sector contain the same angle, 35°. In this case, the sector becomes a general *recipe-angle*, which is an instrument for taking the quantity of any angle contained between two inclining planes.

INSULAR, or Insulated Buildings, such as stand alone.

INSULATED COLUMN, or Detached Column, a column that stands quite clear of a wall, and may be seen all round.

INTAGLIOS, (Italian.) the carved work of an order, or of any part of an edifice.

INTAVOLATA. *See* Cymatium.

INTERCEPTED AXIS, the same as Abscissa.

INTERCOLUMN, (from the Latin *inter*, between, and *columna*, a column.) the open area between two columns.

INTERCOLUMNIATION, the distance between columns, measured by their lower diameters. Under the article Colonnade will be found the several names given to certain distances measured by the diameter. The general distance used by the Greeks in the Doric order was that of the monotriglyph, though in the Doric portico or temple of Augustus, and the portico of Philip, king of Macedon, in the island of Delos, they are ditriglyphs. Also, on account of the triglyphs being placed in the angles of the Grecian-Doric, the extreme intercolumniation will be something less than those of the intermediate columns: as otherwise, if all the intercolumns were equal, each extreme intertriglyph would be broader than the intermediate ones.

INTERDENTILS, the space between dentils. It appears, not only from a comparison of the most celebrated examples in the Ionian antiquities, with that of Jupiter Stator at Rome, but upon the average, that the Romans set their dentils nearer together than the Greeks, and that the dentils themselves, among the former, are of a more trifling character. In the temple of Bacchus at Teos, the space between the dentils is two-thirds of the breadth of the dentil. In the temple of Minerva Polias, at Priene, the space is nearly three-fourths of the breadth. In the temple of Jupiter Stator, which has the boldest entablature of all the Roman examples, the space is about half the breadth of the dentil; and in most other examples in which dentils are to be found, generally less.

INTERDUCES. *See* Inter-Ties.

INTER-FENESTRATION, (from the Latin, *inter*, between, and *fenestra*, a window,) the space between windows.

INTER-JOIST, the space between joists, which may be a foot between centre and centre in good buildings, and in slight houses from 18 to 22 inches.

INTERIOR ANGLE, an angle within any figure, formed by two straight-lined parts of the perimeter, or boundary of the figure; the exterior angle being that which is formed by producing a side of the perimeter of the figure. The exterior and the interior angle of any figure are equal to two right angles, and all the interior angles of any figure amount to twice as many right angles, with four, as the figure has sides: for the figure may be divided into as many triangles as it has sides, by drawing lines from all the angles to a point within the figure. And as the angles of every triangle are equal to two right angles, there will be as many times two right angles as the figure has sides; but as four of these right angles are round the point to which the lines were drawn, consequently all the internal angles of any straight-lined figure are equal to twice as many right angles, wanting four, as the figure has sides. This is only deduced as a corollary from the 32nd Proposition of Euclid, book I., where it is proved, that if the side of a triangle be produced, the exterior angle will be equal to the two interior and opposite angles, and the three angles of every triangle will be equal to two right angles.

Interior Angle is also applied to the two angles formed between two parallels, by a line cutting them on each side of the intersecting line.

Interior and Opposite Angles, an expression applied to the two angles formed by a line cutting two parallels.

Interior Polygon. *See* Polygon.

INTERMITTING, anything which destroys the continuity of another.

INTER-MODILLION, the space between modillions.

INTERNAL ANGLE. *See* Interior Angle.

Internal Angle of a Solid, the inclination of two planes, of which their line of concourse recedes; that is, if a point be taken in each plane, the straight line joining the two points will be without the solid.

INTERPENSIVÆ, (Latin,) in ancient architecture, are supposed to be cantalivers, formed by the ends of joists. *See* Vitruvius, book vi. chap. 3.

INTER-PILASTER, the space between two pilasters.

INTER-QUARTER, the space between two quarters.

INTER-TIES, or Interduces, horizontal pieces of timber, placed between upright posts, to tie or bind them together. They are used in roofing, partitioning, and walling, with timber frames for lath and plaster, or panelled brick-work.

INTRADOS, the under curved surface or soffit of an arch; generally cylindrical or cylindroidal.

INVENTION, (French,) the act of finding anything new, or a thing found; the discovery of a principle, or a new application of a principle already known, in performing certain kinds of motion or construction; contriving instruments or machines for the performance of some useful purpose. Design is very nearly allied to invention, but is commonly applied to a new combination, or new order of things already known.

Invention is of real use; but design is altogether fanciful, though productive of pleasing forms. In invention, we can reason why a principle or thing contrived will answer its intended purpose; not so in design, where the only power of judging of the effects of combination arises from previous experience of things of the like nature. In design, all the simple forms are already known; thus, from a few kinds of moulding, already known, an unlimited variety of cornices, capitals, and imposts, may be contrived or designed. In a building, all the simple forms exist in squares, circles, and other geometrical figures and solids, already known: but, from the combination being unlimited, an effect may be produced different from anything that has ever before existed.

INVERTED ARCHES, such as have their concavity or intrados below the centre or axis. They are useful in every part of a wall which is lower than the two adjacent parts, or where an interruption is made by an aperture near its base. *See* Foundation.

INVOLUTE. *See* Evolute.

INWARD ANGLE, the re-entrant angle of a solid: they are framed in recesses. *See* Internal Angle of a Solid.

ION, son of Xuthus, and grandson of Hellen, king of Phthiosis, in Thessaly. He led a colony of Greeks into that part of Asia Minor, which from him obtained the name of *Ionia*, where the Ionic order first originated. The account given by Vitruvius of the invention of this order will be found in the next article.

IONIC ORDER, the second order of architecture, in point of time, among the Greeks. When the novelty of the Doric order had abated, the desire of producing something new soon led the way to the invention of another species; and in erecting the temple of Diana, they sought a new order from similar traces, imitating the proportion and dress of women. The diameter of the columns was made an eighth part of their height; the base with folds, representing the shoe; the capitals with volutes, in form of the curled hair worn upon the right and left; and the cymatium, for the locks pending on the forehead from the crown. This new order they called *Ionic*, after the name of the country in which it was invented.

Such is the account given by Vitruvius, but it will scarcely obtain credit in the present day. Many other suggestions have been substituted, with more or less reason; but how the order originated must ever remain a matter of conjecture. Some maintain that the idea of the capital was suggested by the curls of a lady's hair, as Vitruvius; others, by the horns of rams slain for sacrifice; others, by the use of twigs placed upon the capital; and others, who adhere to the notion of Vitruvius respecting the model wooden hut, suppose the same idea to have arisen from the splitting and bending, or curling downwards, of the tops of the wooden props, under the weight of the roof-timbers. Others, again, suppose the order to have arisen naturally from the Doric, but these do not pretend to account for the origin of the capital, which forms the most striking and distinctive feature, and on the pre-existence of which all their theory depends. Having found a fair type of the Grecian-Doric in some of the edifices of Egypt, we may naturally look to that quarter for the origin of the Ionic, but we cannot say that we meet with anything very satisfactory in this quarter. It is true, we have some approach to the form of the Ionic capital in some Egyptian buildings; we find, for instance, the volutes arranged in a somewhat similar manner, though in larger numbers, yet we cannot say that the resemblance is so striking as to satisfy us as to their identity. Again, we have in the same country capitals composed of the heads of Isis, with the curls of the head-dress hanging down at each corner of the capital, and this ought almost to satisfy some who rest content with the Vitruvian fables, but we fear not others. The capitals which bear the greatest resemblance to the Ionic, are found amongst the ruins of Persepolis, where the volutes are introduced in a very similar manner, although there is more than two such volutes in each capital. The Greeks were well acquainted with the Persians when the

Ionic order was introduced, and we would suggest this as a not unlikely account of the origin of the order; but this, like all the other suggestions, fall far short of satisfaction.

In this order, the capital becomes the chief characteristic, which is sufficient to distinguish it from any other, although from the preceding or Doric order it is distinguishable by many other marked differences, such as the employment of a distinct base; the much-altered proportions; the increased number and different contour of the flutes, and the introduction of the fillets; the increased ornamentation of the entablature; and by many other variations.

The Ionic capital has not all its sides similar, the similar sides being arranged in pairs, of which two, which may be termed the faces, are ranged parallel to the architrave; and two others, at right angles to the face, and underneath the architrave, which may be called the sides. Spiral bands or volutes, as they are called, ornament each side of the face, and are connected together by a band passing across the upper portion of the face. The volutes, in fact, may be said to be formed by a band passing over the top of the shaft, and curled up at each extremity on either side of the shaft. The band being of the same width of the column, would naturally form a cylindrical roll on each side, and thus may be supposed to have been formed the baluster side of the capital. These balusters, however, are not perfectly cylindrical, but hollowed out both vertically and horizontally, and, if we continue our simile, we may suppose the band composed of some compressible or yielding mass, and the roll to be tied up tightly in the middle, so as to make the intermediate sections of the roll gradually to diminish both ways towards the middle. Otherwise, we may suppose the balusters to represent two tubes or horns, so placed together that the larger ends, or mouths, are at the greatest distance from each other, and abut against the back of the volutes. This arrangement gives the balusters a much lighter appearance, which is considerably enhanced by their being usually decorated with carving.

The face of the capital measured across the volutes is about a diameter and a half, or 90 minutes, equal to the diameter of the base; the whole width is divided into three parts, of which one is given to each of the volutes. The volutes are composed of spiral mouldings, which make several revolutions, and gradually approach closer to each other, as they near the centre, or what is termed the eye of the volute, where they cease.

In the capitals of the Athenian examples of the Ionic, and in that of Minerva Polias at Priene, the lower edge of the canal between the volutes is formed into a graceful curve, bending downward in the middle somewhat like a festoon, and revolving round the spirals which form the volute upon each side. In the temple of Erechtheus, and of Minerva Polias at Athens, each volute has two channels, formed by two spiral borders, and a spiral division between them. The border which forms the exterior of the volute, and that which forms the under side of the lower canal, leaves a deep recess between them, which continually diminishes in its breadth till it is entirely lost when it comes in contact with the side of the eye.

In the temple of Bacchus at Teos, the great theatre at Laodicea, and in all the Roman examples of the Ionic, the channel connecting the two volutes is not formed with a border on the lower edge, but is terminated with a horizontal line, which falls a tangent to the curve of the spiral at the commencement of the second revolution of each volute. *See* Spiral and Volute.

In the example of the temple of Erechtheus, the column is terminated with a fillet and astragal a little below the edges of the volutes, and in that of Minerva Polias in the same manner, with a single fillet; and the colorino or neck of each is charged with a beautiful succession of woodbines, alternately disposed. The upper annular moulding of the column is of a semicircular section, and embellished with a rich guilloche. The echinus, astragal, and fillet, are common to both Grecian and Roman Ionic capitals, and the echinus is uniformly cut into eggs, surrounded with angular-sectioned borders, and with tongues between every two borders. The astragal is formed into a row of beads, with two small ones between every two large ones. These mouldings are cut in a similar manner in all the Roman buildings, except the Coliseum, and what relates to the taste of the foliage.

The necking of the capital is, however, frequently omitted; and the mouldings immediately under the band that connects the volutes, are thus disposed: first, a carved convex moulding, to which succeeds the enriched echinus or ovolo, and below that a bead or some other small mouldings. The abacus is square in plan, and its profile is that of a cyma-reversa or ogee-moulding, either enriched or plain, according to the richness of the capital.

When columns are introduced in the flanks of a building as well as in the front, one of the capitals of each angular column is made to face both the contiguous sides of the building, with two volutes, one upon each side projecting the two adjacent volutes by bending them in a concave curve towards the angle; as in the temple of Bacchus at Teos, of Minerva Polias at Priene, of Erechtheus, and that on the Ilissus at Athens, as also that of Fortuna Virilis at Rome. The capitals of all the columns are sometimes made to face the four sides of the abacus alike on each side, as in the temple of Concord at Rome, from which example the Scamozzian capital was formed.

A curious and probably very ancient specimen of the angular disposition of the volutes, occurs at the temple of Apollo at Bassæ, in which the capital presents four similar faces, and so far agrees with the more modern Scamozzian capital, from which, however, it widely differs in other respects. Each face of this capital is arched vertically as well as horizontally, as it curves downwards on each side from the middle of its upper edge, as well as outwardly to form the angular volutes.

This example offers other remarkable points of difference, more especially in the construction of the base, which is of very simple form, and consists of an annular moulding above a very large one of a concave profile, which spreads out beneath to considerably more than two upper diameters of the shaft.

The base employed in the Athenian Ionics consists of two tori, and a scotia or trochilus between them, and two fillets, each separating the scotia from the torus above and below: the fillet above the torus generally projects as far as the extremity of the upper torus, and the lower fillet beyond the upper torus; the scotia is very flat, and its section an elliptic curve, joining the fillet on each side: the tori and scotia are nearly of equal heights; in the Ionic temple on the Ilissus a bead and fillet were employed above the upper torus, joining the fillet to the scape of the column; the upper torus of the basis of the same temple, and that of the basis of the temple of Erechtheus, are both fluted, preserving the lower part, that joins the upper surface of the fillet above the scotia, entire. The upper scotia of the temple of Minerva Polias is enriched with a beautiful guilloche. The lower torus of the base of the antæ of the temple of Erechtheus is reeded, and that of the base of the antæ of the temple of Minerva Polias fluted, and separated from each other by two small cylindric mouldings of a quadrantal section, having their convexities joining each other. This form of a base is, by

Vitruvius, very properly called the *Attic base*, being invented and employed by the Athenians in all their Ionics. It was also adopted by the Romans, and seems to have been their most favourite base: for it is not only employed in all the examples of this order at Rome, but most frequently in the Corinthian and Composite orders also. However, the proportions of the Attic base as employed by the Romans, are different from that employed by the Greeks, the upper torus of the former being always of a less height than the lower one, both tori plain, and the scotia containing a much deeper cavity. The proportion of the bases of the Ionic and Corinthian orders on the Coliseum, the Ionic on the theatre of Marcellus, and that on the temple of Fortuna Virilis at Rome, have nearly that assigned by Vitruvius. The Ionic bases, as employed in the temple of Minerva Polias at Priene, and in that of Apollo Didymæus, near Miletus, consist of a large torus, three pair of astragals, and two scotiæ, inverted in respect of each other. The upper pair of astragals is disposed below the torus, and the scotiæ separate each pair of astragals. In the temple of Minerva Polias, an astragal is employed above the torus, separating it from the shaft; the torus itself is formed elliptically, and the under part of it is fluted: it has also a flute cut in the upper part, near to the bead. In the temple of Apollo Didymæus, the upper torus is of a semicircular section and plan, and each bead of every pair is separated by a narrow fillet. The base of the Asiatic examples differs little from that which Vitruvius appropriates to this order. In the former, the scotiæ are inverted, which gives a greater variety in the profile than when both stand in the same position as in the Vitruvian base.

The Ionians, besides the base which they appropriated to this order, sometimes used the Attic base also, as in the temple of Bacchus at Teos. This base seems not only to have been the most favourite one among the ancients, but is likewise so among the moderns. It is not so heavy in the upper part as that denominated Ionic; its contour is pleasing, and its general appearance elegant.

The shaft is fluted as in the Doric, from which, however, it differs in this, that the number of flutes is increased to 24, and their junctions are not formed by sharp arrises, but by fillets. The channels being thus multiplied, and set apart from each other, are consequently much narrower than those of the Doric order, and are much deeper in proportion to their breadth; and their extremities terminate in the semicircle, or semi-ellipse.

The architrave of the temple by the Ilissus consists of one broad facia, and its crowning cymatium; the parts of the cornice, as seen in front, are the corona, including its cymatium and sima. The capital or cymatium of the frieze, is wrought under the cornice, and consists of a sima-reversa and bead below it. The height of the architrave is about two-fifths of the entablature; and by dividing the upper three-fifths again into five parts, the plain part of the frieze will occupy three parts, and the cornice two parts.

In the Ionic order of the temple of Erechtheus, and of the temple of Minerva Polias, the architrave consists of three faciæ and cymatium; the cymatium of the frieze is mostly wrought under the corona. If the height of the entablature from the bottom of the lower facia to the top of the cymatium of the corona be divided into nineteen parts, the architrave and the part of the frieze that is seen, will each be eight parts; and the corona, including the larmier and cymatium, the other three parts. The volutes of the capitals of these orders, both for singularity and beauty, exceed every other remain of antiquity.

The Asiatic orders differ greatly from the Attic. In most of the remains of this order, as represented in the *Ionian Antiquities*, the friezes are all wanting—except in one example, and consequently the whole height of the entablatures of those without the friezes cannot be ascertained, though the architraves and cornices belonging to each other have been accurately measured. The one which has the entire entablature belongs to the great theatre at Laodicea; the frieze is pulvinated, and is something less in height than one-fifth of that of the entablature. The architraves of the temple of Bacchus at Teos, and the temple of Minerva Polias at Priene, are each divided into three faciæ below the cymatium. In all the Asiatic examples, the crowning moulding is constantly a sima-recta of a less projection than it has height: the dentils are never omitted, and their height is nearly a mean proportion between the height of the sima-recta and that of the larmier, corona, or drip, being always greater than the height of the corona, and less than that of the sima-recta. The cymatium of the denticulated band is wrought almost entirely out of the soffit of the corona, or recessed upwards, and consequently its elevation is almost concealed. The height of the cornice from the top of the sima to the lower edge of the dentils is equal, or very nearly so, to that of the architrave. The altitude of the frieze without its cymatium, or upper mouldings, may be supposed to be about a fourth part of the whole entablature; for if higher than this, the entablature would be too great a portion of the columns for any analogy we are acquainted with. In point of beautiful proportions and elegant decorations, the entablatures of these two last examples exceed every other remain; and though their proportions are very different from those remaining at Athens, they are still pleasing.

In all the Grecian examples of the Ionic order, there seems to be a constant ratio between the upper part of the cornice from the lower edge of the corona upwards, and the height of the entablature; this is nearly as 2 to 9. If these members were regulated in any other manner, their breadths would be so variable as sometimes to be so diminutive that their forms could not be perceived, and at other times so enlarged as to overcharge the whole when viewed from a proper station. Indeed the great recess of the mouldings under the corona, makes this a very distinct division, and on this account the cornice never appears too clumsy, though the whole denticulated band and cymatium of the frieze are introduced below it, which seems to be the reason of so great an apparent difference between the Asiatic and Attic species. This order, as found in the Ionian territory, is complete; but those at Athens are deficient, from their want of the dentil band, though beautiful in many other respects.

The following account of some of the more noted specimens of Ionic building, still remaining, is extracted from a series of lectures which have been published in the *Builder*.

"The earliest specimen of which any remains are to be found is the celebrated temple of Juno at Samos, which, in the age of Herodotus, was considered as the largest and most stupendous edifice ever raised by Grecian art. This interesting ruin, although often visited, has never, until recently, received any architectural elucidation. It was built about the 60th Olympiad by Rhaechus and Theodorus, two natives of the island; and the style possessing many peculiarities is such as strongly to denote its archaic origin. The bases of the columns are remarkable from the number and complication of their parts; the shaft is not fluted, nor is there any appearance of volutes to the capitals."—(Lord Aberdeen's *Inquiry*, p. 160.)

But the purest and best known specimens are to be found at Athens, where we see at once the simplest and richest modes of employing the style. The former is to be seen in the graceful little temple on the Ilissus, and the latter in the double temple, erected in honour of the Virgin-goddess and Erechtheus. Nothing can be more simple than the design of the former beautiful little building, which is only 20 feet high to the cornice; from the fewness of the mouldings and their freedom from enrichment, it serves as a model for most of the Ionic porticos of the present day, as it is admirably adapted to domestic structures. This temple had a portico of four columns at each end, but was without any lateral columns: the columns are only 21 inches in diameter, and are eight diameters high. The architrave has only one face; and the frieze was probably also plain, although Stuart considers that it may have had an enrichment, as a fragment of sculpture representing several figures, was found at Athens, which exactly fitted the space. The cornice is composed of the fewest possible mouldings, which, throughout the building, are of the simplest character. A more enriched example is that of the temple of Minerva Polias (so called from πολις a city; thus the goddess was emphatically the protectress of the city of Athens) placed in the acropolis, at a distance of 150 feet from the Parthenon. This temple is connected with two other buildings—the Erechtheum and the Pandrosium.

We now proceed to notice this triple temple more in detail, for which purpose a plan is essential. Elevated on three steps is a portico of 6 columns, leading to what is called by Stuart the temple of Erechtheus, but which is considered by others to be the cella of the goddess. The columns are 2 feet 3 inches in diameter, 21 feet 7 inches high, including base and capital, and are 4 feet 8 inches apart. The width of the cell is 32 feet 4 inches, and its depth 23 feet 11 inches. In the rear of the cell, and divided from it by a wall, is the apartments which Stuart ascribes to Minerva, receiving its light from three openings like windows (a rare and valuable example) placed between half-columns, and having on one side a communication with the Pandroseum, and on the other with a noble portico of four columns in front, having a projection of two inter-columns. These three last-named parts are on the same level, which is, however, about 9 feet lower than that of the hexastyle portico. The columns of the tetrastyle are 2 feet 9 inches in diameter, and 25 feet in height. The little building, the Pandroseum, had six female figures, called Caryatides, instead of columns, to support the entablature, and their origin has given rise to much discussion.

There are but few examples of this order as practised by the Romans, remaining entire; amongst them are the theatre of Marcellus, the temple of Concord, and that of Fortuna Virilis. Several portions of the order have, however, been discovered in those buildings which were erected after the decline of the empire, such portions having been plundered from more ancient buildings, to enrich the new edifices. Although some of these Roman examples are of considerable merit, they would seem to fall far short of the Grecian in taste and elegance. The capital was greatly impoverished by the volutes being considerably reduced in size, and thereby losing to a great extent its importance as the chief characteristic of the capital. This fault, however, was afterwards greatly increased by the Italians. In the Greek examples the volutes were connected together by a series of mouldings or hem, hanging down over the echinus, after the manner of a festoon; but in the Roman there is merely a straight line without any moulding carried over the echinus, which is not nearly so graceful as in the former examples. In late specimens, the volute consists of fewer revolutions, and has no secondary spirals upon it; the mouldings of the spiral also, as well as the intermediate spaces between the spirals, are flat, and altogether the volute is less prominent, and less elaborately worked than in Grecian specimens. In the temple of Concord, the volutes are placed diagonally, similar to those of the capital termed Scamozzian, so as to present four similar faces. This is one amongst many varieties of the Roman-Ionic capital, of which there is no lack, some being ornamented with human figures, masks, busts, &c., as in an example given by Pyranesi. These differences are sufficient to show that the ancients did not confine themselves to one and the same treatment of this order on all occasions. The Italians in later times made very considerable alterations, first by reducing the size of the volutes, so as to make them insignificant, and afterwards, by attempting to remedy this defect, and give importance to the capital by the addition of an ornamental necking: another alteration consisted of the addition of festoons to the angular or Scamozzian capital, a festoon being suspended on each side of the capital, from the eye of one volute to that of the other on the same face; an example of this practice is to be seen in the portico to All-Souls Church, Langham-place, London. The Romans make use of the Attic base.

The Roman entablature differs also in some respects from the Grecian, and especially in the proportions of the cornice, which in the latter case is less than either of the other members, averaging at about $\frac{35}{100}$ of the entire entablature, whereas in examples of Roman practice, the cornice is by far the most important division of any, the proportions of the theatre of Marcellus giving 43 minutes to the architrave, 36 to the frieze, and 66 to the cornice, while those of the temple of Fortuna Virilis stand thus: architrave 38 minutes; frieze 29; cornice 70; which gives a great preponderance to the cornice. The projection of the cornice usually equals its height, or nearly so. The upper facia of the architrave is surmounted with a fillet and ogee often enriched, and the lower not unfrequently with a small echinus, also enriched, with a narrow fillet underneath. The frieze is mostly plain, and of little importance, but that of the temple of Fortuna Virilis has an attempt at decoration. The cornice is supported by an ogee-moulding, and dentil-band surmounted by a fillet, a bead-moulding, and a large enriched echinus; the cornice itself consisting of a corona with a small ogee and fillet, on which is placed a cymatium. In the dentil-band, the dentils are often of large size, and placed rather wide apart. The Italians have not unfrequently introduced into this order what is termed a pulvinated frieze, so called from its supposed resemblance to a cushion, its profile being convex; one of the earliest examples of the pulvinated frieze occurs in the baths of Diocletian.

The general proportions of the order, as adopted by the Grecian and Roman architects, are much alike; the principal differences existing, as we have shown, in matters of detail. Chambers gives the height of the column eighteen modules, and that of the entablature four and a half, or one-quarter the height of the column. The base is attic, and the shaft either plain or fluted, and in the latter case with twenty, or more frequently twenty-four, flutings with fillets between, which should not be broader than one-third of the width of the flutes, nor narrower than one-quarter. The ornaments of the echinus of the capital should correspond with the flutes, so as to have an egg or dart over the centre of each flute.

Modern examples of this order in London, are—

St. Pancras Church, copied from the Erectheion, and affording also a specimen of Caryatides with entablature, after the small building called the Pandrosium.

The East India House, after the Asiatic examples.

The portico of Hanover Chapel, Regent-street, after the order of Minerva Polias at Priene, which exhibits the peculiar Ionic base.

The New Post-Office.

The British Museum.

The portico of the College of Surgeons, after the small temple on the Ilissus.

The Church in Regent-square, New Road.

The Law Institution, Chancery-lane.

The subjoined table of proportions, as exhibited in various examples, may be found useful; it is extracted from Knight's Cyclopædia:—

	Height of Column.		Base of Shaft.		Upper diameter of Shaft.		Height of Entablature.	
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
Temple of Apollo Epicurius, at Bassæ			2	1.9	1	9.4	3	9.31
Temple of Erechtheus, Athens	21	7.50	2	3.8	1	11.2	4	11.25
Aqueduct of Adrian	19	1.95	2	2.35	1	11.1	4	2.90
Temple on the Ilissus	14	8.300	1	9.4	1	6.2	3	7.282
Temple of Fortuna Virilis, at Rome	27	0	3	2	2	8.	6	8.6
							Architrave.	
Temple of Bacchus, at Teos.			3	3.6	3	1.8	2	5.4
Minerva Polias, at Priene			4	2.8	3	6.4		
Apollo Didymæus, near Miletus			6	3.2	5	5.8	3	5.2
Propylæa, at Eleusis			3	4.6	2	9.24		

The examples which we have selected for illustration, are as follows:—

Plate I.—Finished drawing of the order from the temple of Minerva Polias at Athens.

Plate II.—The same in outline.

Plate III.—Drawing in outline of column and entablature from the temple of Fortuna Virilis at Rome.

Plate IV.—Drawing in outline of column and entablature from the temple of Marcellus at Rome.

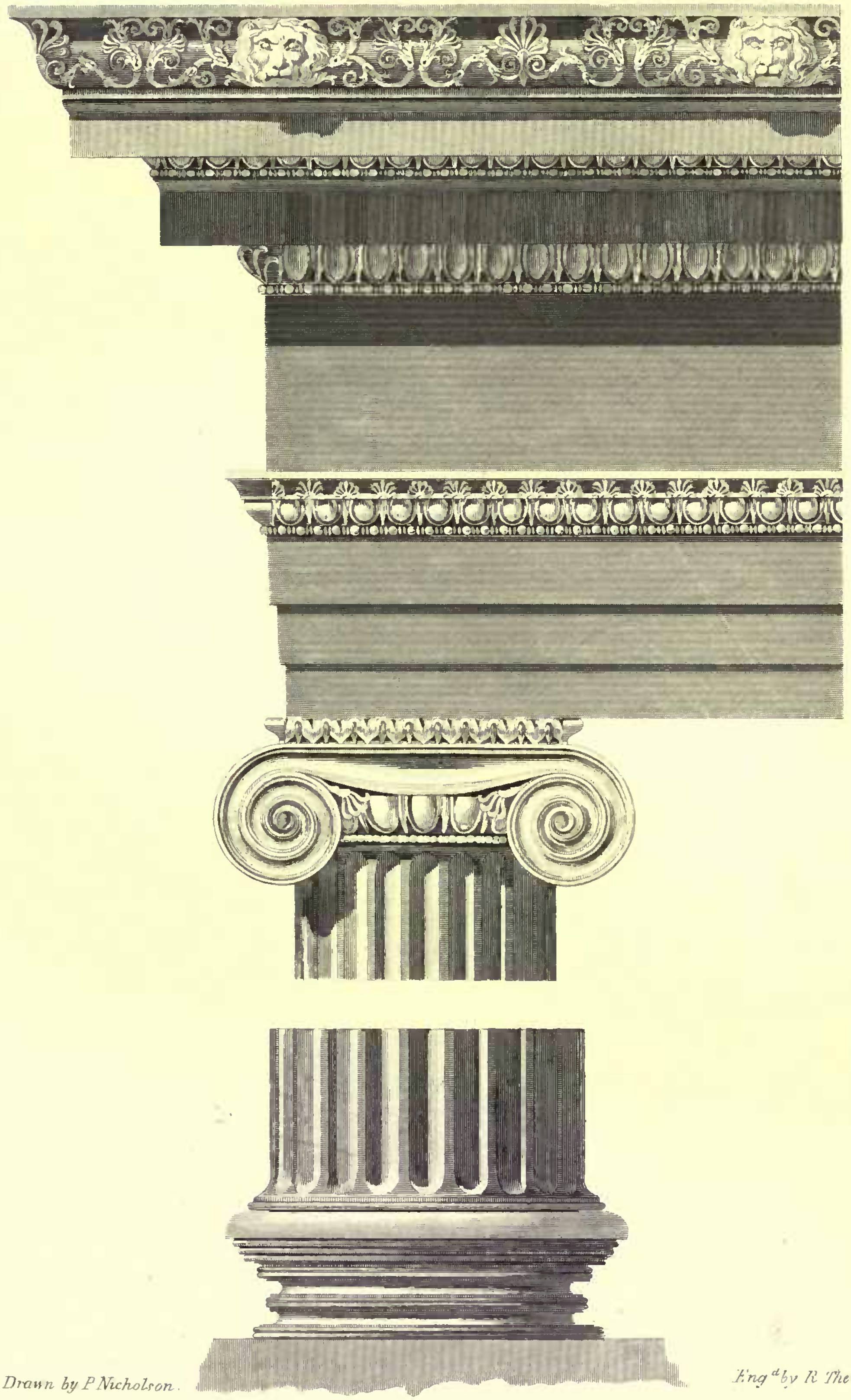
IRON, (from the Saxon *iren*,) a metal of a bluish-white colour; of great hardness and elasticity; very malleable; and exceedingly tenacious and ductile. The hardness of iron in some states is superior to that of any other metal; and it has the additional advantage of suffering this hardness to be increased or diminished at pleasure, by certain chemical processes, without altering its form. It is, nevertheless, easily formed into any shape, and susceptible of a high degree of polish; it is the most elastic of all the metals, and, next to platina, the most difficult of fusion. Its tenacity is also greater than that of any other metal, except gold—an iron wire, the tenth part of an inch in diameter, having been found capable of sustaining more than 500lbs. weight without breaking. Its ductility is such as to allow it to be drawn into wire as fine as a hair. It is the most abundant, the most important, and the most valuable of all the metals. Although a simple undecompounded substance, it is not naturally found in this state, except in comparatively minute quantities, but is the product of art. Some specimens of native iron, nearly pure, have been found in Siberia and South America; also many iron stones, rich in the metal, supposed to be of volcanic or meteoric origin, have been found in numerous parts of the earth; but all the iron of commerce is obtained by chemical means. Iron is so universally diffused as to form a constituent part of almost all animal, vegetable, and mineral substances. Unlike metals of inferior utility, its ores are not distributed in thin veins, or scattered in minute particles, but are thickly stratified over many thousands of square miles, chiefly in the northern regions of the earth, where nature has been less profuse of her other benefits. The use of this metal is of very great antiquity, though, on account of the difficulty of separating it from its ores, and of working it, probably not so remote as the employment of gold, silver, copper, and other comparatively soft metals, which are in many places found in a pure metallic state. It is stated by some writers, that iron is mentioned by Moses as the material of which knives and swords were fabricated; and that Herodotus mentions the presentation of a saucer or vase of iron, very curiously inlaid, by Alyattes, king of Lydia, to the Delphic oracle. Later and more erudite writers have, however, maintained, that the words of those ancient authors have been most incorrectly translated into our language; and that the working and use of iron was unknown at those periods. At what time the manufacture of iron was first attempted in Britain cannot be precisely ascertained. Some suppose (for it is in reality only a probable conjecture) that the Phœnicians, who wrought the tin-mines of Cornwall, introduced into the country men who were skilled in metallic ores, and capable of estimating their value, by applying the minerals to such purposes as their own necessities or the wants of the inhabitants might require. There is, however, much evidence to favour the belief that iron was worked in this country during the time it was in occupation by the Romans; and, that during the establishment of the Danes in England, the arts of mining and manufacturing the ores of iron were much improved.

Iron is obtained from the ore by an operation called smelting, and in this state it is called *crude-iron*, *cast-iron*, or *pig-iron*, but it is very impure. The art of smelting iron was practised in this country during the time of the Roman occupation; and in many ancient beds of cinders—the refuse of iron-works—Roman coins have been found. The principal ancient seats of the iron manufacture in this country appear to have been the Sussex and the Forest of Dean, or Arden, as it was then called. It is known that iron-works existed in that part of Gloucestershire in 1238, because there occurs, among the patent-rolls of Henry III. of that date, one entitled "De Forgeis levandis in Foresta de Dean." Remains of ancient iron-furnaces have been noticed in Lancashire, Staffordshire, and Yorkshire. The art of working in iron and steel was much practised in this island before the Norman conquest; and we are told, that not only was the army of Harold well supplied with weapons of steel and with defensive armour, but that the horses were covered with steel and iron armour; and that every officer of rank maintained a smith, who constantly attended his master to the wars, and took charge of his arms and armour, to keep them in proper repair.

The iron of commerce is usually divided into two distinct qualities, viz., pig-iron, and malleable or bar-iron—the second being the result of an extension of the processes necessary for the production of the first.

The first process is that of reducing the iron stone or ore into a metallic state by means of fusion. This operation is conducted in a blast-furnace, which is charged with certain proportions of iron-ore, of coke, and of limestone. The ore must previously have been roasted or calcined in a kiln, in order to drive out the water, sulphur, and arsenic, with which it is more or less combined in its native state; by the process, it loses one-sixth part of its weight. A furnace of the size commonly used in Wales will produce from 5 to 6 tons of pig-iron in twelve hours. For the largest quantity, the furnace must be charged progressively with 15 tons of roasted iron-ore, 22½ tons of coke, and about 6 tons of limestone. These ingredients are supplied at 50 charges, and must be intimately mixed together in the furnace. The limestone must be broken into small pieces; its use is to act as a flux to the ore, and promote its fusion. The heat that

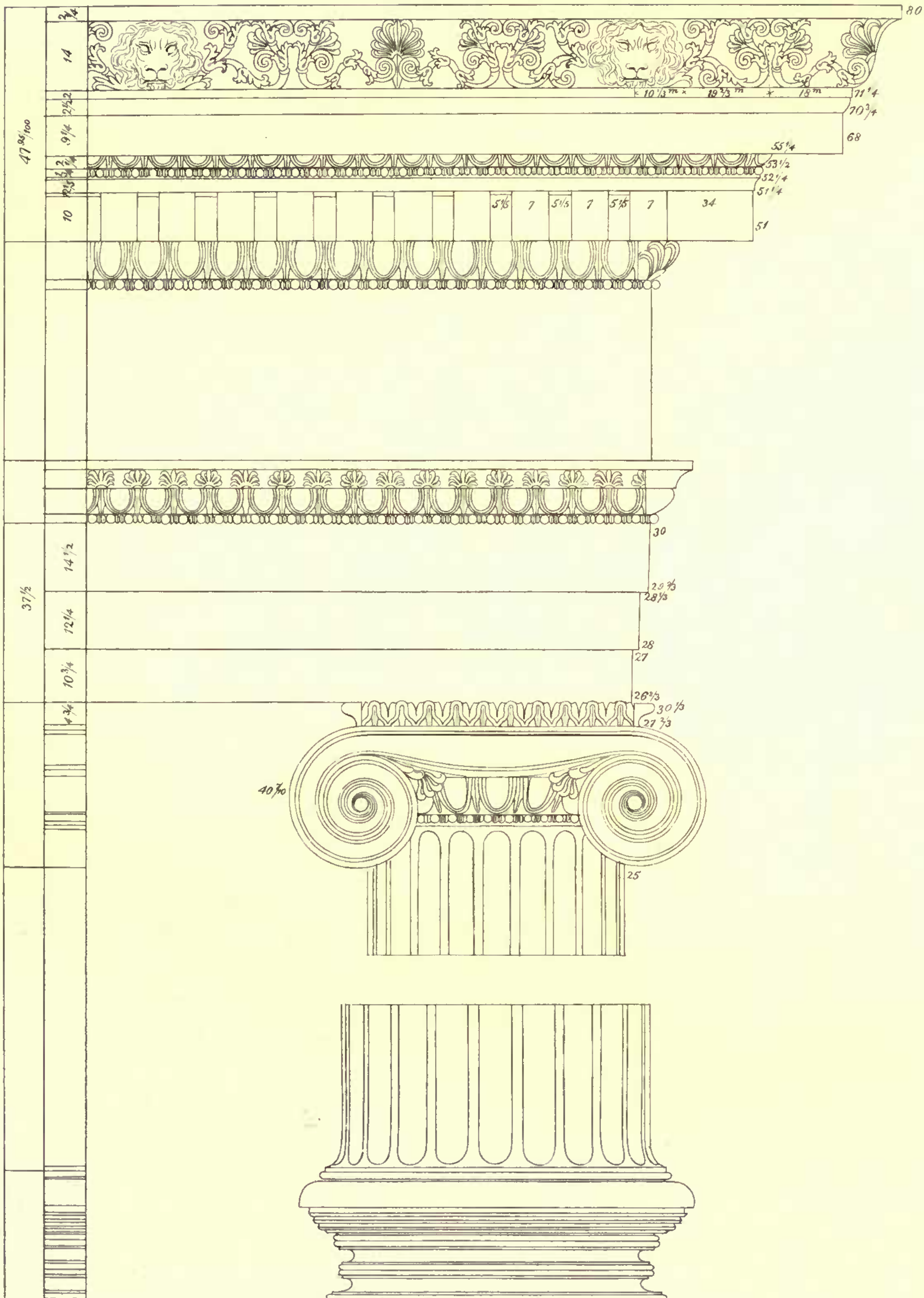
IONIC ORDER, PLATE I.



Drawn by P. Nicholson. Eng^d by R. Thew

IONIC ORDER.

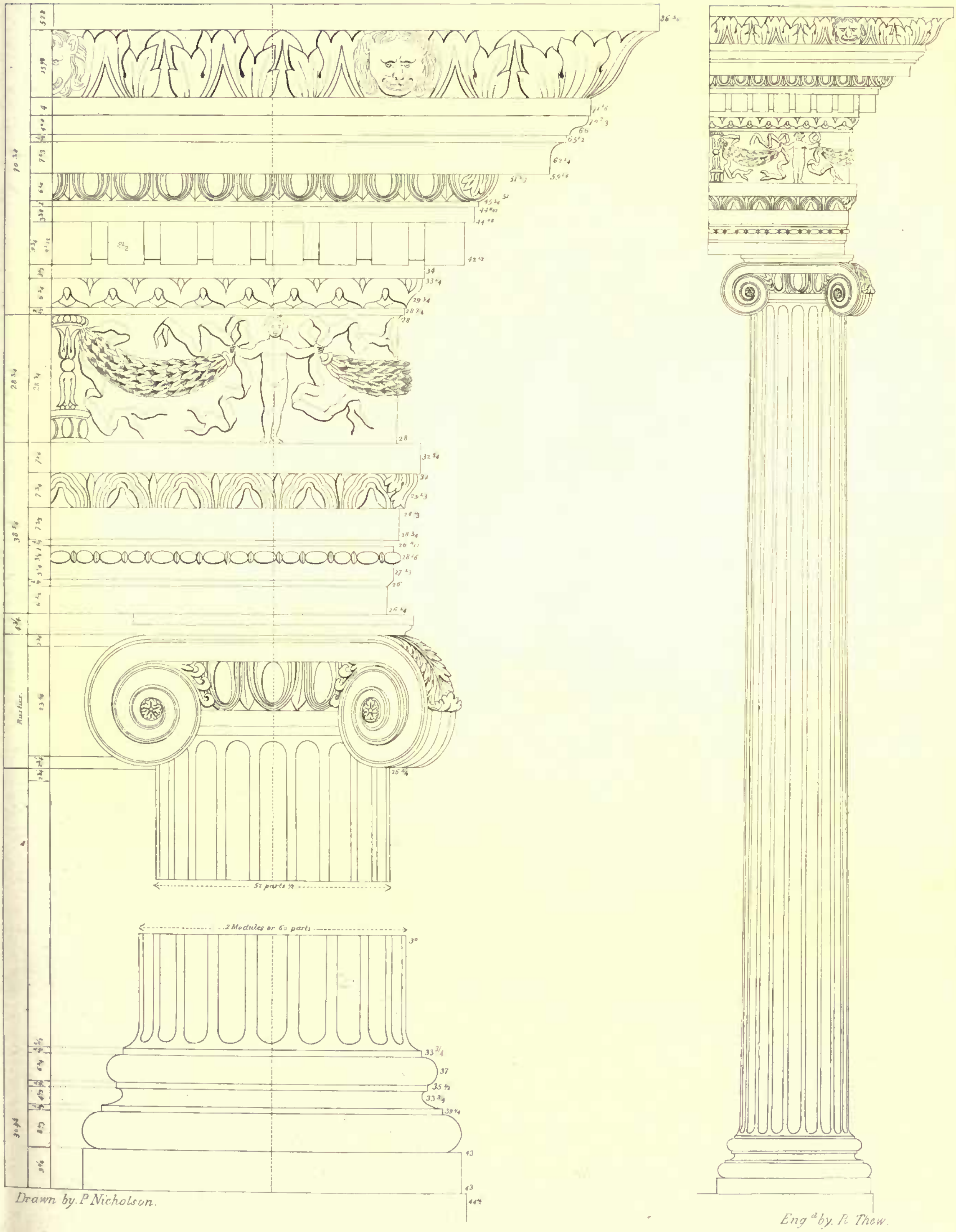
PLATE II.



Drawn by P. Nicholson.

Eng.d by R. Thew.

IONIC ORDER PLATE III



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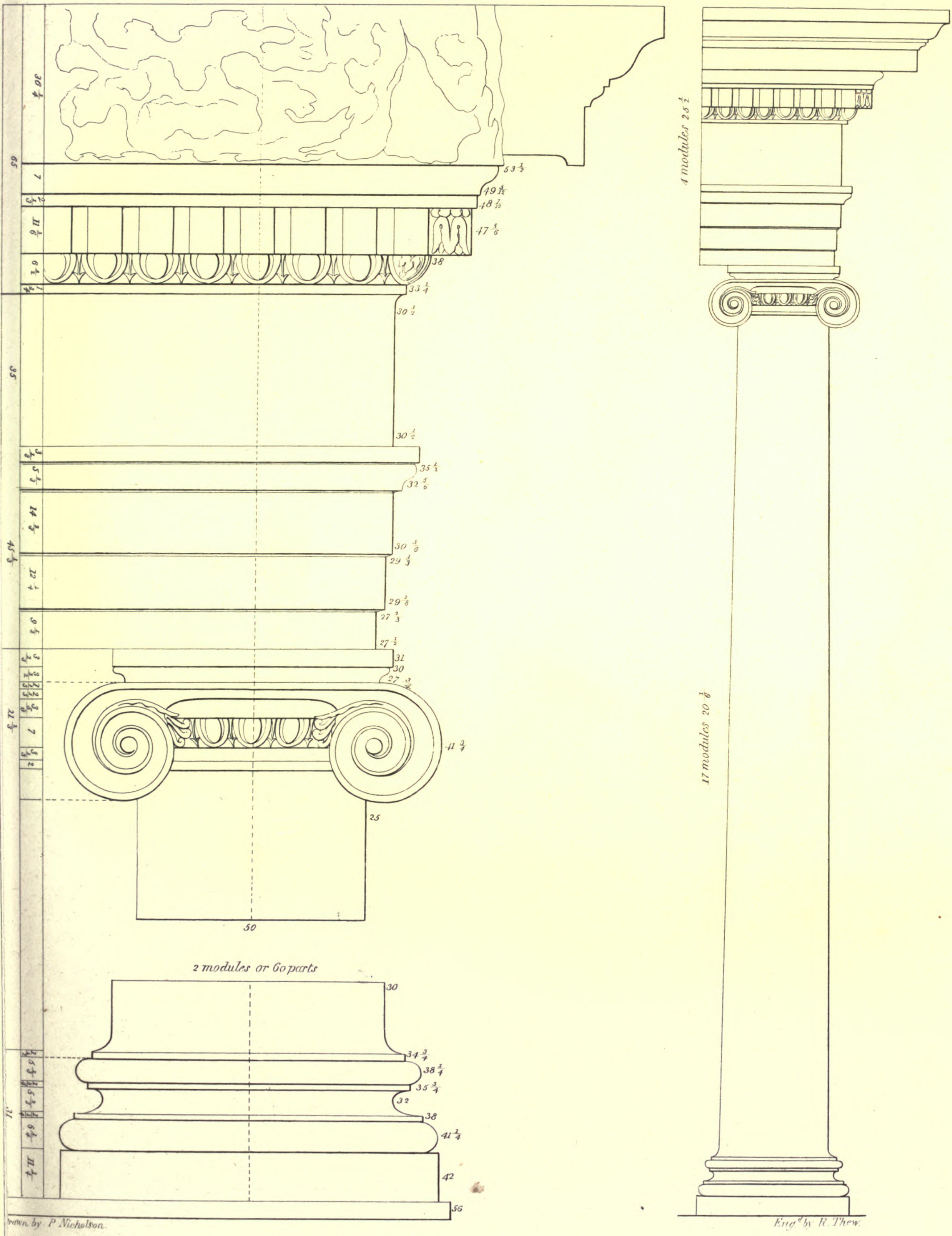
IONIC ORDER.

FROM THE THEATRE OF MARCELLUS AT ROME.

PLATE IV



rawn by P. Nicholson.

Engd by R. Thew.

would be produced in any furnace by merely setting fire to the fuel which is contained in it, would be altogether insufficient for the fusion of the ore, if its intenseness were not promoted by the forcing in of a current or blast of air. For this purpose it is necessary to use a strong mechanical force, and, of late years, the agency of steam has been commonly employed for this purpose. This power is applied to the working of a blowing cylinder, which may be four times the area of the cylinder of the steam-engine. If the blast thus produced were passed immediately from the blowing cylinder through the *tuyères* or tubes to the furnace, the effect would be intermitting and irregular, ceasing at the end of each stroke of the steam-piston. To remedy this inconvenience, the blast is carried into an intermediate chamber, of a spherical or cylindrical shape, called a regulator; and as the air is in a state of condensation when admitted, its effort to expand itself again to its natural volume causes the continuous and regular supply to the furnace which is necessary. The air thus forced into the furnace keeps the heat at the degree of intenseness which is indispensable for the smelting of the ore. Until the last few years, the air thus supplied was uniformly at the temperature of the atmosphere from which it was immediately taken; and the effect was, not only to produce a lower degree of heat, but also to supply a quantity of moisture which is prejudicial to the smelting process.

The blowing of heated air has, however, recently been introduced at several founderies, and likewise at the Clyde iron-works. This improvement is the invention of Mr. J. B. Nielson, of Glasgow, whose patent was enrolled in March, 1829, and is designated "an improved application of air to produce heat in fires, forges, and furnaces, where bellows or other blowing apparatus is required." He proposes, that the air supplied by any kind of machine shall, before it enters the furnace or cupola, be made to pass through an air-vessel heated to very high temperature—a red heat, if possible—by which means a current of hot air will be thrown on the fire, instead of the cold current usually employed. It is recommended that the air-vessel be surrounded with some non-conducting substance, and imbedded in masonry. The capacity of this vessel for a smith's forge he recommends to be about 1,200 cubic inches; and for a cupola or blast-furnace, about 10,000 cubic inches. It was much doubted whether the increased temperature of the fire thus blown would produce advantages equivalent to the expense of constructing the air-vessel and keeping it at the requisite heat; and, as respects the smelting of iron in particular, the theory seems opposed to the well-known fact, that a much larger quantity of iron is yielded by the blast-furnaces in the winter season, or when the air is cold, than during the summer season, when the air is warm. The experiment at the Clyde iron-works have, however, been reported most favourably of; and the saving of coal attending it is so great, that it was stated in the *Glasgow Chronicle* to be calculated to accomplish a saving in the consumption of this island to the amount of £200,000 annually. At the Clyde iron-works, the air was heated to 220° Fahrenheit before it was discharged into the furnace—an effect which was produced by the expenditure of only one-eleventh part of the cost of fuel it takes to heat it to the same temperature in the blast-furnace, which may be accounted for by the circumstance, that Mr. Nielson's air-vessel is heated by coals, while the blast-furnace is heated by coke. Further experience in this invention has fully confirmed the views of the patentee, and it must now be regarded as one of the most valuable improvements in modern metallurgic operations.

"The cost of the process of reduction by the hot-blast," observes Mr. Weale, in his 'Dictionary of Terms of Art,' "being so much less than that with the cold-blast, the ultimate value of the former is of course also partly dependent upon the quality of the produce. On this head much difference of opinion has often been manifested, and with all the earnestness usually displayed in the advocacy of self-interest. The value of each process must, no doubt, arise from the completeness of the fusion produced, and the separation effected between the iron, and the impurities combined with it in the ore. The hot-blast furnace effects the fusion more readily than the cold-blast, but admits a larger combination of cinders with the ore; and the advantage which has been taken of this facility of adulteration, in order to reduce the cost of production, has doubtless led to the introduction into the market of many qualities of hot-blast iron, which are inferior in strength to that made with the cold-blast. The results of some of the most carefully-conducted experiments which have been made upon the strength of cast-iron, and published in the sixth volume of the new series of "Memoirs of the Literary and Philosophical Society of Manchester," show that the transverse strength of the cold-blast iron tried was about 2½ per cent. greater than that of the hot-blast. The experiments here referred to were made upon rectangular bars 1 inch square, and 4 feet 6 inches long between the supports. The mean average breaking-weights, placed at the middle of these bars, were—

In 21 samples of hot-blast iron . . . 445.5714 lbs.
In 22 samples of cold-blast iron . . 456.9090 "

Cast iron, which is scarcely malleable at any temperature, is generally so hard as to resist the file, and is extremely brittle; however, it is equally permanent, in many applications, with wrought-iron, is less liable to rust, and being easily cast into various forms by melting, is much cheaper. Indeed, the labour of wrought-iron, if applied to many of the purposes to which cast-iron is used, would be incredible, and in some cases insurmountable.

The uses to which cast-iron is now applied, are so numerous, that it is quite impossible to particularize them. It is used extensively in the wheel-work of every department of machinery, in crane-work, in iron bridges, in beams, and pillars, for large buildings, and in numerous articles of manufacture. It is employed in the construction of works of the greatest magnitude, and of the most minute character. The immense iron-girders of a railway bridge are made of cast-iron, and offering a striking contrast to the delicate ornaments of the drawing-room fabricated of the same useful metal. Of late years, the perfection to which the art of moulding in iron has been brought is almost incredible, in particular, we may mention, beautiful specimens of ornamental railings, chimney-pieces, figures imitative of ancient sculptures, &c.

Cast-iron is reduced into wrought or bar-iron, or forged-iron, by divesting it of several foreign mixtures with which it is incorporated. The varieties of wrought-iron are the following: *hot-short iron* is so brittle when heated, that it will not bear the weight of a small hammer without breaking to atoms, but is malleable when cold, and very fusible in a high temperature; *cold-short iron* possesses the opposite qualities, and is with difficulty fusible in a strong heat, and though capable while hot of being beaten into any shape, is when cold very brittle, and but slightly tenacious. The iron in general use, which though, in a chemical point of view, not entirely pure, is so far perfect, that it possesses none of these defects; its principal properties are the following: 1st, When applied to the tongue, it has a styptic taste, and emits a peculiar smell when rubbed: 2nd, Its specific gravity varies from 7.6 to 7.8; a cubic foot of it weighs about 580lb. avoirdupois: 3rd, It is attracted by the magnet or loadstone, and is itself, in one of its ores, the substance which constitutes the loadstone. It is also capable of acquiring itself the attraction and polarity of the magnet in various ways; iron, however, that is perfectly pure, retains the magnetic virtue only a very short time; 4th, It is malleable in every temperature, which, as it rises, increases the malleability. It cannot, however, be hammered out so thin as gold or silver, nor even as copper. Its ductility is very great, and its tenacity such, that an iron wire something less than the twelfth of an inch in diameter is capable of supporting, without breaking, 549¼lb. avoirdupois: 5th, It melts at about 158° of Wedgewood: 6th, It combines very readily with oxygen; when exposed to the air, its surface is soon tarnished, and is gradually changed into a brown or yellow colour, usually called *rust:* this change takes place more rapidly, in proportion as it is more exposed to moisture.

"Between the cast-irons made in different parts of Great Britain, there are characteristic differences. The Staffordshire metal runs remarkably fluid, and makes fine sharp castings. The Welsh is strong, less fluent, but produces bar-iron of superior quality. The Derbyshire iron also forms excellent castings, and may be worked with care into very good bar-iron. The Scotch iron is very valuable for casting into hollow wares, as it affords a beautiful smooth skin from the moulds, so remarkable in the castings of the Carron company, in Sterlingshire, and of the Phœnix foundery at Glasgow. The Shropshire iron resembles the Staffordshire in its good qualities."—*Dr. Ure*, *Dict. of Arts.*

The following statement shows the results of some interesting experiments on the cohesive strength of bar-iron, as detailed in an American publication :—

"The mean result of numerous experiments on wrought-iron, detailed in the *Journal of the Franklin Institute*, made by a Committee of the Institute, at the request of the Treasury Department of the United States.

	Specific gravity.	No. of experiments.	Strength in lbs.*
Missouri Bar Iron	7.7708	22	47,909
Missouri Slit Rods		2	50,000
Tennessee Bar	7.8046	21	52,099
Salisbury, Connecticut		46	58,009
Swedish Bar	7.4785	2	58,184
Centre County, Pennsylvania		15	58,400
Lancaster County, Pennsylvania	7.7400	2	58,661
English Ev. best patent Cable Bolt Iron	7.6897	5	59,105
English Ev. best patent Cable Bolt Iron, hammer hardened	7.6897(?)	8	71,000
Russian Bar	7.8014	5	76,069
Phillipsburgh Wire, diameter 333		13	84,186
Phillipsburgh Wire, diameter 190		5	73,888
Phillipsburgh Wire, diameter 156	mmmdmmm	5	89,162
Cast Steel		1	130,681

* Breaking-weight of an inch-square bar, deducting friction.

"The experiments were made at ordinary temperatures on bars of iron averaging ¾ inch by ¼ inch."

To preserve iron from rust, particularly when polished, various methods have been tried with more or less success: among others, the partial oxidation, known by the term *blueing*, has been adopted: the slightest coat of grease is sufficient to prevent rust.

With reference to this subject, more especially as to the effect of sea-water on cast-iron, Mr. Faraday addressed the following observations to Sir Byam Martin, chairman of the "Harbours of Refuge and Defence" commission :—

"Sir,—I hasten to reply to your note, though not, I fear, with any certain knowledge; for infirm health has prevented me from taking up the consideration of the action of sea-water on iron, as my observations will permit. I conclude that the question is of cast-iron in sea-water. Between these two bodies, there is a vigorous action. As far as I have been able to observe, it is the greatest in the water near the surface; less in deep water; and least of all when the iron is buried in sand, or earth, or building-materials (into which the water may penetrate;) for then the oxide and other results formed, are detained more or less, and form sometimes a cement to the surrounding matter, and always a partial protection. Soft cast-iron, as far as my experience goes (which is not much,) corrodes more rapidly than hard cast; soft cast-iron, as far as my experience goes, more rapidly than the brittle white iron. As to the amount of corrosion in any given time, I have not had the opportunity of observing any good and satisfactory cases of illustration.

"In estuaries and the mouths of rivers, it is very probable that great differences of corrosion will arise from the different circumstances of ariable saltness; the soil of the river, if near a town, the metallic will much affect it, thus a wharf of cast-iron might occasionally be greatly injured by making fast to it vessels that are coppered, using iron cables.

"As to the protection of iron, and first by a coating; the permanency of a coat of paint, or of tar, or bituminous matter, can only be ascertained by reference to experience. Of this I have none, except in a case where coated iron sheathed for vessels was brought to me. I was much impressed with the thorough adhesion of the coat to the iron. The process was patent, and I cannot remember whose it was. Zinc-ed iron would no doubt resist the action of the sea-water as long as the surface was covered with zinc, or even when partially crusted with that metal; but zinc dissolves rapidly in sea-water, and after it is gone, the iron would follow.

"As to voltaic protection, it has often struck me that the cast-iron piles proposed for light-houses, or beacons, might be protected by zinc, in the manner Davy proposed to protect copper by iron; but there is no doubt the corrosion of the zinc would be very rapid. If found not too expensive, the object would be to apply the zinc protectors in a place where they could be examined often, and replace them when rendered ineffective. In this manner, I have little doubt that iron could be protected in our sea-water. It is even probable that, by investigation and trial, different sorts of iron might easily be distinguished and prepared, one of which would protect the other; thus soft cast-iron would, probably, protect hard cast-iron, and then it would be easy to place the protecting masses where they could be removed when required.

"Hence, though iron be a body very subject to the action of sea-water, it does not seem unlikely that it might be used with advantage in marine constructions intended to be permanent, especially if the joint effects of preserving coats of voltaic protectors were applied. Perhaps engineers are in the possession of practical and experimental data sufficient to allow the formations of a safe judgment on this point. For my own part, I am not, and therefore am constrained to express the above opinions with much doubt and reserve."

Iron is the most useful and most plentiful of all metals. It requires a very intense heat to fuse it, on which account it can only be brought into the shape of tools and utensils by hammering: this high degree of infusibility would prevent the uniting of several masses into one, were it not from its being capable of welding, a property found in no other metal, except platina. In a white heat, iron appears as if covered with a kind of varnish; and in this state, if two pieces be applied together, they will adhere, and may be perfectly united by forging.

A very extensive manufacture of iron articles is now carried on at Birmingham, Sheffield, and other places, which, although they are cast from fluid metal, are nevertheless malleable. This property is derived from two causes; first, the pigs are prepared from the rich and pure iron ores of Cumberland; and the metal thus obtained, is combined with but a small quantity of carbon, so as nearly to resemble steel in colour, hardness, and the brilliancy of its fracture; and it has in consequence been designated by some manufacturers *run steel.* An infinite variety of articles, including nails, saddler's ironmongery, (and particularly such goods as afterwards receive another metallic coat, as those which are plated upon *steel*,) are cast from this metal. The castings thus produced are exceedingly brittle; but this property is entirely destroyed by a process termed annealing, in which the metal is deprived of the carbon to which its previous fusibility was owing, and is in consequence brought to that state of wrought iron requiring only the operations of the shingling forge and rollers to give it a laminated and fibrous texture. Nails made by this process may be drawn out longer, and bent backwards and forwards, without breaking. The metal is, however, not so strong or tough as hammered and rolled iron; the discovery of the process is nevertheless of great value, as many excellent articles are produced in consequence, which would not without it be made at double the cost. The discoverer of this mode of converting cast-iron goods into malleable, was Mr. Samuel Lucas of Sheffield.

A description of iron was introduced a short time since, under the name of corrugated iron, which has already met with great success, and promises to be very extensively used. It is called corrugated from its grooved or *wrinkly* appearance, produced by putting the sheets between rollers having grooved peripheries. Sheet-iron thus prepared, acquires a strength and stiffness much beyond its ordinary strength, and adapts it for purposes for which the common sheet-iron is found insufficient. Corrugated iron has been much used for roofs of railway stations, and works of a similar kind.

Formerly, large quantities of iron were imported from Russia and Sweden, and previously to the discovery in 1785 by Mr. Cort, of the methods of puddling and rolling or shingling iron, this country imported 70,000 tons of this metal, a vast quantity, considering the state of our manufactures at that time. So much, however, has our own wrought iron been improved in the manufacture, that it may now be considered fully equal to the Swedish. As a proof of this, the Admiralty, East India Company, and other public departments, now contract for British iron only. *See* Steel.

Mr. Jessop, of the Butterley Works, estimated the annual produce in Great Britain (exclusive of Ireland) in 1840, at 1,396,400 tons; and the quantity of coal used for smelting that quantity was 4,877,000 tons, besides 2,000,000 tons for converting into wrought iron.

At the late meeting of the British Association at Cambridge, Mr. Watt read a report on the iron trade in Scotland, from which it appears, that, at the present moment, there are extensive new iron works erecting in Scotland, especially in Ayrshire and in Renfrewshire. At several of the old works, considerable additions are being made to the number of furnaces now at work. The increase in the annual quantity of pig-iron smelted in that country in April, 1845, amounts to 37.4 per cent.; and there is every appearance that, before another year expires, a similar increase will be made in the amount of iron produced in Scotland. Sir J. Guest, of Dowlars Works, in evidence before the Import Duties Committee, 1840, stated, that the iron made at the beginning of this century amounted to 150,000 tons.—In 1806, 258,000.—In 1823, 452,000.—In 1825, 581,000.—In 1828, 703,000.—In 1835, 1,000,000.—In 1836, 1,000,000 —In 1840, 1,500,000. We may remark, that the manufacture of malleable iron is yet but in its infancy in Scotland, although making rapid strides towards an important position. There are five establishments; and the present make may be computed at about 900 tons per week, or 50,000 tons per annum. For superior finish, toughness, and uniformity, it will stand comparison with either English or Welsh iron.

IRON BRIDGE, a species of bridge constructed, as its name implies, of iron, which was first applied to this purpose in England, towards the close of the 18th century. The merit of having employed this material in bridge-building, has been generally claimed for the English, but more accurate writers state that it really belongs to the Chinese. Be this as it may, it is certain that in no country in the world have been erected so many magnificent and stupendous structures as the iron bridges in the United Kingdom.

Under the article Bridge, (p. 58, vol. i.) we gave some account of the "rise, progress, and present state" of bridge-building, reserving to each respective head the more detailed information peculiarly belonging to it. Following that course, we now proceed to describe the several forms of bridges built of iron, as cast-iron arched bridges, cast-iron girder bridges, cast-iron compound girder bridges trussed with malleable iron bars, tubular bridges of various kinds, &c.

The first iron bridge erected in this country was over the Severn, a little below Colebrook Dale, where that river is narrow and rapid. The abutments, which are of stone, are brought to about 10 feet above the surface of common low-water, where they have each a platform of squared freestone for ten feet breadth, which serves for a hauling way, and a base for the arch to spring from. Upon this platform, cast-iron plates, four inches in thickness, are laid, and formed with sockets to receive the ribs. These plates, in order to save metal, have considerable openings in them. The principal, or inner ribs, which are five in number, and which form the arch, are 9 inches by 6½. The second row behind them, and which are cut off at the top by the horizontal bearing-pieces, are 6½ by 6 inches: the third row are 6 by 6 inches: the upright standards behind the ribs are 15 inches by 6½ inches, but they have an open space in the breadth of 5¾; the back standards are 9 inches by 6½, with projections for the braces; the diagonals, and horizontal ties, are 6 inches by 4, and the cast-iron tie bolts are 2¼ inches diameter. The covering plates, which are 26 feet in length, reaching quite across the bridge, are one inch in thickness. The great ribs are each cast in two pieces, meeting at the keys, which, as the arch is circular, 100 feet 6 inches span, and 45 feet rise, are about 70 feet in length. There are circular rings of cast iron introduced into the spandrels, and there is a cast-iron railing along each side of the roadway of the bridge: the weight of the whole of the iron work is 378½ tons. Behind the iron work, at each extremity of the arch, the abutments are carried up perpendicularly of rubble masonry, faced with squared stone, and the wing-walls are also of the same materials.

The iron work was cast and put together in a very masterly manner, under the direction of Abraham Derby, of Colebrook Dale; and the whole was completed in the year 1779. The design was original and very bold, and was, as far as concerned the iron work, well executed; but being a first attempt, and placed in a situation where more skill than that of the mere iron-master was required, several defects became apparent when the bridge was completed. The banks of the Severn are here remarkably high and steep, and consist of coal measures, over the points of which vast masses of alluvial earth slide down, being impelled by springs in the upper parts of the banks, and by the rapid stream of the river, which dissolves and washes away the skirts below: the masonry of the abutments and wing-walls not being constructed to withstand this operation, was torn asunder, and forced out of the perpendicular, more particularly on the western side, where the abutment was forced forward about 3 or 4 inches, and by contracting the span, of course heaved up the iron work of the arch. This was remedied under the direction of that able mason Mr. John Simpson, of Shrewsbury, as far as the nature of the case would admit of, by removing the ground, and placing piers and counter-arches upon the natural ground behind it. Had the abutments been at first sunk down into the natural undisturbed measures, and constructed of dimensions and form capable of resisting the ground behind; and had the iron work, instead of being formed in ribs nearly semicircular, been made flat segments, pressing against the upper parts of the abutments; the whole edifice would have been much more perfect, and a great proportion of the weight of metal saved. We have already stated that one row of the principal ribs formed the arch; the two rows behind are carried concentric with the inner row, until intersected by the roadway, which passes immediately at the level of the top of the inner ribs. This has a mutilated appearance; the circular rings of the spandrels being less perfect than if the pressure had been upon straight lines; for a circle is not well calculated for resistance, unless subjected to an equal pressure all round.

The second iron bridge was built upon the same river, about three miles above the former one, at a place called Buildwas. An old stone bridge was carried away by a very high flood early in 1795, and the county of Salop was obliged to restore the communication. Mr. Telford, the celebrated engineer, was at that time surveyor for the public works of the county, and on his recommendation, the magistrates ordered the construction of a cast-iron bridge, to be of one arch 130 feet span. The Colebrook Dale Company became contractors, both for the iron work of the arch, and the masonry of the abutments. Mr. Telford had some difficulty in making that company depart from their former mode of construction: but he at last prevailed in keeping the roadway low, and adopting the suspending principle, by means of a rib on each side of the bridge, which sprung from a lower base than the bearing ribs, and rose above them to the top of the railing; thus the bearing ribs were supported by the lower parts of those before mentioned, and were suspended by their upper parts. The bearing ribs have a curve of 17 in 130, or nearly one-eighth of their span. The suspending ribs rise 34 feet, or about one-fourth of their span. There are cast-iron braces, and also horizontal ties. There are 46 covering plates, each 18 feet in length, and one inch in thickness. They have flaunches 4 inches in depth, and are screwed together at each joint; so that, by taking the curvature of the bearing ribs, and being firmly secured at the abutments, instead of a load, they compose a strong arch. There being only one rib in the middle of 18 feet breadth of bridge, on each covering plate, a cross rib or flaunch, 4 inches in depth, is cast at an equal distance between the bearing ribs. The suspending ribs are each 18 inches in depth, and $2\frac{5}{8}$ inches in thickness, exclusive of a moulding. The bearing ribs are 15 inches in depth, and $2\frac{1}{2}$ inches in thickness, and each of the ribs is cast in three pieces only, of about 50 feet each; the braces are 5 by 3 inches. The principal king-posts are $10\frac{1}{4}$ by $4\frac{1}{2}$ inches. The springing plates are each 3 feet broad, and 3 inches thick, with openings to save metal. The uprights against the abutments are $4\frac{1}{2}$ inches square. The strongest uprights in the railing are 3 inches square, and those between them 1 inch. They are placed 6 inches apart, between middle and middle. The height of the railing above the surface of the roadway, is 4 feet 9 inches. In each spandrel, there are three circular arches formed with hard-burned bricks, which preserve most of the space open, but they are concealed by iron plates, one inch in thickness, which form the outside facings. On the eastern side of the river, although the banks are not so very high or steep, the quality of the ground being similar to that of the other iron bridge, particular care was bestowed upon the abutments: the space for them was excavated down to the rock, which lay considerably under the bed of the river, and the masonry was sunk into the solid part of the rock. It was built up chiefly of square masonry, and the rest of rubble, laid very close in regular courses, and having the back part formed in the shape of a wedge, pointing to the bank. The wing-walls were curved horizontally and vertically. At the height of 10 feet above the low-water, there is a hauling path on each side of the river. This bridge, which was completed in 1796, has never shown any appearance of failure in any of its parts; nothing can be more perfect than the iron work; it is fitted as correctly as a piece of good carpentry.

It has been objected to this structure, that by connecting ribs of different lengths and curvature, they are exposed to different degrees of expansion and contraction. This appears just in theory; and that no discernible effect has hitherto been produced, is probably from the difference being small. Another objection is, an apparent heaviness in the spandrels, from concealing the circular arches with iron plates. For appearance, these spaces had certainly better not have been concealed, but they are not liable to the objections made to the former iron bridge, because the space around them is all closely filled up; and the roadway being formed with materials similar to this filling-up matter, distributes the pressure very regularly. Upon the whole, considering the strength acquired by placing the covering plates with their deep flaunches, in the form of an arch, we doubt whether a greater degree of strength can be had by any other distribution of the same quantity of cast-iron, viz., $173\frac{1}{2}$ tons: it appears to us, however, that the upright standards, braces, and king-posts, might be made of smaller dimensions.

The third iron bridge was constructed over the river Wear, near Sunderland, in the county of Durham. Its projector was Rowland Burdon, Esq., a gentleman of considerable landed property in that county, and who, for some time, represented it in parliament. The iron-work was cast at the founderies of Messrs. Walkers, of Rotherham, and erected under the inspection of Mr. Thomas Wilson. The confidence in the use of iron for arches of great extent, was by this time established. The span of the second arch, we have seen, is 30 feet more than that of the first; and, in this third instance, the span is 106 feet beyond that of the second, although its rise is only the same as that of the suspending ribs at Buildwas. The arch at Sunderland springs 60 feet above the level of the surface of low-water; the span is 236 feet; the rise, or versed sine, is 34 feet; the width of the roadway 32 feet; and there are six ribs.

In this arch the mode of construction is very different from either of the former. Instead of working with pieces of iron from about 50 to 70 feet in length, each rib is here composed of 125 small frames, each about two feet in the length or curve of the rib, and 5 deep in the direction of the radius. In each frame there are three pieces of 4 inches square, which run in the direction of the curve of the arch; and these are connected in the direction of the radius by two other pieces, 4 by 3 inches. In each side of the larger pieces is a groove, 3 inches broad, by three-quarters of an inch in depth; and opposite each cross piece there is a hole in the middle of the groove. When the abutments were brought up, and a scaffolding constructed across the river between them, six of these frames were placed against the abutments in the manner of arch-stones. Wrought-iron bars, of a length to embrace sundry frames, were then fitted into the grooves. Hollow pipes of cast-iron, 4 inches in diameter, fitted to reach between each two frames, across the soffit, were introduced. Upon the ends of these pipes are flaunches, in which there are holes, answerable to the holes in the four-inch pieces of the frames, and also to those of the wrought-iron bars. Through these holes wrought iron bolts were introduced, which brought all the before-mentioned parts together by means of fore-locks. The frames do not meet at the upright pieces, but on the three points of the four-inch pieces only. On the ends of the hollow pipes, there are small projecting pieces, which embrace the upper and lower edges of the frames opposite each joining. These operations were repeated until the whole of the frames were placed, and the arch keyed, forming six ribs between the abutments. Upon the ribs, perpendicular pillars are placed; and between them are cast-iron circles, which come in contact with the extrados, the upright pillars, and the bearers of the roadway. The bearers and covering, we suppose for cheapness, are made of timber: the railing is cast-iron. The inclinations each way upon the arch, probably to save weight, are inconveniently steep.

From its great elevation and lightness of construction this bridge is justly esteemed a bold effort of art, and a magnificent feature in the country. The wooden bridges in Switzerland, and that in America, are of greater span; but, being placed near the surface of the water, and from the difference of material, their parts being of larger dimensions, there can be no comparison as to the fineness of effect. A cast-iron bridge was also built over the river Witham, at Boston, in Lincolnshire, the design for which has been generally ascribed to Mr. Rennie. That gentleman, however, only gave the width and rise of the arch, and the abutments were founded and built under his direction. The iron arch itself was designed and executed by Mr. Thomas Wilson, of Sunderland. The span of this arch is about 85 feet; the rise about 5 feet 6 inches; the breadth is 36 feet; and there are eight ribs, each rib composed of eleven frames, 3 feet deep in the direction of the radius. At each joining there is a cast-iron grating across the arch which connects the frames, on the same principles as practised at the Pontcysylte aqueduct. Instead of three pieces in the direction of the curve, as at Sunderland, here are only two, but they are 7 inches by 4½. These are, in each frame, connected in the direction of the radius, by pieces, 4 by 3 inches. Upon the back of the ribs, pillars, 4 by three inches, are placed perpendicularly to support the roadway. The superstructure resembles that of the first iron bridge at Colebrook Dale. The arch has been kept very flat, to suit the tide below and the streets above. The frames being made about four times the length of those at Sunderland, and being connected with cast-iron gratings instead of wrought-iron, are essential improvements; but from the pieces in the frames, which are in the direction of the radius, being only 4 by 3 inches, while the main pieces in the direction of the curve are 7 by 4½, a great proportion of the former are broken. This is a defect; and the pillars which support the roadway being perpendicular, do not correspond with the radiated pieces of the frames. The ribs, in springing from the perpendicular face of the masonry of the abutment have also a crippled appearance.

In the improvements made under the direction of Mr. Jessop, at the port of Bristol, it became necessary to change the course of the river Avon, and two very handsome cast-iron bridges were built over the new channel. The span of the iron work of each arch, is 100 feet; the rise 12 feet 6 inches, or one-eighth of the span; the breadth is 30 feet. There are six ribs; each rib is composed of two pieces meeting in the middle, and they are connected crosswise by nine cast-iron ties, which are dovetailed, and wedged into the ribs; the cross sections of these ties are in the form of the letter T. The ribs stand upon abutment-plates, which are laid in the direction of the radius. These plates are 32 feet in length, 2 feet 4 inches in breadth, and 4 inches in thickness. In each plate are 5 apertures, each 5 feet long, and 20 inches in width. The ribs are 2 feet 4 inches in depth in the direction of the radius, and two inches in thickness, and have each 80 apertures, one foot square, separated by bars 3 inches broad, excepting opposite the cross ties, where the solid is 12 inches broad. Where the ribs meet in the middle they have flaunches, 8 inches broad and 2 thick, and they are connected by cast-iron screw-bolts, 3 inches in diameter. Between the ribs and the bearers of the roadway, perpendicular pillars, with cross sections formed like the letter T, are placed: the bearers are of the same form. The whole is covered with cast-iron plates, and there are railings of cast-iron.

There is great simplicity, and much of correct principle, in this design: 1. The springing-plates being placed in the direction of the radius, and the abutments receding to produce a space behind the ribs equal to that between the upright pillars. 2. The ribs being composed of two pieces, and one joint only: and, 3. Wrought-iron being wholly excluded. But we regret still observing the varying dimensions of the parts of the ribs; and that the supporting pillars are still placed perpendicularly; and which, as the arch has more curvature, has a yet worse effect than at Boston.

In the course of his employment as engineer to the board of parliamentary commissioners for making roads and constructing bridges in the Highlands of Scotland, Mr. Telford erected a cast-iron bridge over an arm of the sea, which divides the county of Sutherland from that of Ross, at a part where several of those roads unite. In this bridge, the defects noticed in the former works of this sort appear to be avoided. The arch is 150 feet span; it rises 20 feet, it is 16 feet in width, and has 4 ribs. In the abutments, not only are the springing-plates laid in the direction of the radius, but this line is continued up to the roadway. The springing-plates are each 16 feet in length, 3 feet in breadth, and 4 inches in thickness, with sockets and shoulder-pieces to receive the ribs. In each plate are 3 apertures, 3 feet in length and 18 inches in width. Each of the ribs, for the conveniency of distant sea-carriage, is composed of 5 pieces, 3 feet in depth in the direction of the radius, and 2½ inches in thickness. There are triangular apertures in the ribs, formed by pieces in the direction of the radius, and diagonals between them; but every part is of equal dimensions. At every joining of the pieces of the ribs, a cast-iron grating passes quite across the arch; upon these are joggles or shoulderings to receive the ends of the ribs: the ribs have also flaunches, which are fixed to the gratings with cast-iron screw-bolts. Each rib is preserved in a vertical plane, by covering the whole with grated, flaunched plates, properly secured together, and to the top of the ribs, by cast-iron screws and pins. In the spandrels, instead of circles or upright pillars, lozenge, or rather triangular forms, are introduced, each cast in one frame, with a joggle at its upper and lower extremities, which pass into the sockets formed on the top of the ribs, and in the bearers of the roadway. Where the lozenges meet in the middle of their height, each has a square notch to receive a cast-iron tie, which passes from each side, and meets in the middle of the breadth of the arch, where they are secured by fore-locks. Next to the abutments, in order to suit the inclined face of the masonry, there are half-lozenges. By means of these lozenge or triangular forms, the points of pressure are preserved in the direction of the radius. The covering-plates, in order to preserve a sufficient degree of strength, and lessen the weight, are, instead of solid, made of a reticulated shape; the apertures widen below, to leave the matter between them a narrow edge; and contract upwards, so as to prevent the matter of the roadway from falling through. This disposition of the iron-work, especially in the spandrels, also greatly improves the general appearance.

The success which had attended the use of iron, as a material in bridge building, had now given such confidence to engineers, that works of the greatest magnitude were proposed by the master-minds of Telford, Rennie, and others. At this period, the practicability of constructing a bridge over the Menai Straits had been much discussed. It was deemed expedient by government to facilitate, as much as possible, the intercourse between England and Ireland. For this purpose, an investigation was made as to the most effectual mode of improving the mail-roads from Holyhead through North Wales.

The Island of Anglesea, as is well known, is separated from Carnarvonshire by the celebrated strait or arm of the sea, named the Menai, through which the tide flows with great velocity, and, from local circumstances, in a very peculiar manner. This rendered the navigation difficult, and it had always been a formidable obstacle in the before-mentioned communication. The passage between Anglesea and the opposite mainland was maintained by six ferries, the chief of which was called Bangor Ferry, from its proximity to that town; but a permanent connection, by means of a bridge, had been in contemplation, and various projects for one had been under consideration. From a report of the House of Commons, of June 1810, it appears, that Mr. Rennie, the engineer, had given plans and estimates for bridges at this place in 1802, and had been called on to revise them in 1810. His plans, which appear in the last-mentioned report, are, 1st, One arch of cast-iron, 450 feet span, over the narrowest part of the strait, at a projecting rock named Ynys-y-Moch: and, 2nd, Another upon the Swilley rocks, consisting of three cast-iron arches, each 350 feet span. The expense of that at Ynys-y-Moch is estimated at £259,140, and of that at the Swilley, £290,147. He prefers the latter, because he says, "On account of the great span of the arch at Ynys-y-Moch, and the difficulty and hazard there will be in constructing a centre to span the whole breadth of the channel at low-water, without any convenient means of supporting it in the middle, on account of the depth of water and rapidity of the tide, or of getting any assistance from vessels moored in the channel to put it up; I will not say it is impracticable, but I think it too hazardous to be recommended." And, again, in the same report: "I should be little inclined to undertake the building a bridge at Ynys-y-Moch."

But from the report of June, 1811, it appears that, in May 1810, Mr. Telford was instructed by the Lords of the Treasury to survey, and report upon the best method of improving the lines of communication between Holyhead and Shrewsbury, and also between Holyhead and Chester; and to consider, and give plans for passing the Menai. In the aforesaid report (of 1811), we have his plans and estimate. His explanations we shall give in his own words; but before doing so, it is necessary to observe that much of the following extract may, perhaps, more properly belong to the description of the Menai bridge, which will be found under the head Suspension Bridge. It is, however, given here, as it describes a mode of constructing centres applicable as well to stone as to iron arches:—

"The duty assigned me," says Mr. Telford, "being to consider, and report respecting a bridge across the Menai, I shall confine myself to this object. Admitting the importance of the communication to justify acting on a large scale, I not only consider the constructing a bridge practicable, but that two situations are remarkably favourable. It is scarcely necessary to observe, that one of these situations is at the Swilley rocks, and the other at Ynys-y-Moch. These two being so evidently the best, the only question that can arise is, to which of them the preference ought to be given.

"From the appendix to the second report to the Holyhead roads and harbour, it appears that a considerable number of small coasting vessels, viz., from 16 to 100 tons, navigate the Menai, and that there have been a few from 100 to 150 tons. By statements from the principal ship-builders in the river, made in the year 1800, to the committee for improving the port of London, it also appears that vessels of 150 tons, when they have all on end, are only 88 feet in height above the water-line; and farther, that even ships of 300 tons, with their top-gallant masts struck, are nearly the same height; these in the Menai are extreme cases, and, if provided for, ought, as to navigation, to satisfy every reasonable person; it may, indeed, rather be a question whether the height should not be limited to vessels under 100 tons, by which the expense of a bridge would be considerably diminished.

"In the plans I have formed, provision is made for admitting vessels of 150 tons to pass with all on end; that is, in one design preserving 90 feet, and in the other 100 feet, between the line of high-water and the lower side of the soffit of the arch. The first design is adapted for passing across the three rocks, named the Swilley, Benlass, and Ynys-welldog, which, by their shape and position, are singularly suitable. To embrace the situation most perfectly, I have divided the space into three openings of 260 feet, and two of 100 feet each, making piers each 30 feet in thickness. Over the three large openings, the arches are made of cast-iron; over the smaller spaces, in order to add weight and stability to the piers, semicircular arches of stone are introduced; but over these, as well as the larger openings, the spandrels, roadway, and railing, are constructed of cast-iron. In this way the navigation is not impeded, because the piers, standing near the outer edges, are guards for preventing vessels striking upon the rocks; while the whole structure presents very little obstruction to the wind. From the extremity of the abutments, after building rubble walls above the level of the tideway, I propose carrying embankments until the roadway reaches the natural ground. The annexed drawing will sufficiently explain the nature of the design. I propose the bridge to be 32 feet in breadth; and, from minute calculations made from detailed drawings, I find the expense of executing the whole in a perfect manner amounts to £158,654.

"The other design is for the narrower strait, called Ynys-y-Moch. Here the situation is particularly favourable for constructing a bridge of one arch, and making that 500 feet span, leaves the navigation as free as at present. In this I have made the height 100 feet in the clear at high water spring tides; and I propose this bridge to be 40 feet in breadth. Estimating from drawings, as already described, I find the expense to be £127,331, or £31,323 less than the former. From leaving the whole channel unimpeded, it is certainly the most perfect scheme of passing the Menai; and would, in my opinion, be attended with the least inconvenience and risk in the execution.

"In order to render this evident, I have made a drawing, to show in what manner the centering or frame, for an arch of this magnitude, may be constructed. Hitherto, the centering has been made by placing supports, and working from below; but in the case of the Menai, from the nature of the bottom of the channel, the depth at low-water, and the great rise and rapidity of the tides, this would be very difficult, if not impracticable. I therefore propose changing the mode, and working entirely from above, that is to say, instead of supporting, I mean to suspend the centering. By inspecting the drawing, the general principle of this will be readily conceived.

"I propose, in the first place, to build the masonry of the abutments as far as the lines A B, C D, and in the particular manner shown in the section. Having carried up the masonry to the level of the roadway, I propose upon the top of the abutments to construct as many frames as there are to be ribs in the centre; and of at least an equal breadth with the top of each rib. These frames to be about 50 feet high above the top of the masonry; and to be rendered perfectly firm and secure. That this can be done, is so evident, I avoid entering into details respecting the mode. These frames are for the purpose of receiving strong blocks or rollers and chains, and to be acted upon by windlasses or other powers.

"I next proceed to construct the centre itself; it is proposed to be made of deal baulk, and to consist of four separate ribs; each rib being a continuation of timber frames, 5 feet in width at the top and bottom, varying in depth from 25 feet near the abutments to 7 feet 6 inches at the middle or crown. Next to the face of the abutments, one set of frames, about 50 in length, can, by means of temporary scaffolding, and iron chain bars from the before-mentioned frames, be readily constructed, and fixed upon the offsets of the abutments, and to horizontal iron ties laid in the masonry for this purpose. A set of these frames (four in number) having been fixed against the face of each abutment; they are to be secured together by cross and diagonal braces, and there being only spaces of 6 feet 8 inches left between the ribs, (of which these frames are the commencement,) they are to be covered with planking, and the whole converted into a platform, 50 feet by 40. By the nature of the framing, and its being secured by horizontal and suspending bars, I presume every person accustomed to practical operations will admit that these platforms may be rendered perfectly firm and secure.

"The second portion of the centre frames, having been previously prepared and fitted in the carpenter's yard, are brought, in separate pieces, through passages purposely left in the masonry, to the before-mentioned platforms. They are here put together, and each frame raised by the suspending bars and other means, so that the end which is to be joined to the frame already fixed, shall rest upon a small movable carriage. It is then to be pushed forward, perhaps upon an iron railroad, until the strong iron forks, which are fixed on its edge, shall fall upon a round iron bar, which forms the outer edge of the first, or abutment frames. When this has been done, strong iron bolts are put through eyes in the forks, and the aforesaid second portion of the frame-work is suffered to descend to its intended position, by means of the suspending chain-bars, until it closes with the end of the previously fixed frame, like a rule joint. Admitting the first frames were firmly fixed, and that the hinge part of this joint is sufficiently strong, and the joint itself 20 feet deep, I conceive, that even without the aid of the suspending bars, this second portion of the centering would be supported; but we will for a moment suppose, that it is to be wholly suspended. It is known, by experiment, that a bar of good malleable iron, one inch square, will suspend 80,000 lb., and that the powers of suspension are as the sections; consequently, a bar 1½ inch square, will suspend 180,000 lb.; but the whole weight of this portion of the rib, including the weight of the suspending bar, is only about 30,000 lb., or one-sixth of the weight that might safely be suspended; and as I propose two suspending chain-bars to each portion of rib, if they had the whole to support, they would only be exerting about one-twelfth of their power; and considering the proportion of the weight which rests upon the abutments, they are equal also to support all the iron work of the bridge, and be still far within their power.

"Having thus provided for the second portion of the centering a degree of security far beyond what can be required, similar operations are carried on from each abutment until the parts are joined in the middle, and form a complete centering; and being then braced together, and covered with planking where necessary, the whole becomes one general platform or wooden bridge, to receive the iron-work.

"It is, I presume, needless to observe, that upon such a centering or platform, the iron-work, which, it is understood, has been previously fitted, can be put together with the utmost correctness and facility: the communication from the shores to the centre will be through the before-mentioned passages in the masonry. The form of the iron-work of the main ribs will be seen, by the drawing, to compose a system of triangles, preserving the principal points of bearing in the direction of the radius. It is proposed in the breadth of the bridge (*i. e.* 40 feet) to have nine ribs, each cast in twenty-three pieces, and these connected by a cross-grated plate, nearly in the same manner as in the great aqueduct of Pont-cysylte, over the valley of the Dee, near Llangollen. The fixation of the several ribs in a vertical plane, appearing (after the abutments) to be the most important object in iron bridges, I propose to accomplish this by covering the several parts or ribs, as they are progressively fixed, with grated, or reticulated and flaunched plates, across the top of the ribs. This would keep the tops of the ribs immovable, and convert the whole breadth of the bridge into one frame. Besides thus securing the top, I propose also having cross-braces near the bottom of the ribs.

"The ribs being thus fixed, covered, and connected together, the great feature of the bridge is completed. And as, from accurate experiments made and communicated to me by my friend, the late William Reynolds, of Colebrook Dale, it requires 448,000lb. to crush a cube of one quarter of an inch of cast-iron, of the quality named gun-metal, it is clear, while the ribs are kept in their true position, that the strength provided is more than ample.

"When advanced thus far, I propose, though not to remove, yet to ease the timber-centering, by having the feet of the centering ribs (which are supported by offsets in the masonry of the front of the abutment) placed upon proper wedges; the rest of the centering to be eased at the same time by means of the chain-bars. Thus the hitherto dangerous operation of striking the centering, will be rendered gradual and perfectly safe; inasmuch that this new mode of suspending centering, instead of supporting it from below, may perhaps hereafter be adopted as an improvement. Although the span of the arch is unusually great, yet by using iron as a material, the weight upon the centre, when compared with large stone arches, is very small. Taking the mere ring of arch-stones in the centre arch of Blackfriars' bridge, $156 \times 43 \times 5$, equal to 33,450 cubic feet of stone, it amounts to 2,236 tons; whereas the whole of the iron work, in the main ribs, cross-plates, and ties, and grated covering plates, that is to say, all that is lying on the centering at the time it is to be eased, weighs only 1,791 tons. It is true, that from the flatness of the iron arch, if left unguarded, a great proportion of this weight would rest upon the centering; but this is counterbalanced by the operation of the iron ties in the abutments, and wholly commanded by the suspending chain-bars.

"When the main ribs have been completed, the next step is to proceed with the iron supporters of the roadway; and these, instead of being constructed in the form of circles, or that of perpendicular pillars, as hitherto, are here a series of triangles, thus including the true line of bearing. These triangles are, of course, preserved in a vertical plane by cross ties and braces. Iron bearers are supported by these triangles, and upon the bearers are laid the covering plates under the roadway, which, instead of being solid, are (in order to lessen the weight) proposed to be reticulated.

"If I have, throughout this very succinct description, made myself understood, it will, I think, be admitted, that the constructing a single arch across the Menai, is not only a very practicable, but a very simple operation; and that it is rendered so, chiefly by adopting the mode of working from each abutment, without at all interfering with the tideway.

"In the case of the Swilley bridge, although the arches are smaller, yet being placed on piers, situated on rocks, surrounded by a rapid tide, the inconvenience of carrying materials, and working, is greatly increased; and supposing the bridge part constructed, an enormous expense is still to be incurred before the roadway can be carried over the flat ground on the Anglesea shore. Therefore whether economy, facility of performance, magnificence, or durability, be consulted, the bridge of one arch is, in my opinion, infinitely preferable; and it is no less so, if considered in what regards the navigation." *See* Suspension Bridge.

A very handsome bridge was erected over the river Trent, in the county of Stafford, from the designs and under the direction of James Potter, Esq. The specification for this structure is so ably drawn, and describes so precisely every part of the works to be contracted for, that we think we shall do good service to the student, by transcribing it *in extenso*, as a model for similar compositions.

SPECIFICATION OF WORKS.

Mason's Work.—"Specification of the mason's work of the abutments for the iron bridge intended to be erected over the river Trent, at a place commonly called High Bridge, near to Handsacre in the county of Stafford:—

"The footings to be in 3 courses, laid on level beds; the courses to be not less than 1 foot thick, and the front or outside courses to be laid header and stretcher alternately; the stretchers to be not more than 4 feet long, and to average 2 feet in width upon the beds; the headers to average 4 feet in length, and 2 feet upon the beds; the stones to be all properly worked on the beds, that is, to have a tool draught round them, and dressed off fair between with a point or pick: the joints or ends of the stretchers to be squared their whole length, and the joints of the headers squared in the width of the stretchers, and the other parts dressed or squared with a pick; all the space between the courses to be filled in with ashlar of the same thickness as the outside courses, the beds prepared as before directed, and thes ides and ends squared with a pick, and laid in proper bond to fall in with the outside courses, and when a course is finished, to be grouted; the whole surface is then to be dressed off level before another course is begun to be set.

"The front courses of these abutments, cutwaters, and wing-walls, to be not less than 1 foot thick; laid on level beds with bond, that is, the joints to overlap about 8 inches, header and stretcher alternately; the headers to average 3 feet 6 inches wide; the stretchers to be not more than 4 feet in length, and 1 foot 6 inches wide. The beds of the stones to be all worked fair, and the joints squared the width of the stretchers, and the face of them clean-tooled. The wing-walls to be built curvilinear on the plans, finishing with octangular piers, and battering in a curve line 3 feet in the whole height; the joints to be rusticated.

"The hearting of the abutments, that is, between the outside courses to be worked, to fall in with the radii of the arch, as shown on the section. The stone composing this part of the abutments, to be about 1 foot thick where they terminate at the bottom, and when they extend to require stones more than 18 inches thick, they may be in two courses if required; the stones must average not less than 2 feet upon the beds, and from 3 to 4 in length; the beds to be fair dressed by a tool draught round, and dressed off between with a pick; the headings and side joints squared and set in proper bond as before expressed; and when one course is set, it must be dressed off fair to its radii, and grouted before another course is begun.

"The springing-stones, that is, those on which the springing plates of the arch are to rest, to be 4 feet on the face on which the plates rest; the projection, or string-course, to be worked on the same stones. These stones to be not less than 3 feet on the beds.

"The cornice and plinth of the wing-walls, and piers, to be worked according to drawings, that is, to match the iron cornice. The caps of the piers and cutwaters to be each in one stone, and worked as shown on the drawings.

"To be a puddle of clay 3 feet thick put in against the back of the abutments, and wing-walls carried up with the masonry as it proceeds, and filled in behind with spoil (got out from the foundations) to the extent of the wing-walls, and well rammed down to keep the puddle in its proper place.

"The stone to be used for the works to be got from Tixall or Western quarry, or any other of as good a quality; it must be free from clay-holes or dry rents, and all to be set on its natural or quarry bed.

"The mortar to be composed of barrow lime and river or drift sand, two parts of sand to one of lime; mixed up in small quantities, as it is used, with as little water as possible, and well beat with a beater before it is used. The grout must be made with the same lime mixed up with coarse sand and small gravel, in the same proportion as above mentioned.

"The contractor must find all materials, tools and utensils, for his part of the work, and shall not let any part of the work, except quarrying the stone, and carriage of the same and other materials, to any person, but the whole to be done by men on day-wages. The excavating the earth for the foundations, to be done by the county.

"The works are to be done under the superintendence of the surveyors of the public works for the county of Stafford, or such surveyor as the justices assembled in quarter sessions shall at any time hereafter appoint; and should it at any time appear during the execution of any parts of the works to such surveyor, that the contractor is neglecting or doing any part of the work contrary to the true meaning and intent of this specification, the magistrates shall have it in their power to take the work out of his hands, and employ others to finish it; and what money may be due to the said contractor, to remain in the hands of the treasurer of the county till the whole is completed; and any loss that may be sustained by the neglect or misconduct of the said contractor, to be paid for out of it.

"*Iron work.*—Specification of the iron work for a bridge intended to be erected over the river Trent, at a place commonly called High Bridge, near to Handsacre, in the county of Stafford:—

"Upon each abutment is to be a springing plate of cast-iron, each cast in one piece, and to have shoulderings and sockets to receive the ends of the ribs. Each plate is to be of the form and dimensions as shown upon the drawings. The back of each socket, or the part against which the ends of the ribs will abut, is to be clipped, and made to have a true and even face to the exact radius of the arch.

"There is to be but one arch of 140 feet span, and rising 14 feet; the arch is to be composed of 5 ribs, each cast in 7 pieces of equal lengths. The ribs are to be 36 inches deep, in the direction of the radius, and of the exact shape and dimensions as shown upon the drawings. The parts of each rib and the ribs are to be connected by cast-iron tie or connecting plates, each cast in one piece, and passing quite across the arch; the parts composing each rib are to have flanges cast upon each of the ends which abut against the connecting or tie plates, and are to be secured to them by 3 inch square threaded wrought iron screw-pins in each flange. Each flange is to be clipped, and made true over the whole of its surface to the exact radius of the arch, so as to have a solid and true joint. The ends of the parts of the ribs which are to be fixed in the sockets of the springing-plates are to be clipped, and made true over their whole surface of section, so that they may have a sound, solid, and true abutting joint. The parts of each tie or connecting plate against which each part of the rib abuts, must, for the whole area of each flange, be made to the exact radius of the arch, and be clipped and made to have a true and even face. Joggles are also to be cast upon each tie or connecting plate, which are to fit into the joggles cast on the ends of the parts of the ribs. Both the male joggles upon the tie or connecting plates, and the female joggles at the ends of the ribs, are to be made to the radius of the arch, and clipped, and made true over their whole surface, so that each joint may be solid and true throughout.

"Upon the top of each of the ribs is to be a shouldering, running its whole length, having sockets to receive the joggles upon the bottom of the spandrils. Diagonal braces of cast-iron, of the same section, form, and dimension, and disposed in the manner as represented in the drawings, are to be used; each of the parts composing the braces are to abut against the ribs in the situations and in the manner shown upon the drawings, and secured to them by keys and cotters, or wedges, filed, and made true upon their edges; the parts of the braces which abut against the ribs, and also the face of the snugs or bed-pieces, cast upon the ribs to receive them, must be chipped so that they may have a true solid joint.

"The spandrils are to be of the same form and dimensions as shown upon the drawing. The spandrils over each rib are to be the same in every respect, excepting that upon the outside face of the outside spandrils a fillet must be cast, running round each opening, as shown upon the drawing; the fillet to be $1\frac{1}{2}$ inch wide, and projecting $\frac{3}{4}$ of an inch upon the bottom of the spandrils; at the point of each lozenge must be cast joggles to fit into sockets on the tops of the ribs. Ears also to be cast at the same place; the situations of the joggles and ears marked upon the drawings. At the central intersection of each lozenge there must be a brace running quite across the bridge; each must be done as shown upon the drawings, viz., having a wrought-iron screw bolt $1\frac{1}{2}$ inch in diameter, passing through cast-iron tubes, with washer, plates, &c., quite across the bridge. These braces are to be placed in the situations as marked upon the drawings. The spandrils may be cast in any convenient lengths, and connected by flanges of proper strength, and $1\frac{1}{2}$ inch wrought-iron screw-pins.

"The outside spandrils are also to have a flange cast on their tops, running the whole length of the bridge, to bed the cornice, &c., upon.

"The cornice is to be of the same form and dimension as shown upon the drawing, having strengthening pieces cast inside, not farther asunder than 3 feet. It must be cast in lengths not exceeding 9 feet; and each piece is to be connected to the other by internal flanges and three $1\frac{1}{4}$ inch wrought-iron screw-pins in each joint. The bottom of the cornice will lie upon a flange cast upon the top of the outside spandrils, and be secured to it, and the road-plates $1\frac{1}{4}$ inch wrought-iron screw-pins, two in each road-plate.

"The plinth is to be of the dimensions and form as shown upon the drawings; it must be cast in lengths not exceeding 8 feet 6 inches, each piece to be connected to the other by a dove-tailed joint. Ears are also to be cast on the bottom of each side, to secure it to the top of the cornice by $1\frac{1}{4}$ inch wrought-iron screw-pins, not more than two feet asunder. Sockets are to be cast in the top of the plinth, to receive.

"The palisade bars are to be $1\frac{1}{4}$ inch square, placed arris-ways, and not more than 6 inches asunder from centre to centre. The handrail is to be of the same dimensions and form as shown upon the drawings, having sockets cast on the under sides to receive the tops of the palisade bars; and it is to be screwed to the top of every sixth palisade bar, with a counter-sunk headed screw, and it must be secured or connected with the pedestals in the manner shown upon the drawings. The pedestals are to be of the same dimension and form as shown upon the drawings, having sunk panels on the front and back; internal flanges to be cast on the top to receive the handrail, and the caps are to be put on with counter-sunk headed screws. Brackets are also to be cast on each side of every sixth palisade bar, of the same form as shown upon the drawings, and secured by screw-pins to the plinth.

"The covering or road-plates are to be reticulated, and of the same dimension and form as shown upon the drawing, having flanges cast on their under sides to receive the bearers or tops of the spandrils; they are to be secured to the top of the centre spandrils, and to the flanges cast on the top of the outside spandrils, by $1\frac{1}{2}$ inch wrought-iron screw-pins, two in each joint. They are also to be connected to each other by flanges cast on their under sides, and two $1\frac{1}{2}$ inch wrought-iron screw-pins in each joint.

"None of the castings are to be run from the blast-furnace, but the whole work must be made from good No. 2 pig-iron, of a quality satisfactory to the surveyor or surveyors of the works of the county of Stafford. All the screw-pins, nuts, washers, keys, cotters, wedges, &c., are to be made of the best malleable iron. All the joints are to be made in a good workmanlike manner; and the whole of the work must be fitted and fixed at the contractor's works, and inspected by the county surveyor previous to its being sent off. All the work must be moulded, wrought, fitted, and erected, in a substantial and workmanlike manner, and to the entire satisfaction of the county surveyor or surveyors.

"The contractor must find and pay for all patterns, materials, tools, cement, tackling for fixing his work, and all other utensils or requisite things connected with the construction and fixing his part of the work. The estimates are to be given in a gross sum, and must include carriage of all materials to, and fixing the work at, the place of the intended erection.

"The county of Stafford will be at the expense of the whole of the masonry of the abutments, and cutting and letting in the iron-work into the masonry, and will also provide centering for turning the arch.

"Should any alteration be made hereafter in the dimensions or method of executing any part of the work, the extra price or deduction, whichsoever it may be, shall be agreed upon by the contractor and the county surveyor or surveyors, before such part or parts of the work are put in execution. But such alterations shall only be considered as affecting the matter or object thus specified, and not have any tendency to annul the general contract.

"The whole of the works are to be under the superintendence of the surveyor of the public works of the county of Stafford, or of such surveyor or surveyors, person or persons, as the justices assembled in quarter sessions shall at any time hereafter appoint. And should it appear, at any time during the execution of the works, that the contractor is neglecting, or doing any part contrary to the true spirit and meaning of this specification and drawings attached, then the magistrates shall have it in their power to take it out of his hands, and employ any other person or persons to complete it; and what money may remain due to him shall remain in the hands of the treasurer of the public stock of the county of Stafford till the whole work is completed; and any loss that may be sustained through the neglect or misconduct of the said contractor, to be paid for out of it.

"The whole of the work must be delivered, fixed, and completed, on or before the day of in the year

"The bridge was erected in the year 1830. The total weight of iron-work, which was executed by the Colebrook Dale Company, was 340 tons.

The whole cost of the bridge was as follows:—

Iron-work, delivered, fixed, and completed . .	£3,800 0 0
Masonry	3,193 0 0
Foundations, which were piled according to the most approved method; and the approaches, which are of considerable length and height	2,500 0 0
Total, ...	£9,493 0 0

We come now to the erection of one of the most celebrated structures in the world—the iron bridge over the river Thames—Southwark Bridge. This splendid work crosses the water between London Bridge and Blackfriars. The spot seems to have been well selected, and great improvements and alterations, particularly on the Surrey side, have taken place in consequence of its erection. Southwark Bridge was built in compliance with an act of parliament obtained by a company of proprietors in the year 1811, but not without great opposition on the part of Sir William Curtis and others. The first stone of the south pier was laid by Lord Keith, on the 25th of May, 1815, who, with the gentlemen of the committee of management, partook of a cold collation on a temporary bridge erected on the works. On the 7th June, 1817, the Right Honourable Matthew Wood, as Lord Mayor, laid the first stone of the northern abutment, and the works were then carried on with great energy. The whole was completed in something less than five years, and opened to the public at midnight, in April, 1819.

The arches of this gigantic edifice are of the largest span of any known to exist. The soffits consist of solid masses of cast-iron, of a depth similar to the voussoirs of a stone bridge, and exhibit the first instance in which such a bold plan has been carried into effect. The middle arch rises 24 feet, with a span of 248 feet, and is 4 feet wider than the famous iron bridge at Sunderland. It is composed of eight ribs, riveted to diagonal braces; each principal rib being 6 feet deep at the top of the arch, and gradually extending to 8 feet at the abutments, or parts that rest upon the stone-work. Its whole height above low-water mark is 55 feet to the roadway. The other arches are similarly formed; the span of the two side ones being 210 feet. The abutments are of solid masonry, laid in radiating courses, with large blocks of Bramley-fall and Whitby stones. Vertical bond was adopted, running through every two courses at intervals, thereby giving to the whole mass a solidity perfectly immovable. The masonry of the piers, in like manner, was carried up with horizontal and vertical courses to the springing of the arches; from which points they radiate in a wedge-like form. These piers are 60 feet high from the bed of the river to the top of the parapet, and 24 feet in breadth. The foundations of this bridge were laid in coffer-dams, which were of necessity made very strong, from the irregularities of the bed of the river at this spot. The dams were elliptical in form, and were constructed of three rows of piles of whole timber. In the spaces occupied by the base of the masonry of the piers, a row of whole timber sheeting piles were driven all round the outer edge of the offsets, making, as it were, a square internal dam. These piles, while they formed a secure barrier to the foundations of the piers, acted as a powerful auxiliary to the main dam in securing its base. The centerings on which the arches were turned were of very ingenious construction; and with such skill was the whole work designed and carried into execution, that the settling of the centre arch was only 1 inch and 7-8ths. The bridge is 718 feet long between the abutments, and 42 wide between the parapets. The width of the roadway is 28 feet, with footways 7 feet wide on each side. The weight of metal in the centre arch is 1,665 tons; in the side arches, 2,928. The total weight of iron in the whole structure is stated to be about 5,780 tons.

This noble bridge was designed and executed by the celebrated Rennie. The whole of the iron castings were made at the extensive works of Messrs. Walker and Company, at Rotherham, and there put into arches before being shipped to London. The masonry was executed by Messrs. Jolliffe and Banks. The cost of the whole, including its connecting avenues, amounted to nearly £800,000.

Iron bridges had, about this time, also attracted the attention of the French engineers; and the following description of the Pont des Arts at Paris will be interesting, not only from its being the first iron bridge erected in France, but also from its presenting much novelty of design.

The Pont des Arts was designed by M. de Cossart, the inspector-general of roads and bridges, but some variations were afterwards made from the original design by M. Dilon, to whom the execution of the work was intrusted.

The bridge is a nine-arched structure, the width between the piers measuring between 56 feet $9\frac{1}{2}$ inches, and the thickness of the piers themselves, 6 feet $4\frac{1}{2}$ inches above the footings. Each arch consists of five ribs, 7 feet $11\frac{3}{4}$ inches apart from centre to centre, each rib forming a large cast-iron arch, $6\frac{3}{8}$ inches in depth, and $3\frac{8}{16}$ inches in thickness, formed of the two beams meeting at the crown of the arch. The extremities of the arch rest on skew-backs of cast-iron, embedded in masonry at the top of the piers. The chord of the arc measures 60 feet $8\frac{3}{4}$ inches, and the versed sine 10 feet 8 inches. The smaller arches of iron are turned over the piers springing from the haunches of the adjacent principal arches, and supporting the roadway above the piers. Upright supporters are carried from the centre of the piers to the crown of the small arches, and are strengthened by struts supported on the larger arches. The ribs of each arch are bound together by tie-rods fixed to the top of the large arches. At first, the upright supports of the smaller arches were connected by only one cross-piece, and had no braces in the upper part; but owing to the visible effect produced upon the bridge by a large number of persons crossing suddenly from one side to another on the occasion of some public spectacle, it was deemed expedient to insert additional braces. The general appearance of the bridge is very good—especially for a foot bridge—for which purpose it is admirably adapted. It is of exceedingly light and elegant appearance, as also of skilful and scientific construction, and would form an excellent model for a bridge not subject to any great strain.

Iron arch-bridges of various dimensions have, since the completion of the great works we have described, become so numerous, that it is impossible, as indeed it is unnecessary, to describe or enumerate them. With the extension of railway works, however, it became apparent that some modification of the ordinary form of those bridges was desirable. It is well known by persons conversant with railway matters, how much trouble engineers have to encounter in arranging the crossings of the numerous roads, &c., by which a line of railway is intersected in its course over an extent of country. Either in passing over or under the line, there is frequently great difficulty in obtaining sufficient height, or "headway," as it is termed, for the railway trains to pass under the road-bridge, as in the former case, or for the road traffic to pass under the railway, as in the latter case. As the legislature imperatively requires a certain headway should be given, and will not permit any alterations in the levels of roads which shall increase their acclivities beyond a certain extent, immense expense has been entailed on railway companies in fulfilling all these required conditions.

The desideratum for railway-bridges then was the means of adapting iron to the construction of bridges perfectly flat, or in which might be preserved the minimum distance from the under side, or soffit of the girder, to the level of the roadway above. Bridges of this kind, it is true, had been built of timber, that is, simply of horizontal beams laid across the opening to be spanned; but the application of cast-iron girders in the construction of bridges, had as yet been made only to those of very limited span. For, the maximum length of bearing to which single cast-iron girders, liable to be loaded with heavy weights, could be safely applied, having been commonly taken at 40 feet only, it followed that the use of these girder bridges was necessarily much restricted. The convenience of this form of structure, however, was so obvious, and so desirable was it to extend its application to bridges of larger span, that attempts were continually made to combine in every variety of construction wrought-iron with cast metal, in such a manner as should impart to the compound structure the power to resist the extension of wrought-iron itself. A paper, by Mr. John Storey, describing an ingenious mode of so combining malleable iron bars or rods with cast-iron girders, and thus forming as it were a kind of metal trussing, was read at one of the meetings of the Institution of Civil Engineers.

The author states, "that his attention has been long directed to the extensive construction of the brick and stone bridges usually erected over and on the line of railways, and the apparent want of durability in the timber-bridges, which have in some instances been substituted; as well as to the cast-iron bridges, which have generally been constructed in situations where the height between the top of the rails and level of the roads which they span, were so limited, as not to admit of a stone or brick arch. In the latter case, cast-iron girders have been employed, but their great weight has rendered them expensive, and has obliged the abutment-piers for supporting them to be very substantial.

In order to obviate these objections, the author has introduced combinations of cast and wrought iron in forms which he contends may be advantageously adopted for occupation-bridges, or even for carrying the railway, and that they may be constructed at a less cost than stone, brick, or even timber bridges. These bridges consist of longitudinal and segmental girders of cast-iron, abutting against each other at the ends, secured together by bolts and nuts through the flanges, and resting on masonry abutments; a system of wrought-iron tie-trussing is then applied, and struts are placed at certain distances where they are requisite. As many of these principal trusses are used as the strength of the bridge demands, and they are connected by transverse braces, and distance-pieces of cast iron, thus preventing undue outward pressure, sockets are cast upon the girders to receive the timber joists, and the platform is covered with Dantzic deal planking spiked to the joists. The wrought-iron struts at the top, clasp the girders, to which they are also firmly bolted, and their lower extremities pass through the truss, so that on the nuts being screwed up, the truss is brought to its proper degree of tension, and being made sufficiently strong to bear the weight calculated for the bridge, independent of the segmental girders, the weight and strain are brought upon the abutments in the most favourable manner. Bridges thus constructed do not require any centering for their erection, as each side may be put together near the spot, and, by means of purchases, may be lifted entire on to the abutments, or the whole bridge may be put together before the earth is excavated from between the abutments, excepting only as much as is necessary for receiving the trussing.

The dimensions are given of occupation-bridges calculated to bear 8 tons, which is stated to be a greater weight than is required by the land-owners. The total weight of cast and wrought iron in an oblique bridge of a span of 86 feet 3 inches, and 11 feet wide, is 11 tons 7 cwt.. and that of a square bridge of 106 feet 6 inches span and 11 feet wide, is 14½ tons; their total cost, including excavating the ground, the masonry, stone penning on the sides of the excavations, the timber-work, and the painting, was for the former £280, and for the latter, £342; these sums are stated to be much less than the expense of similar bridges of stone, or even of timber.

A design is also given of a stronger kind of bridge of similar construction, for carrying two lines of railway. The span is 90 feet, and the width 22 feet between the side railings. The weight is 43 tons, and the total cost, including the masonry, is estimated not to exceed £1,200. It is calculated to bear about 50 tons, which is as much as could be brought upon it by any passing train.

Numerous railway-bridges have been erected within the last few years, in a similar manner to that suggested by Mr. Storey, and also by other engineers. Many of these designs show much ingenuity, and great variety of arrangement, and exhibit almost every form of combining wrought with cast iron. A bridge of a very novel construction, however, requires particular notice, not only from the boldness of its design, but from its being, we believe, the first application of the suspension principle to a railway-bridge.

The iron tie-bridge over the Regent's Canal at Camden Town, on the line of the London and Birmingham railway, is one of the most ingenious structures on the whole line, and was designed by Mr. Fox, one of the resident engineers, for the purpose of conveying the railway at an elevation of only 13 feet above the surface of the water, and with a span of not less than 50 feet. The structure consists of three main cast-iron ribs, each composed of two large castings, extending the whole width of the opening, and having a bearing at each end of 4 feet. These minor ribs are connected together by transverse iron bracing. The pedestals on which the ribs take their bearings, are 10 feet long, 6 feet wide, and 30 feet high, and are built of brick and stone, founded on a bed of concrete 2 feet in thickness. Eight cross girders run from either side main rib to the centre main rib, from which they are severally suspended at each end by vertical rods and keys. The girders are of fish-bellied form, and are each 28 feet in length, and 2 feet deep in the middle. The thrust of each arch is sustained by wrought iron tie-bolts running from end to end of the ribs. To the front of the ribs is bolted open ornamental work, which gives to the whole a pleasing appearance. The extreme width of this bridge is 60 feet. The rails over the bridge are set in chairs, and bolted thereto. The chairs are fixed on oak slabs running longitudinally, and resting on the tops of the girders. The side and intermediate spaces, and also the space beneath each pair of rails, are covered with iron gratings, furnished with flanges underneath to strengthen them.

A good example of cast-iron compound girder bridge trussed with malleable iron bars, was erected some years since over the river Lea, on the line of the Northern and Eastern railway. This bridge is formed with girders, each girder being 70 feet long, and made of two castings, joined at the centre by bolts passing through vertical flanges. Upon the meeting ends of the two castings, are cast dove-tailed projections, or bosses, with wrought-iron clips fixed over them.

"These bosses give additional security to the joinings of the castings. Each girder is perfectly horizontal from end to end, and the top and bottom lines parallel. The girders are 36 inches in depth, with bearings on the abutments of 2 feet at each end; the clear span between bearings being 66 feet. The sections of the castings shows a vertical rib, and projecting flanges at top and bottom. The truss bars are arranged in sets of 4 bars on each side of the girder, and pass obliquely downward from the top of the girder over the bearings at either end, to the under side of the girder, at a distance of about 11 feet short of the centre. The space between of 22 feet has horizontal truss-bars passing beneath; both horizontal and oblique bars are secured by bolts or pins 3 inches in diameter, passing through projecting saddles under the lower flange of the girders. The bars at their upper extremities pass through sockets cast upon the girders, and are keyed through them."

It would be easy to multiply examples of iron bridges, many of them possessing great merit; but the lamentable failure of some large bridges of this construction, has, within the last few years, led to the conclusion, that some radical defect existed in these compound constructions.

This defect evidently consists in the impossibility, in structures of this kind, of connecting wrought and cast iron in such a manner as to bear equally the strain of such a load as a railway train, passing over at a high velocity. This became fatally apparent in the failure of the largest bridge of this kind, erected over the river Dee, near Chester, and on the line of the Chester and Holyhead railway.

"This bridge, which crosses the Dee at an angle of 48 degrees, consists of 3 spans or bays, each 98 feet wide in the clear, the three series of girders forming the bridge being supported on two abutments of masonry, one at either end, and two intermediate piers. The width of the bridge is formed by 4 of these girders, placed parallel to each other, in 2 pairs, one roadway or railway being supported between each pair of girders, and formed of 4-inch planking laid upon transverse balks of timber, which rest upon the bottom flange of the girders. The girders are secured transversely from moving outward or away from each other by tension-bars, fitted at the ends to dove-tailed sockets, cast upon the girders. The entire bridge thus comprises 12 girders, each having a clear span of 98 feet, and a total length of 109 feet; that is, including a bearing at each end of 5 feet 6 inches in length. Each of these girders, 109 feet long, is composed of three castings, or lengths, having a uniform vertical depth of 3 feet 9 inches. The dimensions of the section are as follow:—vertical rib or web, $2\frac{1}{8}$ inches thick; top flange, $7\frac{1}{2}$ inches wide, and $1\frac{1}{2}$ inch thick; bottom flange, 2 feet wide and $2\frac{1}{2}$ inches thick. The sectional area of the top flange, including the moulding, is equal to 14 square inches; of the bottom flange, including the moulding, 66 square inches; and of the rib, 80 square inches; making a total uniform sectional area of 160 square inches. The joints of the three castings, in each girder, secured by wrought-iron bolts, passing through flanges, are strengthened by additional cast-iron joint plates, 3 feet deep at the centre, over the joint, and 13 feet in length, bolted to and scarped over the top flanges of the castings, over a length of 6 feet 6 inches upon each; dove-tailed bosses, cast upon the lower flanges, are also secured with clips of wrought-iron.

"The total depth of the girders, at each joint, is thus increased to 6 feet 9 inches. Similar plates of half the length of those over the joints, are also bolted over the ends of each compound girder; and the vertical inclination of the truss-bars, from the top of the girder at each end of the bottom of it at the joints, is thus increased to about 6 feet. The malleable iron truss-bars are arranged in sets of 4 each, 1 set on each side of the girder, each bar being 6 inches wide and $1\frac{1}{4}$ inch thick, put together in lengths or long links, similar to those used for suspension bridges, and secured by bolts at the joints of the girders, passing through the cast-iron girder and the 8 wrought-iron bars. The upper ends of the bars are secured with wrought-iron keys, driven through the bars and the casting, so as to tighten them well up in their position. By the great length of the girders, and the comparatively small depth thus afforded for the trussing, the action of the bars is reduced to nearly a horizontal direction, and their power to avert deflection in the girders is thus much diminished. Besides this, it must be remarked, that the sectional area of the bars is much less when compared with the total length of each girder, than in all smaller structures on this principle; and the relative effect of any increase of temperature in extending their length, and thus reducing the effectiveness of their assistance, is similarly augmented."—*Dempsey, Treatise on Iron Girder Bridges.*

The failure of one of these girders was ascribed to various causes, and much discussion on the subject took place at the time; but to whatever the accident in this particular case might be attributed, the inherent weakness of such combinations of wrought and cast iron became perfectly clear.

The attention of the government having been for some time past, by this and similar failures of iron girder bridges, directed to the subject, a commission was at length appointed to inquire into the whole question of the application of iron to railway structures. In the evidence given before this commission, will be found an immense mass of valuable information, obtained under all the advantages of a Board so appointed; and although in their report the commissioners do not express any very decided opinion on the merits of the various forms of construction so strongly recommended to them, there is much practical knowledge to be gained by a careful perusal of the evidence and examination of the ingenious plans attached to it. We shall now proceed to give some extracts from this report:—

"The simplest bridge," observe the commissioners, "and that which admits of the greatest possible headway at a given elevation, is, undoubtedly, the straight girder bridge.

"The length of a simple cast-iron girder appears to be limited only by the power of making sound castings, and the difficulty of moving large masses. Thus the practical length has been variously stated to us as 40, 50, and 60 feet. The form resulting from Mr. Hodgkinson's former experiments on this subject is universally admitted to be that which gives the greatest strength, but the requirements of construction compel many variations from it, especially in the ratio between the top and bottom flanges. Moreover, the convenience and the necessity of keeping the roadway for rails as low as possible, has introduced a practice of supporting the beams which sustain the rails upon one side of the bottom flange. The pressure of the roadway and of the passing loads being thus thrown wholly on one side of the central vertical web of the girder, produces torsion (which is not always taken into account in determining the proportions of the girder.) The existence of this torsion is admitted on all hands, and various schemes are employed to counteract and diminish it; but the form of a girder that will effectually resist this disturbing force without incurring other evils, still remains a desideratum.

The requisite length of girders is increased considerably by the excessive use of skew bridges, and it is much to be regretted that difficulties should often be thrown in the way of altering the course of existing roads and canals when the line of a proposed railway happens to cross them at an acute angel. Partly from these causes, and partly from a little indulgence in the pride of construction, skew bridges may be found, of which from the obliquity of the bridge, the girders are more than double the length that would be required by the direct span of the opening to be crossed.

When the span of the opening, or other circumstances, render the use of single straight girders unadvisable, straight girders built up of several separate castings bolted together, and sometimes trussed with wrought-iron tension rods, are largely employed, and necessarily with great varieties of construction. By these means the girders may be extended to spans of upwards of 120 feet.

When wrought-iron is combined with cast-iron in the manner of trussing, several difficulties arise from the different expansions of the two metals, and the difference of their two masses, which causes the wrought-iron rods to be more rapidly effected by a sudden change of temperature than the cast-iron parts. The constant strain upon the wrought-iron tends to produce a permanent elongation, and hence tension-rods may require to be occasionally screwed up. We have sought for opinions and information upon all these questions, and these show that the greatest skill and caution is necessary to insure the safe employment of such combinations. It is not admitted that the vibration of railway trains would loosen or injure the bolts or rivets of compound girders. Nevertheless, wood, felt, or other similar substances, have occasionally been introduced between surfaces, to diminish the communication of vibration.

The general opinion of engineers appears to be, that the cast-iron arch is the best form for an iron bridge, when it can be selected without regard to expense, or to the height above the river or road which is to be crossed. For low bridges the bowstring girder is also strongly recommended. Lattice bridges appear to be of doubtful merit.

We come now to the description of that new mode of construction introduced by Mr. Stephenson and his able coadjutors, and perfected in the magnificent structures to which the public attention has been so long directed, the Conway and Britannia tubular bridges :—

The application of iron in this form of bridge consists in the riveting together boiler-plates as in iron ship-building, combined in various ways with cast-iron. Hollow girders are thus formed, which are either made so large as to admit of the road and carriages passing through them, as in the bridges above described, or else these tube girders are made on a smaller scale, and employed in the same manner as the ordinary cast-iron girders, to sustain transverse joists which carry the road. The first kind is applicable to enormous spans, those of the two bridges above-mentioned being 400 and 462 feet respectively. The second kind are said to be cheaper and more elastic than other forms, for spans that exceed 40 feet. These methods appear to possess and to promise many advantages, but they are of such recent introduction, that little experience has yet been acquired of their powers to resist the various actions of sudden changes of temperature, vibrations, and other causes of deterioration. The eminent engineers examined before the commissioners, however, very generally expressed opinions favourable to the tubular form of bridge.

Before proceeding to describe the Britannia and Conway Bridges, it may be desirable to give a slight sketch of the circumstances which led to their erection :—

In the session of 1844, a Joint Stock Company proposed to parliament to undertake the construction of a railway from Chester to Holyhead, in continuation of lines already made. The bill introduced for this purpose contemplated the use of Telford's celebrated suspension bridge over the Menai straits, as the means of conveying across the railway, carriages and waggons, divested of the ponderous locomotive engine. The Commissioners of Woods and Forests, however, who had the jurisdiction of the bridge, would at first only consent to this proposal as a temporary measure, and afterwards objected to its being made use of at all. The company not being prepared with any plan for a permanent bridge, were obliged to content themselves with an act of parliament which gave them power to construct a railway from Chester to Bangor, and through the Isle of Anglesea to Holyhead, leaving an hiatus of five miles at the Menai straits. The means of filling up this break was reserved for future consideration, and for a permanent bridge to be sanctioned by the act of a subsequent session. In the following autumn, Mr. Robert Stephenson, the engineer of the company, prepared plans for a cast-iron bridge of two arches, each having a span or clear width of 350 feet. The height of each arch was to have been 100 feet at the crown, and the total cost of the bridge would have been £250,000. The Britannia rock, about a mile to the west of the suspension bridge, was selected as the most eligible point for crossing the straits ; but in consequence of the rapid current, and other circumstances of difficulty which exhibited themselves at this point, added to the necessity of interfering as little as possible with the navigation of the straits, Mr. Stephenson proposed to build the arches of this bridge, not upon supports from beneath, as is usually done, but by stringing on, as it were, a series of iron blocks or vertebræ from each pier, until they should meet in the middle, in a way somewhat similar to those which had been proposed in former years by Mr. Telford and Sir J. Brunel. The railway company made their application to parliament in the session of 1845, in order to obtain power to construct this bridge. The company, however, found themselves strongly opposed, not only by parties interested in the navigation of the straits, but by others whose interest lay in driving them to Port Dynllaen. An appeal was then made to the Lords Commissioners of the Admiralty, as conservators of the navigation, and after a lengthened inquiry, the bridge proposed by Mr. Robert Stephenson received their lordships' veto, and a form of structure was prescribed, which should leave a clear opening of not less than 450 feet over each of the two navigable channels on each side of the Britannia rock, with a height of 105 feet above high-water over 370 feet of that opening, the remaining 80 feet being allowed to have less height, so as to admit of the construction of an arch of that form, should it be desired by the company.

It was this that led to the grand and untried design of the present rigid wrought-iron tubular bridge, which Mr. Robert Stephenson, after great thought and labour, assisted by Mr. Fairbairn, Mr. Hodgkinson, of the Royal Society, Mr. Edwin Clarke, the engineer of the works—gentlemen well known for their mathematical and scientific attainments—matured. The entire length of the stupendous structure is 1,841 feet from end to end, consisting of four large sections, the two side-tubes being each of them 230 feet long, and the two middle ones 460 feet each. When originally proposed before the committee of the House of Commons, the plan was received with general incredulity. The word "tube," it may here be observed, is not one of the best epithets that could be used to describe the structure, seeing that the bridge, instead of being round, is a perfect square. Though almost a misnomer, the name arises from the circumstance of the experiments that were to decide the form of the bridge, having been made with cylindrical, elliptical, and rectangular tubes; but in reality, the structure, as it now rests on the banks of the Menai, the site of its construction, is one immense closed-in iron corridor, forming a horizontal iron gallery or passage, within which the rails for the trains are to be placed, and 450 feet in length. It is hollow from end to end, and would, if filled with shops, and lighted by sky-lights, make a Burlington Arcade.

A structure of this kind, though on a rude and miniature scale, appears to have existed for years on the Cambridge line of the Eastern Counties Railway; and Mr. Stephenson, the originator of it, amplifying upon this, designed the present tube. A long series of experiments, by engineers and mechanics fully conversant with such researches, were made, directed to the ascertaining—divested of all preconceived ideas—the strongest form for a sheet-iron tubular bridge; and the inquiry, in addition to the more immediate object it had in view, has been of immense public service in determining the strength of the materials used in the formation of railways. These experiments have been extremely laborious, and very costly. In the course of them, the remarkable fact has been disclosed, that the power of wrought-iron to resist compression is much less than its power to resist tension, or exactly the reverse of that which holds with cast-iron; and the important fact has also been arrived at, that rigidity and strength are best obtained by throwing the greatest thickness of material on the upper side. While the cylindrical tube, with a given weight, was ruptured by tearing asunder at the bottom, the elliptical showed weakness at the top: both were consequently discarded; and the rectangular tube, which indiacted strength of a higher order, and greater rigidity, was adopted. The result of every recent experiment on this species of structure, on a small scale, over the Conway, are very interesting, as confirming the accuracy of the original calculations. Measured by a cord-line in the inside of the tube, formed by the axis of a powerful telescope fixed to its side, the deflections have been made with a weight of 52 tons, 0·48 inch; 112 tons, 0·98; 173 tons, 1·30; 235 tons, 1·47; and on the removal of these loads, the tube has recovered its rigidity in ten minutes. The tube is constructed to bear, in addition to its own weight, 2,000 tons, a load ten times greater than it will ever be called upon to sustain. The deflection caused by trains and locomotives passing at full speed is very slight. A weight of 300 tons has produced a deflection of 3 inches. A very remarkable phenomenon is connected with this huge mass of iron of 1,600 tons, caused by changes of temperature in the weather, which affect it like a thermometer. A little sunshine raises the centre an inch, and produces a horizontal deflection of an inch and a half.

Its great length, and the nature of its material, so sensitive to temperature in the peculiar form that it takes, causing it to expand .0001 of its length, or ½ an inch for each increase of 50° of Fahrenheit, and contracting in the same ratio, is the assigned cause of its being such a delicate thermometer. Alternate sunshine and showers of rain cause these tubes to expand and contract; and one of them, if placed on end in St. Paul's churchyard, would be 107 feet higher than the top of the cross. It is calculated that the wind, at a velocity of 80 miles an hour—the rate of a hurricane—would only give a total pressure of 128 tons, distributed over the whole side of these tubes.

We have now to describe the means by which this gigantic structure was raised to its present lofty height, and the enormous towers by which it is supported there.

The spot selected by Mr. Stephenson for the site of the bridge, was at that part of the Menai straits where the Britannia rock rises from the bed of the stream nearly in its centre. On this rock is erected a tower of masonry; at the limit of the water-way on either side of it, similar towers; and on the land, on each shore of the strait, beyond the towers, continuous abutments of masonry. The bridge is therefore supported by the Britannia rock in the centre; at 460 feet from it, on each side, by a tower built in the same manner as that on the rock; and at 230 feet from each of these towers, by the land abutments.

The following description of these masses of masonry is taken from a very interesting little work published by Mr. Weale, "*Treatise on Tubular and other Iron Girder Bridges*," by Mr. Dempsey, C. E.

Britannia Tower.—62 feet by 52 feet 5 inches at the base, and reduced by the batter to 55 feet by 45 feet 5 inches at the height of 102 feet above high-water line, at which level the tubes pass through it. A plinth extends round the base of this and the other towers; and the height of this tower above high-water level is 200 feet, or nearly 230 feet from the bottom of the foundation on the rock. The stone used for the external parts of this, and the other towers and abutments, is a limestone of hard and durable quality, known as 'Anglesea marble.' It is quarried at Penmaen, on the shore, and near the north-eastern extremity of the island, and is 'got' in stones of great size, some of them weighing 10 to 14 tons. The interior of this, and the other masonry, is constructed of red sandstone, which is a soft stone, and therefore easily worked. It is quarried at Runcorn, in Cheshire, and is durable for inside work. The solid contents of this tower, if solid, would exceed 575,000 cubic feet, but it is constructed with hollow spaces or chambers within it, and the quantity of stone said to be actually used in it is 148,625 cubic feet of the limestone, and 144,625 cubic feet of the sandstone. The total weight of the masonry in this tower is about 20,000 tons, and about 387 tons of cast iron in beams and girders are built in it.

"The foundations were laid, and the work up to the level of high-water was constructed, during the intervals of tide, no coffer-dam being employed, and thus some months were occupied in laying the first course, which was commenced in May, 1846. The scaffolding used for this and the other parts of the work, was of whole timbers or balks, put together with iron straps and bolts where required, and braced with diagonal half-balks connecting the upright posts. Parallel timbers were laid horizontally on the tops of the posts, and rails fixed upon them, and upon these rails travelling crabs or 'jennies,' were enabled to pass in both directions, to pick up the stones from the ships, raise them to the required height, and deposit them exactly in their intended places. The stones in the whole of the masonry are left with the quarry or rough face, except at the angles, where they are dressed to a square arris, and in the recesses and top entablature, where they are dressed to a fair face all over."

"*Anglesea and Carnarvon Towers.*—The same dimensions at the base as the Britannia tower, viz., 62 feet by 52 feet 5 inches, reduced by the batter to 55 feet by 32 feet at the level of the bottom of the tubes; height from level of high-water 190 feet, or 10 feet less than the Britannia tower. In architectural design and general appearance these towers exactly resemble the Britannia tower, and they are said to contain 210 tons of cast-iron in beams and girders."

"*Anglesea and Carnarvon Abutments.*—These are also battered similar to the towers, and are 176 feet in length, and of width corresponding to the towers, viz., 55 feet at the level of the bottom of the tubes. The raised part of the abutments, in which the ends of the tubes are supported, are continuous across the railway, forming in fact complete towers, of smaller height than, but otherwise similar to, the towers already described. The remainder of the abutments are built of stone-work externally, but built up internally with longitudinal and cross walls, and intermediate arches of brick-work. Over the two parallel spaces formed between the longitudinal walls, corresponding with the two lines of railway, cast-iron girders are fixed, to support the roadway. The continuations of the abutments are surmounted with parapet-walls of solid masonry and considerable height, each of which terminates at the extremity of the bridge with a projecting pedestal, on which a couchant lion, in the Egyptian style, and of colossal dimensions, faces the approaching visitor, and seems to guard the entrance to the iron wonder behind. Each of these lions is composed of eleven pieces of limestone, and measures 25 feet in length and 12 in height, weighing about 30 tons. 'Repose and dignity' are skilfully blended in the expression, and these lions are probably, in more than one respect, among the *greatest* of the works which the talented chisel of Mr. Thomas is destined to produce.

"The four spaces between the Britannia tower and the towers, and between these towers and the abutments, are, as already described, of two dimensions, viz., two of 460 feet, and two of 230 feet. These four spaces have therefore to be spanned by the iron tubes; and as each tube serves for one line of rails only, 8 tubes are required, 4 of 460 feet net length, and 4 of 230 feet net length: the 4 longer ones being across the water, the 4 shorter ones over the land."

In the completion of the work, however, these several tubes are united together, and (with the short lengths also constructed within the towers, and joined to the other lengths,) forming two lines of tube parallel to each other, each of the length of 1,513 feet, and each line carrying its respective line of rails. The process of building and placing these tubes was conducted as follows:—

The land tubes were constructed in their proper positions, on scaffolding of enormous strength erected for that purpose. The portions of tube intended to occupy the Anglesea and Carnarvon towers, after being completed on the scaffolding at either end, were launched forward to meet the main tubes; while these again were built on the land, floated to the proper place, and then raised by hydraulic presses of immense power, to their destined situation. The method of floating these tubes from the building-stages to the base of the towers, was thus accomplished. Several large pontoons having been provided, they were placed at low-water under the tube to be floated, in such a manner that each end of the tube rested on four of these pontoons. As the tide rose lifting the pontoons, the tube borne by them was also lifted, and safely floated to its proper position, ready to be raised by the hydraulic presses.

The following graphic description, by an eye-witness, of the floating of the first tubes, is too interesting to be omitted. The operations were conducted by Captain Claxton, who, with Mr. Stephenson, and other gentlemen, was on the tube directing the proceedings. "Captain Claxton was easily distinguished by his speaking trumpet, and there were also men to hold the letters which indicated the different capstans, so that no mistake could occur as to which capstan should be worked; and flags red, blue, or white, signalled what particular movement should be made with each. About half-past seven o'clock in the evening, the first perceptible motion, which indicated that the tide was lifting the mass, was observed, and, at Mr. Stephenson's desire, the depth of water was ascertained, and the exact time noted. In a few minutes the motion was plainly visible, the tube being fairly moved forward some inches. This moment was one of intense interest; the huge bulk gliding gently and easily forwards as if she had been but a small boat. The spectators seemed spell-bound; for no shouts or exclamations were heard, as all watched silently the silent course of the heavily-freighted pontoons. The only sounds heard were the shouts from Captain Claxton; as he gave directions to 'let go ropes,' to 'haul in faster,' &c., and 'broadside on,' the tube floated majestically into the centre of the stream. I then left my station, and ran to the entrance of the works, where I got into a boat, and bade the men pull out as far as they could into the middle of the straits. This was no easy task, the tide running strong; but it afforded me several splendid views of the floating mass, and one was especially fine. The tube coming direct on down the stream,—the distant hills covered with trees,—two or three small vessels and a steamer, its smoke blending well with the scene, forming a capital back-ground; whilst on one side, in long stretching perspective, stood the three unfinished tubes, destined ere long to form, with the one then speeding on its journey, one grand and unique roadway. It was impossible to see this imposing sight, and not feel its singleness, so to speak. Anything so mighty of its kind had *never been before; again* it would assuredly be; but it was like the first voyage made by the first steam-vessel, something till then unique. At twenty-five minutes to nine o'clock, the tube was nearing the Anglesea pier, and at this moment the expectation of the spectators was greatly increased, as the tube was so near its destination; and soon all fears were dispelled, as the Anglesea end of the tube passed beyond the pier, and then the Britannia pier end neared its appointed spot, and was instantly drawn back close to the pier, so as to rest on the bearing intended for it. There was then a pause of a few minutes while waiting for the tide to turn, and when that took place the huge bulk floated gently into its place on the Anglesea pier, rested on the bearing there, and was instantly made fast, so that it could not move again. The cheering, till now subdued, was loud and hearty, and some pieces of cannon on the shore gave token, by their loud booming, that the great task of the day was done."

The preparations for performing so important and perilous an undertaking as that of hoisting the enormous fabric, to place it in its permanent position over the straits, were on a scale of immense magnitude. This will be the more readily understood, when it is stated that the total dead weight lifted 100 feet high from high-water mark, was upwards of 2,000 tons, or equivalent to the elevation to that height of upwards of 30,000 men. During the progress of this great work, a general impression appeared to prevail with the public, that when the tubular bridge was *floated*, the whole operation would be completed; but that, if it may be so termed, was a vulgar error. The floating was nothing more than the launch of the great iron ferry to the precise site, where it was to be raised by mechanical power, specially constructed for the purpose, to a height nearly equal to that of the dome of St. Paul's. The stroke of the hydraulic presses employed for the purpose, was 6 feet, that is to say, they were only capable of raising 6 feet at one lift. The tube of 2,000 tons weight was consequently to be sustained while the presses were lowered, and a fresh hold obtained. This sustentation, owing to the immense magnitude of the labour, was effected by building up successive layers of masonry at every 6-foot lift, under the tube, to support it securely in its upright ascent, during which arrangements were made for another 6-foot hoist, until the whole 100 feet were finished. Had it not been for this process of building up, the operation would have only occupied about a day, but as it was, it took a fortnight. The precaution was adopted by Mr. Stephenson and Mr. Clark, to guard against the probability of casualty, seeing that, should any accident occur, the labour of years, and the outlay of half a million of money, would have been inevitably sunk. To insure security, however, some contrivances were adopted, by which the supporting chains, as they rose, were continually followed up by wedges of wood, so that in the event of any accident having arisen to the lifting machinery, no injury, it was expected, would happen to the tube. The mechanical contrivances for the purpose were the largest in the world, and the most powerful ever constructed.

We are enabled, from a close inspection, to give a description of the vast apparatus for hoisting the huge burden. The machine used to effect this, was an enormous hydraulic press, a contrivance invented by Bramah, and used in operations where intense pressure is required. Its construction was of the most simple character, and consisted only of an exceedingly thick and very heavy iron cylinder, like a mortar. A strong piston, or plunger, also of iron, called the ram, and fitted with a leather collar at the shoulder, so as to render it water-tight, worked up and down inside this cylinder. Water was forced into the cylinder by a force-pump, through a small orifice which might be compared to the touch-hole of a gun. The whole secret of the immense power of this machine, consisted simply in the prodigious force with which the water was driven into it, and which in the present instance was so great, that it threw the water to the height of nearly 20,000 feet, which is more than five times as high as the neighbouring noble pinnacle of Snowdon, and 5,000 feet higher than the monarch of mountains, Mont Blanc. It in fact resembled the piston of a steam-engine, but instead of using steam at 30 or 40lb. pressure to the inch, water was used at a pressure of 800 or 900lb. The cylinder of course was of almost adamantine strength, to enable it to sustain and withstand that pressure. The sides of the largest of these presses used in raising the bridge, were 11 inches thick. The weight of the cylinder, which was of cast-iron, in one piece, was 16 tons alone; but the whole machine complete was 40 tons. The ram or piston within it, was 20 inches in diameter, and when worked to its utmost power, would alone be quite capable of raising one of the tubes. The marvellous thing above all was this, that in spite of its immense proportions, its stupendous action was guided and controlled with the most perfect ease and precision by one man. This hydraulic giant was constructed by Messrs. Easton and Amos, engineers of Southwark. It stood on two beams on a lofty sort of eyrie, at the top of one of the towers, whence a grand and open view is obtained of the straits seaward, while its elevation above the ravine was upwards of 200 feet. The press was composed of wrought-iron plates, riveted together at the top of the side towers, where, with its assistant machinery, it occupied a large chamber to itself, about 29 feet above the level to which the bridge had to be raised.

The sensations experienced on looking down from this lofty elevation over the rushing stream of the straits, and the great tubes and machineries strewn round about below, were of a peculiarly impressive character. In addition to this large press, there were two smaller presses, with rams 18 inches in diameter, placed side by side at a similar level on the Britannia tower, and which acted in conjunction with the large press. The chains by which the power exerted by these presses in their lofty position was communicated to the tubes lying at the base of the tower, resembled the chains of an ordinary suspension-bridge, and were similar to those of the bridge at Hungerford. They were manufactured by the patent process of Messrs. Howard and Ravenhill, of London, and consisted of flat links seven inches long, one inch thick, and six feet in length, with an eye at each end, and were bolted together in sets of eight and nine links alternately. The weight of the chains employed in lifting the 2,000 tons, was about 100 tons, far exceeding that of the well-known equestrian statue of the Duke of Wellington at Hyde Park, which has hitherto been regarded as one of the greatest "lifts" of the age. These chains were attached to the tube at two feet from the end, and in order to get sufficient purchase at the part, three strong frames of cast iron were built into each end of the tube. The innermost frame only stiffens and supports the sides, while the tube was resting on its ends. The two outer frames were the lifting frames. The chains were attached to them by three sets of massive cast-iron beams, placed across the inside of the tube, one above another, their ends fitting under deep shoulders or notches in the lifting frames, where they were secured by screw-bolts. As an additional precaution, two very strong wrought-iron straps passed over the upper pair of beams, and descended into the bottom cells beneath the frames, where they were strongly keyed. The weight of these lifting frames and cast-iron beams was 200 tons, and it was even a matter of wonder among the engineers themselves, how machinery could be made strong enough to raise the ponderous load. The way in which the chains were connected with the press, was by an exceedingly thick and heavy beam of cast-iron, strengthened by wrought-iron ties across the top. It rested like a yoke on the shoulder of the ram, and was called the cross head of the press. The two chains passed through square holes at either end of the cross head, and were securely gripped at the top of it by an apparatus called the *clams*, consisting of two strong cheeks of wrought-iron, drawn together by screws like a blacksmith's vice. The beams on which the presses stood, the cross heads, and all the parts that were subjected to a very heavy strain, were either constructed of, or strengthened by wrought-iron, which was found to be less brittle and more trustworthy than cast-iron. As the tube was 12 feet longer, allowing 6 feet at each end, than the distance between the towers in which the presses worked; recesses or grooves were left in the face of each, of 6 feet deep, in order to receive the additional length, and of sufficient width to allow the end of the tube to slide up easily within them. The recesses extended from the bottom of the towers to nearly the height of the hydraulic machines. It was in the low end of these recesses, on a soft bed of timber placed to receive it, that each great tube rested, after being floated there, until the vast mechanical equipments for ballooning it to its permanent level, 102 feet above high water mark, were completed.

The entire completion of this celebrated structure, the wonder and admiration not of a kingdom only, but of the world, perfects the communication between England and the sister country. The interchange of transit, and conveyance of correspondence between their respective capitals, may be daily within the compass of ten or twelve hours. This rapidity of locomotion in the present day may be well contrasted with the slow doings of former times. In 1685 it took the then Lord Clarendon, at that time Lord-Lieutenant of Ireland, from six o'clock in the morning to three in the afternoon, nine hours to get from Conway to Bangor, a distance of 14 miles, while a short time since the distance was accomplished by the present Lord Clarendon, Lord-Lieutenant of Ireland, in exactly twenty minutes. At the same period it took a king's messenger, "by express," six days to get over the ground now traversed between London and Chester, 188 miles, in five hours; and it is but twenty years since, that the same distance by coach took more than twenty-four hours.

These are the immediate advantages; the prospective ones consist in the completion of the great harbour of Holyhead, now being constructed for the Admiralty by Mr. Rendel the engineer, the pier at which is completed, and the breakwater for commencing the vast operations fixed. Should the Admiralty, as has been long expected, on the completion of this harbour, remove to it the West India packets, now starting from Southampton, and the Galway line of railway be finished, the voyage to the United States by this route would be shortened four or five days.

We cannot close this article, and necessarily imperfect account, of the Britannia bridge, without a passing allusion to the unfortunate *difference* that occurred during its progress, between Messrs. Stephenson and Fairbairn. It is greatly to be lamented, that men so eminent for talent should differ as to their respective claims to the conception and execution of so grand a work. It is not for us to presume to settle such claims, but surely each possesses in himself merit so surpassing ordinary minds, that he may well afford to yield a portion of honour to the many competitors who may join with him in the race for fame. A work like this might afford distinction for many minds, and varied talents; to all give honour, where honour is due. Let us then award to a Stephenson the merit justly due to him for his original conception; to a Fairbairn, the unwearied perseverance and the vast practical ability, by which that conception was realized and brought to perfection; to all associated in the undertaking, each in his peculiar walk, the merit of talent, zeal, and untiring industry.

Iron Chain, pieces of iron linked together. Iron chains are very serviceable under the roofs of circular buildings, where there is no intermediate tie, particularly at the bottom of stone domes, in order to prevent them from spreading or pushing out the walls, which, without this precaution, might be subject to separation, especially when the dome has to support an immense turret or lantern of stone. The dome of St. Paul's Cathedral, London, has two chains let into a bondage of Portland stone laid for the purpose.

Iron Girders. Girders of wrought and cast iron have now been used for some years in the construction of buildings, but more especially in the formation of railway bridges, stations, &c. The article on iron bridges will show how extensively they have been applied in that way. Various forms of girders have been recommended, and various methods suggested of combining wrought with cast iron, but these improvements have been more directed to the use of girders in the construction of railway and other bridges, than in buildings. Cast-iron beams for warehouses, and other large buildings, have been used with success.

Iron King-Posts and Queen-Posts, are in many instances preferable to those constructed of wood, and are not more expensive where both bolts and straps are used.

Iron Stone, an ore of iron composed of iron combined with oxygen, silex, carbonic acid, and water. When of a superior quality, it yields near 40 per cent. of iron. In Missouri, United States, iron stone has been found yielding 75 per cent. of metal.

Iron Wood, the popular name of some species of a genus of trees distinguished for their hardness. The *diospyrus ebenus*, or ebony, is sometimes called ironwood.

IRREGULAR, in the art of building, a term applied not only to the parts of an edifice which deviate from the proportions established by antique monuments; as when the Grecian-Doric is made more than six diameters in height, the Ionic more than nine, and the Corinthian more than ten; but also to places where the angles are unequal, and to edifices whose counterparts do not correspond in the several elevations.

A column is said to be irregular, not only when it deviates from the proportions of any of the three regular orders; but when its ornaments, whether in the shaft or capital, deviate from the established forms peculiar to the order.

Irregular Bodies, solids not terminated by equal and similar surfaces.

Irregular Figure, a figure whose sides and angles are not equal.

Irrigation, in agriculture, the art of causing water, by artificial means, to be distributed over the surface of the land, to afford moisture to the plants, &c., where insufficiently supplied with it by nature. Of late years a practice has been adopted, and with great success, of irrigating lands situated near large towns with the sewage-water diverted from the sewers, and conveyed by means of pipes to the required spot. The distribution is then effected in various ways, according to the nature of the ground to be irrigated, and other circumstances.

ISAGON, (from the Greek, *ισος*, *equal*, and *γωνια*, *an angle*,) in geometry, a figure consisting of equal angles.

ISIAC TABLE, one of the most considerable monuments of antiquity, being a plate of copper or brass, discovered at Rome, in 1525, and supposed, by the various figures in bas relief upon it, to represent the feasts of Isis, and other Egyptian deities.

With regard to the history of this monument, we may observe, that the copper or brass ground was overlaid with a black enamel, artificially intermixed with small plates of silver. When, in the year 1525, the constable of Bourbon took the city of Rome, a locksmith bought it of a soldier, and then sold it to Cardinal Bembo, after whose death it came into the hands of the Duke of Mantua, and was kept in that family till it was lost at the taking of that city by the Imperialists, in the year 1630, nor has it been ever heard of since. By good fortune it had been engraved in its full proportion, and with all possible exactness, by Æneas Vico of Parma. This tablet was divided into three horizontal compartments, in each of which were different scenes, containing different actions. These compartments are, as it were, different cartouches, distinguished sometimes by single strokes only, but oftener by a very large fascia, which is full of hieroglyphics, that is, of that mysterious writing, consecrated by the ancient Egyptians to the mysteries of religion. The four sides of the table were enclosed with a border filled up, like the ground, with several figures of the Egyptian gods, and with a great number of the hieroglyphics. There have been various opinions as to the antiquity of this monument: some have supposed that it was engraved long before the time when the Egyptians worshipped the figures of men and women. Champollion judged it to be the work of an uninitiated artist, little acquainted with the true worship of the goddess Isis, and probably of the age of Hadrian. Others, among whom is Bishop Warburton, apprehend, that it was made at Rome, by persons attached to the worship of Isis. Dr. Warburton considers it as one of the most modern of the Egyptian monuments, on account of the great mixture of hieroglyphic characters which it bears.

ISLE. *See* AISLE.

ISODOMUM, a species of walling used by the Greeks. *See* WALL.

ISOSCELES TRIANGLE, a triangle with two of its sides equal.

ISOTHERMAL LINES, curves supposed to be traced on the surface of the earth, so that each may pass through a series of points, at which the mean annual temperature is the same.

ISTHMIAN GAMES: these were one of the four great national festivals of Greece; the others being the Olympian, Pythian, and Nemean. They were celebrated under the presidency of the Corinthians, near Corinth, on the isthmus connecting Peloponnesus with the continent—hence their name,—and were performed at intervals of four years, corresponding with the recurrence of the other festivals above mentioned, so that each year had its solemnity. The Isthmian games were first established in honour of Melicertes, the son of Ino (Paus. i. 44); but were reorganized by Theseus in honour of Neptune, the presiding deity of the Isthmus. The crowns bestowed on victors were of pine leaves. See OLYMPIAN GAMES, and CIRCUS.

ISIS, one of the chief deities of the Egyptians, the sister of Osiris, was represented as the goddess of fecundity, and the cow was therefore sacred to her. She was said to have first taught men the art of cultivating corn. Heads of Isis are a frequent ornament of Egyptian capitals on the pillars of the temples. See EGYPTIAN ARCHITECTURE.

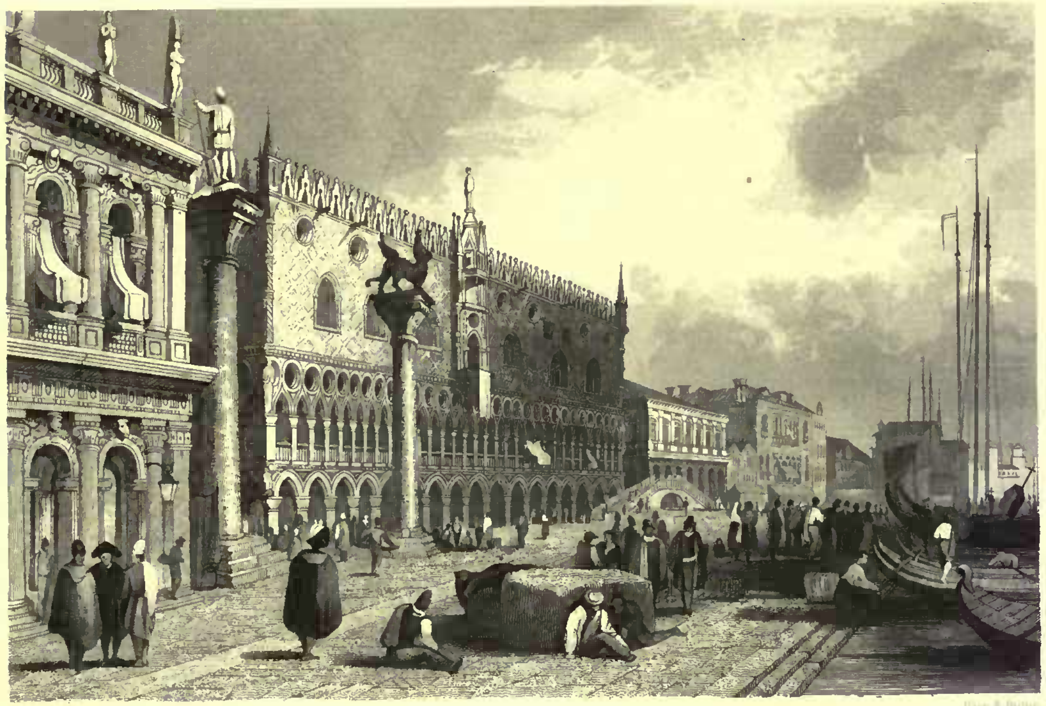
ITALIAN ARCHITECTURE.—A style of architecture prevalent in Italy during the fourteenth and two following centuries, but more especially during the fifteenth, from which circumstance it obtained another designation, being known likewise under the name of the *Cinque-cento* style. The term "Italian" does not include every style and class of building to be found in Italy, but is restricted to that style which was deduced from the ancient Roman or classical manner of building. To attempt to affix to this style anything like a precise or definite character would be perhaps impossible owing to the many varieties of design and different modes of treatment which it exhibits; all we can do is, to give some general notion of the prevailing character of the style.

After the fall of the Roman empire, its architecture declined into a state of semi-barbarism, and degenerated into what is commonly termed the Romanesque style; the cities of Italy were adorned with edifices in either the Byzantine or Lombardic manner, as their intercourse preponderated with Byzantium or Rome. Gothic architecture did not make its appearance in Italy until a comparatively late period, nor even then did it possess any decided or lasting influence; it was, however, in vogue to some extent during the thirteenth century, and, although of a mixed character, may be said to have been the prevailing style of that date. Of the buildings of the Pointed style in existence previous to the revival of the Roman method, the palace of the doge at Venice will form a fair example.

This edifice consists of three stories, the lower two of which are comprised in the lower half of the building. The first or lowermost story contains eighteen simple pointed arches springing from low stunted columns, above which, and forming the second story, is an open gallery of thirty-six small pointed ogee arches having the intrados formed in the shape of a trefoil. In the centre of the upper arcade is a large balcony with tabernacle-work above, to the right and left of which the wall is formed of masonry jointed diagonally, and containing six large pointed windows. In the centre of the building is an attic crowned by statues, and the horizontal cornice is terminated with a pierced battlement.

This style of building was not, however, destined to prevail much longer. At the close of the thirteenth century, a new cathedral was to be built at Florence, and was commenced on a grand scale in A.D. 1298, by Arnulfo di Cambio da Colle, or, as stated by other authorities, by Arnulfo di Lapo. The design of this architect was, at the outset, of an original character, and differed materially from the style then in use; this difference, however, was much increased by the alterations of succeeding architects who where engaged upon the work, amongst whom may be enumerated the names of Giotto, Taddeo Gaddi, Andrea Orgagna, and Felippo di Lorenzo. In 1408, a meeting of architects was called by the citizens, to discuss the best means for completing the cathedral, and it was at this time that Brunelleschi made his bold proposal to raise the dome, and it was he who completely effected the alteration of style. This building, which was of unusual size and magnificence, had great influence in effecting a change of style throughout Italy, and led ultimately to what is called the revival of Roman art. This, however, is not a fair designation of the mode of building prevalent in Italy in the fifteenth century; it was not a re-introduction of the old classic styles, but rather an adaptation of classical details to buildings of entirely different character, disposition, and arrangement. It is true that the artists who introduced this style adopted the classic orders, reduced them to a system, and determined their form and proportions most minutely, yet, nevertheless, applied them in a very different manner to the ancients, and to buildings of entirely different composition. Even in their delineation of the orders, they were guided rather by the writings of Vitruvius, than by existing Roman examples, and endeavoured rather to make the latter agree with the former, than the descriptions of the writer with actual examples.

It would be difficult, as we before observed, to give a definite description of Italian architecture; we can, however, attempt to give some general notion of a few of its leading characteristics. One of the main points in which it differs from purely classical art, is its partiality for fenestration or the introduction of windows, so as to form a marked feature in the design. The employment of lighting apertures had become indispensable, and in some Italian buildings was carried to great excess, so that, what with the windows and the external ornamentation, little space was left of naked walling. Now, the employment of windows, especially to such an extent, at once furnishes us with a feature of very great importance, and it is questionable whether it is not of greater importance than that of columniation: it is at least equally if not more strongly marked. The two systems of fenestration and columniation form two grand distinctions in architectural design, and are in a certain sense antagonistic in principle, nor can they readily be made to harmonize together: for fenestration either interferes with the effect aimed at by columniation, as in the case of a colonnade, where the simple and chaste effect produced by the repetition of a range of columns receding one behind the other, is marred and broken, and the unity of the composition destroyed; or otherwise is reduces columniation to an inferior and secondary position as



Venice

a mere means of decoration, to, in short, a mere accessory, as is evidenced in the use of engaged columns, and pilasters, and in the adoption of small columns, &c., for the adornment of only portions of an edifice. The latter is the method resorted to by the Italians, and though it may be said with some reason, that the columnar-fenestrated is an anonymous style, and that the terms astylar and fenestrated ought in practice to be synonymous, yet when we behold some of the beautiful structures raised in this style, we cannot yield ourselves entirely to this opinion. In our idea they may lawfully be combined when one is made clearly and distinctly an accessory to the other, and when the pre-eminence of the one is at once palpable and evident to the senses: but they may not be so employed where they hold equally important positions in the same edifice, one or the other must be ostensibly predominant. The Italians have employed the orders as ornamental accessories, and have been in many instances eminently successful, as far at least as regards the production of elegance and taste in the design; if we were to criticise too severely, and enter into the question of the unity of design and construction, we might not be so well able to vindicate the claims of this style; it will not bear such rough-handling as the Pointed.

In some instances, which are indeed the least removed from the classic in this respect, the entire edifice, or at least the principal portion of it, is comprised in one order, which is thus made to embrace two or more stories of the building, and the same number of ranges of apertures; and sometimes the main body of the building is crowned by a single pediment. This is what some would have us call classical, or at least very nearly classical; but we must confess we do not recognize the resemblance, and if there be a likeness, it is by no means a flattering one. This method would appear to us to be the first bungling attempt at adapting the ancient orders to the altered requirements of that age; such a system can be termed neither the columniated, nor the fenestrated, nor even a combination of the two, for there is no agreement or unity between the two principles so applied; you have them both together, it is true, but not in combination or unity: they are in open war, and, destroying each other's beauties, they are both spoiled—self-destroyed. The two systems are individually too prominent, they jar, and cannot blend together. Besides all this, it seems unnatural and ridiculous to comprise several distinct stories under one order; and if it seems so in theory, it has certainly no less the appearance in practice.

This system, however, was fortunately by no means universal; it was a more usual practice to give to each story its separate order, and this employment of different orders, or repetitions of the same order one above the other, in the several stories of a building, affords us another important feature of the style. This practice led to some other peculiarities worthy of especial notice, amongst which may be noticed, that of abandoning all proportion of intercolumniation, and spacing the columns according to the breadth of the piers, and the apertures between them. This again led to the abandonment of insulated columns, and the substitution of engaged columns of half or three-quarter projection; the reason for which is evident, for if insulated columns had been adopted, when placed at so great a distance from each other, they would have had an exceedingly tame and meagre effect, especially when raised tier above tier. But another alteration was still requisite, for with half or three-quarter columns, the entablature was made to project so far from the face of the wall as to produce the appearance at once of heaviness and weakness, the overhanging entablature seeming to have no support between the widely separated columns. To obviate this inconsistency, the Italians fell into a still greater, by breaking the entablature over each column, and recessing it in the intercolumn. We say a greater inconsistency, for the nature and functions of the entablature are thus entirely disregarded, but, as before observed, the designs of the Italians will not bear comparison with the requirements of constructive science. This objection, however, was somewhat lessened by the introduction of pilasters in the place of columns, which, from their slight projection, allowed the entablature to be continued without break or interruption. This was so far an improvement, but it will be noticed, that all this while, the columns and other divisions of the order were losing their natural character and office, and had at last dwindled down to nothing better than aids to decoration. Thus, by their diminution in size and projection, and by their loss of constructive propriety, columns became of little significance when compared with the windows and other apertures, which were often highly decorated with architraves and cornices, and sometimes with small columns in the jambs supporting an architrave and pedimental head, which was either triangular or segmental. This method of decorating the windows was employed where each story of the edifice was arranged as a separate order; but not unfrequently the order was entirely omitted, and columns employed only as decorations to apertures, and often were dismissed altogether, the windows having an architrave dressing only, with cornice supported by ancones on either side of the architrave. These illustrate the triumph of fenestration over the combination of the two systems; and if the former do not excel in appearance, which we are somewhat inclined to think it does, it at least surpasses in consistency. We have fair specimens in London in the Reform Club and Bridgewater House, by Mr. Barry, as also of the other system in the Carlton, Conservative, and Army and Navy Club Houses, all of which, and several other excellent examples, are in close proximity to each other, and afford ample means of judging of their comparative merits.

The walls of Italian buildings are frequently formed of rustic masonry of various descriptions, and this is more generally the case with basements, and the lower or less important stories, and in such a situation gives an appearance of great strength and massiveness, where it is most required; it adds also to the apparent strength and durability of the entire edifice; not, however, without imparting at the same time a degree of heaviness. This method of decoration, if it may be so termed, is sometimes applied to columns, but it is rather a barbarous ornamentation, as is also another practice very prevalent, of leaving projecting cubical blocks surrounding the shaft of the column at regular intervals in its height. In edifices of the astylar system, the angles are often finished with quoins.

We must not forget to allude to a feature which is common to almost all Italian buildings, and that is, the boldly projecting cornice, or cornicione, as it is termed, at the summit. It is of very unusual projection, proportioned to the entire building, and often very highly enriched; it forms a noble finish or crowning, and adds considerably to the importance of the façade. Sometimes the edifice terminates with an attic or cornice with a balustrade, which again is crowned at intervals by statues or other acroteria. Columns and pilasters in this style are frequently set upon pedestals, which is an innovation upon classic art, copied from the Roman triumphal arches, in which the practice was first resorted to. Columns also are frequently fluted in a spiral direction round the shaft, which gives them an appearance of weakness; they are also twisted and crooked, which produces an effect no less disagreeable, than the construction is unscientific and barbarous. Another innovation upon ancient precedent consisted in breaking the outline of the pediment by cutting it in the middle like a mitre; this practice was even more unsightly and unscientific than the preceding; for whereas the ancient pediment was formed for the purpose of throwing off the rain; this, on the contrary, would seem to be shaped for the very purpose of collecting and retaining it. This barbarism is frequently accompanied by another equally unauthorised and equally ugly; we allude to the practice, when the upper of two colonnades is narrower than the lower, of placing on each side of the upper story, a huge reversed console, or sort of volute, which has an exceedingly unsightly appearance. This arrangement is of common occurrence in churches, where the aisle-roofs are lower than than that of the nave, the difference of level being made up by these tasteless masses. These few last mentioned peculiarities form some of the worst features of the style; many buildings, however, are entirely free from such defects, and are of chaste and elegant design.

As we have above stated, the first attempt towards the introduction of this style was made by Arnulfo di Cambio, in his design for the duomo of Florence; but very little progress was made in this direction till the time of Brunelleschi, who may be said to be the father of the Italian style. From his time the style rapidly extended its influence throughout Italy, and was considerably varied, and in some instances improved upon, by his successors; of the life and works of the principal of them, a short account will be found in the succeeding table:—

Name of Architect.	Born.	Died.	Native of	Practised at	Erected buildings.	Wrote works.
Brunelleschi.	A. D. 1375	A. D. 1444	Florence.	Florence, Rome, and Mantua.	Dome of Cathedral, and Church of San Lorenzo, and commenced the Palace Pitti, Florence.	
Alberti.	1400		Florence.	Rome, Florence, Mantua, and Rimini.	Palazzo Rucellai, part of the church of the Annunciation, Florence; Church of St. Francis, Rimini; and St. Andrew, Mantua.	De re Ædificatoria.
Bramante bino.	1444	1514	Castel Durante, or Fermignano.	Rome.	Cloister of Convent della Pace, Cancellaria, Palazzo Giraud, part of the Vatican, commencement of St. Peter's, and the oratory of the cloister of San Pietro Montorio, Rome.	
Micheli.	1484		Verona.	Verona.	Palazzi Pompeii, Berilacqua, Canossa, Verona; and Palazzo Grimani, Venice.	
Michael Angelo, Buonarotti.	1474	1563	Florence.	Rome	St. Peter's Cathedral, finished the Farnese palace, Rome; and portions of Church of San Lorenzo, Florence.	
Sansorino.	1479	1578	Florence.	Venice.	Libreria Vecchia, Palazzi Cornaro and Delfino, La Zecca, the Public Library, and the Church of San Francesco della Vigna, Venice.	
Serlio.	1475	1552	Bologna.	Vicenza and Fontainebleau.	Theatre, Vicenza; Palace Fontainebleau.	Opere di Architettura.
Vignola	1507	1573	Vignola, Modena.	Bologna, Assisi, Perugia, Rome, &c.	Palazzo Isolani, near Bologna; Church at Massano; the Madonna degli Angeli, Assisi; St. Francesco, Perugia; Villa Giulia, Church of St. Andrea, Rome; Palace at Caprarola.	Treatise on the Five Orders.
Palladio.	1519	1580	Vicenza.	Vicenza, Venice.	Palazzi della Ragione, Tiene, Valmarana, Chieracati, Porti, Barberino, and Villa Capra, and Teatro Olimpico, Vicenza; Churches of St. Giorgio Maggiore, and Il Redentore, Venice.	
Scamozzi.	1552	1616	Vicenza.		Finished Public Library, Venice; and the Teatro Olimpico, Vicenza; Cathedral of Salzburg, the Churches of St. Nicholo di Tolentino, and SS. Simone e Giuda, and the Procuratie Nuove, Venice; Palazzi Roberto Strozzi, Florence; and Pretorio and Trissino, Vicenza.	Treatise on Perspective. Architettura Universale.
Borromini.	1599	1667	Como.	Rome.	Churches of La Sapienza, St. Agnes, and the College di Propaganda, Oratory Chiega Nuova, and the Doria Palace, Rome.	
Bernini.	1598	1680	Naples.	Rome.	Palace Barberini, Façade of the College di Propaganda, Colonnade in front of St. Peter's, and Colonnade joining the Vatican, the Church of St. Andrea à Monte Cavallo, the Palace Bracciano, &c.	

Italian architecture is usually divided into three kinds, which, with a very decided similarity in general treatment, have peculiarities sufficient to distinguish them from each other. The three classes are named after the cities in which they each prevailed, not that any one of the styles were in use at any place to the exclusion of the others, but that each style was predominant in its own locality. The cities are those of Florence, Rome, and Venice, and the classes are styled after their names—Florentine, Roman, and Venetian.

The architecture of Florence, and more especially of its palaces, is very peculiar; strong, massive, severe, and from these very qualities, grand; but at the same time gloomy and heavy, presenting the appearance of fortresses rather than the residences of merchants. Nor was this appearance a false or deceitful one, for the strength of these mansions was required for purposes of defence. The rival parties of the Guelphs and Ghibellines, and, at a later period, of the Neri and Bianchi, were the cause of ceaseless civil discord, and their quarrels kept the city in a state of continual commotion, from an early period of its history, to the time of the Medicis. It was this state of circumstances which originated the peculiar appearance of the buildings to be found in this city. Large blocks of stone were readily procurable from the quarries of Tuscany; and solidity and strength were, to some extent, demanded in residences which were not unfrequently required to answer the purpose of a stronghold. Florentine buildings excel in dignity and grandeur those of Rome and Venice, but fall far short of them in lightness and elegance; they are inferior in the refinement of detail, but surpass all others in bold and imposing masses.

Although the revival of the classic orders first took place at Florence, in the cathedral of the above city, yet the previous style, or rather many of its details, lingered there for a considerable time, and even as late as the middle of the fifteenth century, as is evident in many of the windows, some of which have the intrados of their archivolts semicircular, while the extrados is carried up in a pointed arch; others again are composed of two lights with semicircular heads, both enclosed within a larger semicircular arch, and the lights divided by a central column. The apertures on the ground floor are usually square and unimportant, and the naked of the wall of this and the other stories most frequently rusticated, a mode of decoration very much in vogue. The façades are usually continued in an unbroken line, and there is little diversity in plan. A bold cornice runs round the summit of the edifice, which is proportioned to the entire building, although smaller cornices frequently intervene between every two stories. A very important distinction between this and the other two classes of Italian architecture, is evidenced in the absence of columns from the external façades.

The court in the interior presents often a very different aspect from that of the exterior; indeed, the external distribution scarcely ever indicates that of the interior, which generally consists of a colonnaded or arcaded quadrangle.

"The buildings of Florence," says a French author, "appear to be not the work of ordinary men; we enter them with respect, expecting to find them inhabited by beings of a nature superior to ours. Whether the eye is arrested by monuments of the age of Cosmo de Medici, or of the times which preceded or followed it, all in this imposing city carries the imprint of grandeur and majesty. Frequent revolutions obliged the chief parties to consider their personal safety along with the magnificence of their dwellings. Externally, they are examples of the skilful union of grace with simplicity and massiveness, internally models of exquisite taste. After Rome, Florence is the most interesting city to every artist."

Brunelleschi may be said to have been the founder of this style, and he was succeeded by Alberti, Raffaelle, Sanzio, Ammanati, and others; the style dating from A. D. 1400 to 1600. Some of the finest examples are the cathedral, the palaces Strozzi, Pitti, Medici, Riccardi, Vecchio, Podesta, and the churches of SS. Michele, Maddelina, Pancrazio, Lorenzo, and Spirito.

Descriptions of a few of the above edifices may not be out of place.

The Cathedral of S. Maria del Fiore, or the Duomo, as it is termed, was the first building in which the Italian features were introduced; several of the peculiarities of the old style still remaining, so as to give to the edifice a kind of transition-character between the Gothic and Italian, of which it is a mixture. The edifice was commenced, A. D. 1298, by Arnolfo, and not entirely completed by Brunelleschi, who constructed the dome. The plan is that of a Latin cross, the length measuring 520 feet, and the width across the transept 313 feet. The nave is divided into three aisles by arcades resting on piers, decorated with Corinthian pilasters, the height of the central avenue being 153 feet, and that of the aisles, properly so termed, 96½ feet. The space at the intersection of the arms of the cross is octagonal, being 140 feet in width, and the terminations of the choir and transepts are semi-octagonal, covered with semi-cupolas. Above the top of these cupolas, at the intersection of the nave and transepts, rises an octagonal drum, with a circular window on each side, and terminated at the top by a horizontal cornice from which springs the octagonal dome. Above this again is a lantern, on which rests an octangular pyramid, surmounted by a ball and cross. The drum rests on four massive piers, its height is 43 feet, and the thickness of its wall 16 feet. The dome is double, consisting of two shells one within the other, with an interval of 5 feet between; the thickness of the lower shell being 4 feet 3 inches at the lower extremity, and 1.0 foot at the vertex; and of the inner one, 5 feet 6 inches at bottom, and 2 feet 1 inch at vertex. The span of the dome is 140 feet, the radius of internal curvature, 120 feet; height from drum to lantern, 116 feet; from ground to cupola, 280 feet; height of lantern, 45 feet; diameter, 24 feet.

The arcade in the nave consists of pointed arches, each segment being described with a radius equal to two-thirds of the span. From the top of the piers, or rather of the pilasters which adorn them, rises a second order, to support the ribs of a pointed vault. The aisle-windows are of two lights, divided by a central column, and having trefoil heads to each light, both of which are included under a larger pointed arch; on the exterior they are crowned by a rectilinear pediment, with a pinnacle at either end. The upper windows are circular. The external wall is almost entirely encased in coloured marbles, and is ornamented with pilasters, which at the eastern extremity are connected by semicircular arches.

Attached to the cathedral is a separate campanile, erected by Giotto and Taddeo Gaddi, A.D., 1334, which consists of five stories, ornamented on the exterior with pilasters, like the cathedral. The three lowermost stories have narrow rectangular windows, the fourth two tiers of pointed windows, of two lights each, divided by a twisted pillar, and having trefoil heads, and the uppermost one wide pointed window of three lights. At the summit is a gallery supported on brackets.

The Pitti palace was designed and partially erected by Brunelleschi, at the close of the fourteenth century. The main body or central portion of the building, is in plan a parallelogram, with a wing projecting at right angles at each extremity; behind the centre is a small cortile. In elevation, the edifice consists of three stories of equal height, each story being somewhat less in frontage than the one below it, so as to give to the whole the appearance of a pyramid, which appearance would have been increased, had the original design been carried out, in which a fourth story was contemplated. Each of the stories is of rustic masonry, and crowned by a cornice supporting a gallery with balustrade in front. The windows are placed one above another, and number alike, except in the lower story, where there is only one window under each alternate one above. They are semicircular-headed apertures, and have the voussoirs grooved at the joints. The elevations of the cortile consist of three orders, one to each story; the lowermost of which is Tuscan, with shafts fluted horizontally. The second order is Ionic, with square blocks ranged at intervals up the shaft, and between the columns are semicircular-headed recesses, containing windows, which have architraves and pilasters on the jambs, and are crowned by pediments; underneath each window is a projecting table, supported by two corbels placed under the architrave. The uppermost order is Corinthian, also with square blocks on the shafts, and between the columns are recesses with horizontal lintels, formed by voussoirs; within which again is another semicircular-headed recess, and windows crowned by a curvilinear pediment.

The Palazzo Strozzi is of rusticated masonry throughout the entire façade, in horizontal and vertical channels. The building consists of three stories; in the centre of the lowest is a doorway, with semicircular head flanked on each side by three windows having square heads. The windows in the upper story consist of two lights separated by a column, and having half-columns in the jambs. Both the lights have semicircular heads, and are included under a common semicircular arch, the spandrils of which are filled up with pateræ. Each story is separated from the adjoining one by a frieze of dentils, the entire building being crowned with a plain frieze and boldly projecting cornice, in which both dentils and modilions are employed.

The Richardi palace consists of three stories, as does the Strozzi palace, which it resembles also in many other features. The lowest story, however, is somewhat peculiar, being formed of uncoursed masonry, with some blocks projecting forward beyond the others; as in the previous example, the doorway is semicircular in the head. The second story is rusticated, and contains seventeen windows in close proximity to each other; they are of two lights, with a column in the centre, and have semicircular heads, which enclose the heads of the two lights, also semicircular. Above these windows is a large surface of naked wall, above which is a dentil band, separating this story from that above. The third story is of plain ashlar, and contains windows the same in number and description as those of the second story; the whole is crowned by a bold cornice.

The church of San Lorenzo, by Brunelleschi, is in plan a Latin cross, the length of which is considerable when compared with the width; the height of the building follows the same proportions. The body of the church is divided into a central nave with two aisles, by means of an arcade; the arches of which rest upon Corinthian columns, carrying isolated entablatures, from which the arches spring. At the intersection of the nave and transept, the building is covered by a spherical dome, which stops short ere it meets at the summit, the void so formed being covered by a hemisphere of smaller diameter; this answers to the lantern more usually applied in such positions.

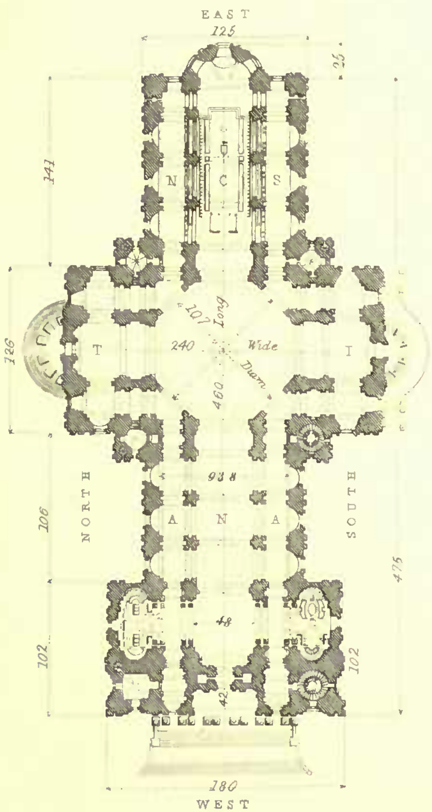
"The church of Santo Spirito is a beautiful example by Brunelleschi. All the fronts are complete except the principal one, and it is certainly the finest of Brunelleschi's designs; though subsequent to the architect's death, as the works were then unfinished, they were carried on with some departure from the original design. These alterations, though not affecting the general conception, have justly excited the anger of Vasari against those who fancy themselves better qualified than artists. Oh that Vasari were alive now! The plan is a Latin cross, with aisles carried round the transepts of the choir. The intersection is surmounted by a dome ornamented with leaf-work, and rising from a low tholobate, pierced with circular openings. The clere-story and aisles have circular-headed windows. The wall being of great thickness, there is sufficient space for large niches, which occupy each intercolumn, and the wall of the lower clere-story, or that to the aisle is above the inside to the lower wall, and has circular windows similar to those of the tholobate. Thus there were three distinct levels of roof besides the dome. The interior has Corinthian columns, each supporting an entablature, from which spring semicircular arches. At the extremities of the choir and transepts there are four windows, instead of an odd number. The high altar beneath the dome is surmounted by a magnificent canopy. There is an internal dome with a lantern beneath those of the exterior. It is panelled, and perforated by the windows of the tholobate. In this church we remark the most perfect harmony of lines. Character is given to the building by the constant use of circular forms, whilst too great sameness is prevented by the occasional use of horizontals. The sacristy attached to this church, and the second cloister, are both fine works."

The edifices of Rome are of a very different character to those of Florence; they have lost the massive appearance of the latter, and assumed an air of lightness and elegance. This style forms the connecting link between the Florentine and the Venetian; for while, on the one hand, it is much less heavy and severe than the former, it is not so gay and lightsome as the latter. Columns are of frequent introduction in the façades, in which, also, the entrance becomes an important feature. The interior courts are mostly surrounded by arcades, and from them a grand staircase of imposing dimensions leads to the principal apartments. The churches consist of nave and aisles, separated by arcades, the latter being flanked by chapels. The transepts are not extended far beyond the nave, and the intersection is covered mostly by a dome. Apsides are common. The façades are generally of an inferior description, often plain; and when decorated, it is without taste; they are often only masks, having no relation to the internal distribution of the edifice. Bramante was the founder of this style; and the principal examples are St. Peter's cathedral and the Farnese palace, which we proceed to describe. Of the former, which is a subject of general interest, we shall take this opportunity of giving a full description.

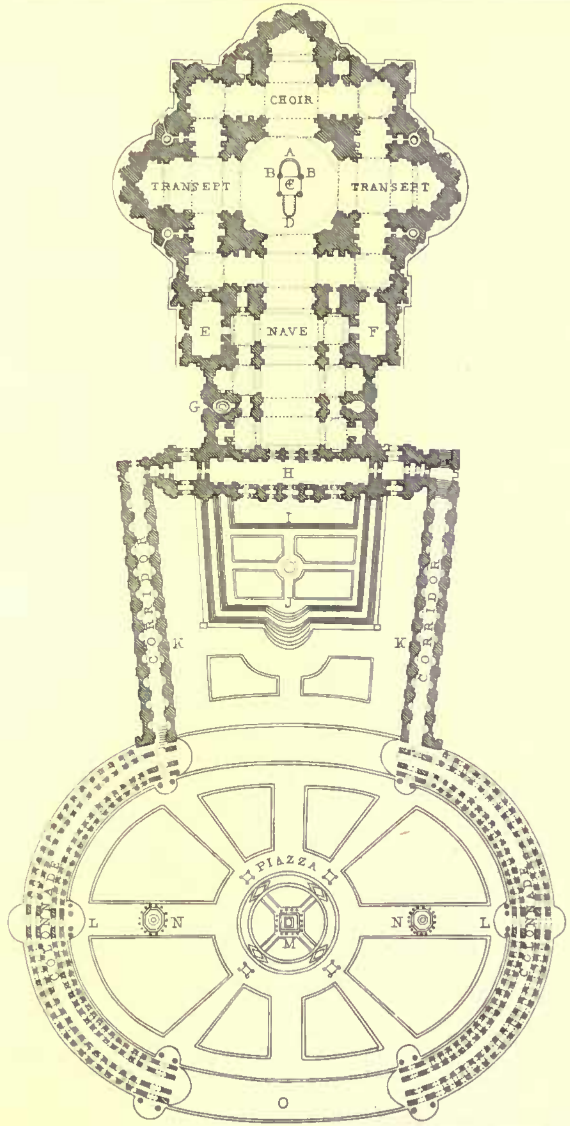
The plan of St. Peter's is that of a Latin cross, with a narthex, or porch, at the west end, extending in width beyond the general line of the building. Internally, the breadth of the church is divided into three portions, central nave and aisles on either side, by means of an arcade, supported on massive piers, four of which, at the angles formed by the intersection of the nave and transept, are more massive than the rest, and serve to support the central dome. There are four arches on each side of the nave, and one in the choir, all springing from piers which are ornamented with pilasters. A chapel is formed at the extremity of each aisle, where they meet the transept, which is rectangular in plan, projecting beyond the general line of building on the exterior, and covered with a spheroidal dome. At the western extremity of the nave is a porch, as above noticed, extending in frontage from north to south beyond the main line of the building, and projecting from the extremity of the nave as much as 50 feet; this porch is separated from the nave by a wall containing five doorways, to agree with the number of doors in the outer wall of the porch itself, which forms the grand façade and entrance. The elevation of this façade is adorned with half-columns and pilasters, ten in number; leaving nine intercolumnar spaces in the whole façade; the columns are surmounted by an entablature, the height to the top of which is 125 feet, and the four central columns are included under a pediment rising above the entablature, which in consequence is broken above these columns as it is also above every column beyond the pediment. This order contains two stories in height, the lower one being occupied by the entrances, and the upper by windows. In the central compartment of the lower story is the principal doorway, with horizontal head, and in the nearest compartments on either side a smaller doorway with semicircular head, on either side of which again is one more similar to the first. In each of the extreme intercolumns which project beyond the main building is a magnificent doorway with semicircular head, and similar ones on the two other sides of each of those projections which are not contiguous to the church. In the upper story of each of the intercolumns is a window, with a segmental or triangular pediment, the two forms alternating with each other. Above the entablature is another story or attic, and above this again a balustrade.

From the four great piers at the intersection of the nave and transept, spring four large semicircular arches which support a drum or cylindrical wall 70 feet high, and perforated at intervals by windows. The windows are rectangular, surmounted alternately by triangular and segmental pedi-

GENERAL PLAN OF ST. PAULS IN LONDON AND ST. PETERS AT ROME.



GENERAL PLAN OF ST. PAULS.



GENERAL PLAN OF ST. PETERS.

R. Brown Archt.

R. Thew sc.

ments; and between every two are a pair of coupled Corinthian columns, supporting an entablature projecting over each column. Above the entablature the wall rises 20 feet, and upon the top of this, springs the magnificent dome: it is a double dome consisting of an external and internal shell at a short distance from each other, the extreme diameter of the outer one measuring 189 feet, and that of the other on the inside, 138 feet. Both domes are of the spheroidal shape, but the inner is flatter than the outer one, the height of the former being 77 feet, while that of the latter is 100 feet; they are connected together by sixteen vertical ribs of masonry. Above the cupola is a lantern 40 feet in height, and above that a small spire supporting a ball and cross. There are three tiers of windows in the dome.

From the front of the church, and commencing at the extremities of the porch, project two corridors, one on each side, in such a manner as to approach nearer and nearer to each other as they recede from the façade of the building, and enclosing a space of ground or area in the form of a trapezoid, the length of which from east to west measures 400 feet. From the western extremity of each of these corridors, is carried a semicircular colonnade, which is surmounted by an entablature and balustrade, crowned at regular intervals by statues. The area thus enclosed is 650 feet long from north to south, and 500 feet from east to west; in its centre is a large Egyptian obelisk of black marble, and on each side of it a large fountain. The trapezoidal area contains the steps to the cathedral.

The original design for this cathedral was furnished by Bramante, but was altered by almost every architect employed upon the building, so that he cannot lay claim to the design of it as executed. Bramante commenced the erection, but did not proceed far with the work, the body of the church being erected by Peruzzi and San Gallo; the dome by Michael Angelo and Fontana; the nave and west façade by Carlo Maderno; and the colonnades by Bernini. The plan was originally designed as a Latin cross, which was changed into a Greek cross by Michael Angelo, and again into the Latin form by Carlo Maderno.

The following dimensions of the cathedral and its several parts may be found useful, especially in the comparison of this and our cathedral of St. Paul, the dimensions of which are given in a parallel column.

The Plan.—Length and Breadth.

	St. Peter's. Ft.	St. Paul's. Ft.
The whole length of the church and porch	729	500
The breadth within the doors of the porticos	510	250
The breadth of the front with the turrets	364	180
The breadth of the front without the turrets	318	110
The breadth of the church and three divisions of the nave	255	130
The breadth of the church and widest chapels	364	180
The length of the porch within	218	50
The breadth of the porch within	40	20
The length of the plateau at the upper steps	291	100
The breadth of the nave at the door	67	40
The breadth of the nave at the third pillar and tribune	73	40
The breadth of the side aisles	29	17
The distance between the pillars of the nave	44	25
The breadth of the same double pillars at St. Peter's	29	—
The breadth of the same single pillars at St. Paul's	—	10
The two right sides of the great pilasters of the cupola	65.7½	25.35
The distance between the same pilasters	72	40
The outward diameter of the cupola	189	145
The inward diameter of the same	138	100
The breadth of the square by the cupola	43	—
The length to the same	328	—
From the door within to the cupola	313	190
From the cupola to the end of the tribune	167	170
The breadth of each of the turrets	77	35
The outward diameter of the lantern	36	18
The whole space upon which one pillar stands	5,906	875
The whole space upon which all the pillars stand	23,625	7000

The Height.

	St. Peter's. Ft.	St. Paul's. Ft.
From the ground without to the top of the cross	437½	370
The turrets as they were at St. Peter's and are at St. Paul's	289½	222
To the top of the highest statues on the front	175	135
The first pillars of the Corinthian order	74	33
The breadth of the same	9	4
Their bases and pedestals	19	13
Their capitals	10	5
The architrave, frieze, and cornice	19	10
The Composite pillars at St. Paul's, and Tuscan at St. Peter's	25½	25
The ornaments of the same pillars above and below	14½	16
The triangle of the mezzo relievo with its cornice	22½	18
Wide	92	74
The bases of the cupola to the pedestals of the pillars	36½	38
The pillars of the cupola	32	28
Their bases and their pedestals	4	5
Their capitals, architrave, frieze, and cornice	12	12
From the cornice to the outward slope of the cupola	25½	40
The lantern from the cupola to the ball	63	50
The ball, in diameter	9	6
The cross, with its ornaments below	14	6
The statues upon the front, with their pedestals	25½	15
The outward slope of the cupola	89	50
Cupola and lantern, from the cornice of the front to the top of the cross	280	240
The height of the niches in front	20	14
Wide	9	5
The first windows in front	20	13
Wide	10	7

Mr. Gwilt has prepared a table of areas of the two edifices, as also of that of the Duomo, Florence; and as this table contains likewise the area occupied by piers and other means of support, it will give an idea of the comparative merits of the buildings as regards construction, and when taken in connection with the comparative sectional areas, will give a just ratio between the size or capacity of the building, and the quantity of material employed in its construction.

	St. Peter's.	St. Paul's.	St. Mary, Florence.
	Ft.	Ft.	Ft.
Area on plan	227,069	84,025	84,802
Do. of points of support	59,308	14,311	17,030
Ratio of areas . . .	1.026t	1:0170	1:0201
Sectional area at transepts	8,325:10000	6,865:10000	8,855:10000

We shall have to speak more particularly about St. Paul's presently, but must now return to examples to be found at Rome.

The great Farnese palace is probably one of the finest specimens of Italian palatial architecture in existence, and covers an area of 256 feet, by 185 feet, the height of the building measuring 177 feet. The material of the walls is brick, with the exception of the dressings, which are of Travertine stone. The edifice is three stories in height, each of which contains a range of thirteen windows, with the exception of the first, where the place of one is occupied by a doorway; those on the first story are of a rectangular form, with architrave, and horizontal cornice, supported by ancones, or corbels on either side of the window. The doorway is semicircular-headed, with prominent voussoirs. The windows in the next story are of a more ornamental character, being still of the rectangular form, but having pediments alternately triangular and segmental; the jambs, also, are decorated with columns. In the uppermost story, the windows have semicircular heads, with columns and triangular pediments. The stories are separated by impost cornices, and the entire building crowned by a boldly projecting cornice. In the interior quadrangle, the building surrounds a court 88 feet square, and presents a very different appearance to the exterior, being divided vertically into arcades. The lower arcade is of the Doric order, and is supported on piers whose sides are adorned with Doric columns, and which sustains an entablature enriched with triglyphs, &c. The upper arcade is of the Ionic order.

The Palazzo Giraud at Rome is by Bramante, and consists of a range of building enclosing a quadrangle 89 feet square, the external measurements being 249 feet by 190 feet. The front elevation contains three stories, all of which are rusticated, the lowermost by both horizontal and vertical grooves, but the upper by horizontal grooves only. In the centre is a semicircular-headed door, with horizontal cornice, and on each side of it three square windows. In the second story, the piers between the windows are ornamented with coupled pilasters, similar to those of the Corinthian order, standing on high plinths, which again rest on a podium extending all along the building, but broken under the pilasters. The pilasters support a simple entablature, and between them are seven semicircular-headed windows, with horizontal cornices, the archivolts resting on pilasters, and the spandrels filed with sculpture. Above the piers of the second story, the third story have coupled Corinthian pilasters, arranged in a similar manner on plinths and podium. Between these are two tiers of windows, the lower having rectangular, and the upper semicircular heads. Above this order is the entablature proportioned to the building, the frieze of which is occupied by blocks to support the cornice. The roof has sloping sides, and is covered by hollow tiles.

In one of the shorter sides of the building is the vestibule, which is 47 feet long, by 34 feet wide, and is divided longitudinally into three portions by two rows of columns. This gives entrance to the principal court, which is surrounded by an arcade resting on piers, ornamented with half-columns, and roofed with a groined ceiling. Opposite the entrance is a passage, the sides of which are ornamented with pilasters and niches, and which leads to a smaller court in the rear.

The Venetian style is characterized by its pre-eminent lightness and elegance, and more especially by the frequent and almost universal employment of pilasters and arcades; it bears altogether a more lively and decorative character than either of the preceding. Another feature having a similar tendency is shown in the close proximity of the windows, and the large proportion of the elevation occupied by apertures. San Michaeli, or Sansovino, may be said to have been the founder of this school, and they were followed by Palladio, Scamozzi, &c. Good examples are, the library of St. Mark, Venice, the Pompeii palace, Verona, and the chapel of St. Bernardino.

The library of St. Mark, Venice, is by Sansovino, and consists of two stories, each composed of one order, the lower one Doric, and the upper Ionic. The lower story is raised three steps above the piazza, and consists of a portico of twenty-one arches, at the back of which is a range of similar arches used as shops, and opposite the central arch is a magnificent staircase leading to the library. The piers of this story are ornamented in front by pilasters of the Doric order extending to the top of the arches, and carrying a noble entablature enriched with triglyphs, and above them with a fine cornice, with dentil-band underneath. The archivolts rest on a moulded cap or impost, and have carved key-stones which finish under the entablature. Above this is an Ionic order carried upon pedestals, ranging with which, and underneath the windows, is a balustrade, flanked by other smaller pedestals, upon which stand small Ionic columns placed in the jambs to support the archivolt, the windows having semicircular heads. As below, the order extends to the top of the arches, which have ornamented key-stones, and rest on impost mouldings; the spandrels between the archivolt and the pilasters being filled up with sculpture. The entablature to this order is very lofty, and the frieze highly decorated with sculpture; the cornice is bold, and highly enriched, being supported by modillions, and having a dentil-band underneath. The cornice is crowned by a balustrade, on every alternate pier of which is placed a statue, and at the angles of the building a pyramidal acroteral ornament.

In the same piazza is the Procuratie Vecchie, also by Sansovino. This building consists of three stories, the lowermost of which has an arcade supported on piers, and the upper ones a similar arrangement on columns, the arches of these stories, however, being so much smaller than those below, as to be admitted in pairs above the single ones on the ground-floor. The stories are divided by plain podia, and the whole crowned by an entablature, with a frieze perforated at intervals with circular apertures.

The Pompeii palace, by Michaeli, consists of two stories, the lower one of which is rusticated throughout, the apertures, with door and window, having semicircular heads, without architrave or other decoration; the doorway is in the centre, having three windows on either side. Above each of the apertures is a balustrade, and above these are the upper windows, which are of similar shape, but the piers between them are decorated with single three-quarter columns of the Doric order, which support an unbroken entablature over the windows.

Amongst the buildings of this class, we have to notice those of an architect, whose works may be said to comprise a new style, and which, for this reason, have been designated the Palladian style. Many opinions have existed, and do still exist, respecting the merit of Palladio's works, and the

school which they gave rise to, some writers extolling them above all others of the Italian style, and others decrying them with equal zeal; for ourselves, we must confess that we are no great admirers of his school.

In Palladio's designs, the ground stories are generally composed of arcades of not very ornamental design, serving as basements to the principal stories above, which are decorated with an engaged order, and most frequently with a pediment in the centre of the building above the cornice, though sometimes, when a pediment is introduced, the cornice is discontinued beneath it. His buildings frequently have vestibules consisting of three arches or rectangular openings in front. The arches of his arcades are usually of the semicircular form, but sometimes the space between the piers is subdivided into three portions by two lesser piers, the central compartment only being arched over. This form is sometimes carried out in his windows, which, however, are usually rectangular; sometimes also a semicircular shape is adopted, divided into three parts by vertical mullions.

In his churches he follows the Basilican form faced with a portico consisting of an order with entablature reaching to the height of the building, and covered by a pediment rising with the nave-roof, those of the aisles having each a kind of half-pediment to agree with the slope; so that the central pediment has the appearance of having been placed in the centre of another so as to divide it equally into two parts. Amongst Palladio's other works, those of the church of the Redeemer, and the Olympic Theatre at Vicenza, stand conspicuous.

The form of this latter building is semi-elliptical, round which the seats are extended in front of the proscenium. The entire width of the building is 109 feet, that of the proscenium 80 feet, and its depth 21½ feet. The front of the scena is composed of two tiers of Corinthian columns on pedestals, the lower tier of which is detached with pilasters behind, and the latter are half-columns attached to the walls. Between the columns stand niches with rectangular and circular pediments resting on fluted Corinthian pilasters, and above the upper tier is an attic broken by piers, the spaces between which are filled with sculpture. Three doors in the scena give admission to five passages, the sides of which are adorned with representations in relief on wood of a variety of buildings seen in perspective. The upper tier of seats is surrounded by a row of Corinthian columns, supporting an entablature, and this again surmounted by a balustrade with statues.

The church of the Redeemer at Venice was built by this architect. The form would be that of a Latin cross, were it not that the nave is flanked on either side by three chapels open to the body of the church, ranging the entire length of the nave, and receding from it to the same depth as the transepts. The division between them and the nave is effected by an arcade of semicircular arches springing from entablatures over Corinthian pilasters, which flank the piers of the nave. These piers are faced towards the nave by half-columns coupled, and extending to such a height as to carry an entablature over the arcade; above which on each side is a clere-story pierced with three semicircular windows, divided into three by vertical mullions. The choir is surrounded by isolated columns, and its extremity, as also those of the transept, is apsidal. At the intersection a cylindrical drum is supported on four large arches, and is surmounted by a cupola or dome.

The church is considerably elevated above the ground, and is approached on the exterior by a flight of steps extending the breadth of the nave, and fronting the portico, which consists of two three-quarter columns and two pilasters, covered by a pediment. On each side of this, a wing projects in the line of façade, adorned with Corinthian pilasters of less height than those of the portico, and continued round the sides of the building. The door under the portico is semicircular-headed, ornamented with half-columns, entablature, and pediment. The roofs of the aisles lean to, and in the façade present the appearance of a second pediment broken in the middle for the insertion of the portico.

After the death of Palladio, Italian architecture began to decline, under the auspices of Borromini. This architect introduced many innovations, and in his desire to produce novelties, had little care for elegance or simplicity; striving to surpass his rivals and predecessors in variety and originality, he laid aside all the common rules and restrictions, and gave form and substance to all the extravagant vagaries of his imagination. In his designs, straight lines are the exception, curvature and irregularity their ruling features. Curves, both convex and concave, appear in plan and elevation, wherever it was possible to introduce them, and that without any regard to construction; his designs are the result of an inventive and pregnant, but also a reckless and uncultivated, fancy.

The church della Sapienza, by this architect, is of a polygonal plan, of which the sides are alternately concave and convex; the exterior of the cupola, which is surrounded above by a balustrade, is of a similar plan, the convex parts being formed into steps, interrupted by buttresses. But the lantern is still more whimsical, having its vase in a zig-zag form, on which is erected a spiral staircase, sustaining a crown of metal, with a ball and cross at the top. His most extraordinary work is the church of San Carlino alle Quatro Fontaine, which abounds in his eccentricities, as does also the oratory of the Fathers della Chiesa Nuova. Here we have disorderly mixtures of all kinds of lines, straight and circular, convex, concave, and twisted; undulating coronæ which retain the rain, delicate mouldings under great weights, and strong supports without anything to sustain; breaks only in the architrave of the entablature; prominences, contortions, and every kind of absurdity. Of all his buildings, the church of St. Agnes in the Piazza Navona, is most free from his usual abuses; the façade of this, however, is in plan a curve of contrary flexure.

Bernini's buildings, though not of so bizarre a character as Borromini's, are not equal to those of his predecessors; his principal works are the colonnade in front of St. Peter's, the principal façade and staircase of the palace Berberini, the Curia Innocenziana, and some few others. Of the first of these works, a description has already been given, we pass on therefore to the second.

The palace Berberini consists of a central portion and two wings, which project at right angles to the front. In the lowest story of the central compartments, are two parallel rows of arches resting on piers, forming a vestibule, which has a groined roof. The building consists of three stories, the lower one being ornamented with a Doric order, and the upper with Corinthian columns, between which are semicircular arches springing from imposts. Each of the wings has three tiers of rectangular windows placed in recesses, which are formed by narrow projections of the wall after the manner of pilasters. Attached to this building is a Belvedere turret, with windows in each side, and having pilasters on the exterior.

The best period of Italian architecture was now over, and there are scarcely any buildings erected after this time which require comment; we shall therefore pass on to a consideration of this style as practised in England.

During the time of Palladio, Italian architecture began to be copied successfully in various parts of the Continent; and Palladio's method had become very generally popular. A mixture of Italian and Gothic architecture had been in vogue since the time of Elizabeth, after whose name the style procured the title of Elizabethan; the pure Italian, however, did not make its appearance here till the reign of James I., and Inigo Jones was the first architect to introduce it. In the early part of his practice, this architect had followed the mixed style, but on his return from a journey to Italy, he brought back with him the manner of the Palladian school, in which his principal works were, the portico of Old St. Paul's, Whitehall Palace, York-stairs, and the church of St. Paul, Covent Garden.

The first building of unmixed Italian architecture erected in England, was that of Whitehall, by Inigo Jones. This edifice was commenced during the reign of James I., A.D. 1619, but was never completed according to the original design, which contemplated the erection of an immense range of building containing seven courts, extending in one direction from the park to the river, the façade towards which would have measured 720 feet, and that towards Charing Cross, no less than 1152 feet. Only a small portion of this magnificent design was carried into execution, and this was the banqueting hall, which was completed in two years. This portion is 115 feet in length, and from its appearance we may form some idea of what the entire building would have been. The hall consists of three stories, of which the lower one is a plain rusticated basement, with simple rectangular apertures, without architrave or other decoration; the upper ones consisting of two complete orders, the lower of which is Ionic, and the upper Corinthian. Each story contains seven windows, with a column or pilaster between every two, and coupled pilasters at the angles of the building, thus making up ten columns in each story. The windows are all rectangular, and surrounded with architraves, above which are cornices supported on ancones; the lower tier, however, differs from the upper in having pediments above the cornice alternately triangular and segmental; this tier is also furnished with a balustrade which is wanting in the upper story. Both orders are surmounted by a complete entablature, which is broken over each column; the walls throughout are rusticated, and the building finished at the summit by a balustrade.

Jones's next work was the new portico to the then St. Paul's, but of this of course no remains are left. St. Paul's, Covent Garden, was another work which exhibits a chaste example of the Tuscan order; it was partially destroyed by fire in 1795, but has been restored in its original character. A beautiful, though small example of Jones's taste is exhibited in York-stairs, leading down to the river from the west end of the Strand. It consists of three arches, of which the central one is the largest, and the spaces between them are decorated with four half columns, supporting an entablature which is broken over the capitals; this again is surmounted by a segmental pediment, the tympanum of which is somewhat decorated with sculpture. The Strand front differs from that towards the river, in substituting pilasters in the place of half columns.

The great fire of 1666 gave an opportunity to the newly adopted style of architecture, which in all probability it would not otherwise have obtained; nor was it a light advantage in its favour, that it secured the services of Sir Christopher Wren; who, however we may find fault with some of his works, was undoubtedly a man of unusual attainments in his profession, and of unwonted energy and perseverance. As a proof of this assertion, we need do no more than point to the multitude of buildings erected under his superintendence. Of his twenty-five London churches, his palaces, and other public and private buildings, we can here say but little; but will endeavour to give a full account of his chef-d'œuvre, the Cathedral of St. Paul, forasmuch as it furnishes us at once with a specimen of Wren's skill, and with our most magnificent example of Italian architecture, as applied to sacred purposes. We shall commence by giving a cursory glance at the history of the structures which anciently occupied the same site.

It has been thought that, during the residence of the Romans in Britain, a temple, dedicated to Diana, had occupied the situation on which the present edifice is erected; and this opinion is said to have been confirmed by the digging up, at different times, horns and skulls of animals supposed to have been sacrificed; but Sir Christopher Wren, who found no such indications in all his researches, in the extensive excavations which he made for the foundations, gives very little credit to the common tradition. However this may be, it appears that one of the earliest Christian churches in England was erected upon this site, about the year 610, by king Ethelbert, who had been converted to Christianity by St. Augustine.

Erkenwald, the fourth bishop of London, who died in 685, expended large sums upon this church; but whether for additions, or to complete Ethelbert's plan, is not ascertained. The church was accidentally consumed by fire in the year 961, but was rebuilt immediately. In 1087, it was again destroyed by a conflagration, which also laid waste the greater part of the metropolis. At this time Maurice, or Mauritius, bishop of London, conceived the vast design of erecting the magnificent edifice which preceded the present cathedral; but the undertaking was so extensive, that neither Maurice nor his successor, De Belmeis, lived to complete it. The succeeding bishops, Gilbertus Universalis, and Robertus de Sigillo, are not known to have done anything towards the finishing of the building, till the second De Belmeis, who, following his uncle's example, contributed largely towards the work. In 1135, the edifice was again exposed to the injuries of fire, which consumed all that was combustible. The enterprise of that age, however, was not to be repressed even by such repeated disasters; for, in 1221, the central tower was finished; and, in 1229, bishop Niger undertook to rebuild the choir in a new style of architecture, and enlarged dimensions: this was completed in 1240.

The cathedral was farther enlarged by the addition of the Lady Chapel, eastward of the choir: these new works, as they are called in the records of the church, were begun in 1256, and finished about 1312; in which year we find a contract for paving this additional building with marble, at fivepence per foot.

In 1315, a great part of the timber spire being decayed, it was rebuilt, and a new cross erected at the top. In the same year, an exact measurement of the building was taken, by which the length was found to be 690 feet, the breadth 130 feet; the height of the nave, from the floor to the top of the vaulting, 102 feet, and the height of the choir 88 feet. The altitude of the tower, from the level of the ground, was 260 feet, and of the spire 274 feet; and yet, according to Dugdale, who gives these dimensions, the total height did not exceed 520 feet; this difference may be accounted for, by supposing the height of the tower to have been taken to the top of the battlements, or pinnacles, and that of the spire, to have been reckoned from its base.

This lofty spire was fired by lightning in 1444; and in 1561 the steeple suffered by a similar catastrophe; but a subscription was set on foot by Queen Elizabeth, and the damages were repaired. In the reign of James I. the church had become very ruinous throughout, owing, perhaps, to some defect in the original construction; and though large sums of money were collected, and materials provided for the reparation, it remained in the same state till the preferment of the celebrated Laud to the see of London. This prelate exerted himself zealously and successfully in favour of the neglected building, and a general subscription, supported in a munificent manner by king Charles I. was soon collected. to the amount of £101,330 4s. 8d. Having thus provided the necessary means for an entire restoration of the church. Inigo Jones was appointed to superintend the undertaking. The repairs were begun in 1633, and. in the course of nine years, a magnificent portico was erected at the west end; the whole exterior of the body of the church was new cased with stone, the roof and leaden covering were completed, and the vaulting, which was much dilapidated, and stood in need of repair, was well centred, and supported with some hundreds of tall masts.

During the time of the commonwealth, the building became exceedingly ruinous, and great part of the church was converted into stables and barracks; the choir, however, was still used for public worship.

Under the reign of Charles II. the regular government of the church being re-established, the dean and chapter proceeded immediately to remove the encroachments, and to restore the stalls and other appendages of cathedral worship; but their revenues not affording the means for a general reparation, another subscription was opened, and the repairs were commenced in 1663. Sir John Denham, the surveyor-general, had the superintendence of the works.

Dr. Wren, afterwards Sir Christopher, (as appears from the *Parentalia*) was employed to make a survey of the building, the result of which is given in an elaborate report, contained in that work. In this paper, the architect, after remarking on the general bad construction of the body of the church, and recommending a new and massy casing of stone, pronounces a final condemnation upon the tower, which, together with adjacent parts, he represents as "such a heap of deformities, that no judicious architect would think it corrigible by any expense that could be laid out upon new dressing it; but that it would still remain unworthy of the work, infirm and tottering." He therefore proposed a bold alteration of the primitive form, by cutting off the inner corners of the cross to reduce the middle part to a spacious cupola, or hemispherical roof, and upon this cupola, for the outward ornament, a lantern with a spring top, to rise proportionally; but not to the unnecessary height of the former spire. This proposal does not appear to have been much approved of by his employers, and the public opinion was expressed strongly for retaining the tower in its ancient form. The great fire of London, in 1666, at length decided the question, and this unfortunate building again became a prey to the flames, which consumed the roof; and by precipitating the vaulting, weakened, cracked, and ruined the walls and piers in such a manner, that they were judged incapable of repair. Still some years of irresolution elapsed before it was finally determined to erect a new cathedral.

Such was the fate of this venerable edifice; and, like many other monuments, it might have passed into oblivion, had not the meritorious antiquary, Dugdale, with the assistance of Hollar, preserved, in his *History of St. Paul's*, some considerable memorials of its form and decorations.

The ancient cathedral of St. Paul's must always be regarded as one of the great works of the architecture of the middle ages: in magnitude of dimension it far surpassed every other religious edifice of this country; and it is represented by historians as equally pre-eminent in magnificence and splendour of ornament.

The general form of the plan was a simple cross. with a very long choir, and a transept rather short in proportion to the extreme length of the building. The body of the church was in the Norman style of architecture; huge clustered pillars on each side divided the nave from the aisles, and supported large semicircular arches: immediately above these extended an open gallery, with arcades of the same form and width as those below, but of a much shorter proportion. From this level a different style of building prevailed, for the windows above the gallery were pointed. The vaulting, which covered the nave, was also of the pointed form, of the simplest groined construction, with soffits and diagonal ribs only, similar to Salisbury cathedral and the transept of Westminster abbey. Slender circular shafts, placed against the centre of each pier, rose from the pavement without any interruption of mouldings, and received the springing of the arches: the transept was in the style of the nave. Hence, we may conjecture that the original work of Maurice and De Belmeis comprehended the body of the church as high as the gallery; the vaulting being, undoubtedly, part of these works, which, in the preceding historical sketch, are mentioned as completed in 1221; and it thus became one of the earliest examples of the use of pointed arches in this country.

Sir Christopher Wren was of opinion, that this Norman building had been erected upon the remaining foundations of the more ancient Saxon church, for these he found to be composed of Kentish rubble-stone, cemented with mortar of extreme hardness, and both much superior to the materials used in the superstructure.

At the intersection of the nave with the transept, four massy pillars supported the tower; and, from this part, a broad flight of steps led to the choir, which was enclosed by a magnificent screen, elaborately adorned with niches and statues. The choir, which was a grand specimen of the architecture of Henry VIII.'s time, was completely in the pointed style, with a vault of a more complicated structure than that of the nave, each severy being composed of five ribs. The Lady Chapel, at the end of the choir, was a continuation of the building in the same form and style, and terminated, at the eastern extremity, by a rose window of extraordinary size and magnificence. A spacious, lofty crypt, extending beneath the eastern part of the cathedral, was appropriated to religious rites, under the designation of the church of St. Faith, and the chapel of Jesus. Three ranges of massy piers, enveloped by slender cylindrical shafts, divided the area into four equal aisles, and supported a high-pitched vault of the simplest groined construction. The exterior of the building presented a curious medley of the styles of different ages. At the western front, Inigo Jones had erected a portico of the Corinthian order, thus displaying a signal example of that bigotry in taste, which, only admitting of one mode of beauty, is insensible to the superior claims of order and congruity. This portico was, however, singly considered, a grand and beautiful composition, and not inferior to anything of the kind produced in modern times. Fourteen columns, each rising to the lofty height of 46 feet, were so disposed, that eight, with two pilasters placed in front and three in each flank, formed a square peristyle, and supported an entablature and balustrade, crowned with statues of the kings, the predecessors of Charles I. who claimed the honour of this fabric. Had the whole front been accommodated to Roman architecture, it might have deserved praise as a detached composition; but, though cased with rustic work, and decorated with regular cornices, the pediment retained the original Gothic character in its equilateral proportions, and it was flanked by barbarous obelisks and ill-designed turrets. A representation of this curious elevation is given in the works of Inigo Jones, edited by Kent. The great restorer of Roman architecture in this country, was, doubtless, pleased with having an opportunity of triumphing over the Gothic style of building, in one of its strong holds; and it must be allowed, that he only followed the example of the architects of the middle ages themselves, who have generally shown as little moderation and respect for the works of their predecessors; since we everywhere find the styles of different eras engrafted upon each other, in the most crude and undisguised contrast.

It appears that the whole body of the church had been cased and reformed in the same manner, which had obliterated every detail of antiquity, leaving only the general forms and proportions. The buttresses were converted into regular piers, and a complete cornice crowned the whole. Some of the windows were without ornament, while others were decorated in a heavy Italian manner, with architrave dressings, brackets, and cherubic heads. The transepts presented fronts of the same incongruous style as the western elevation, and without any of its beauties. At the centre of the cross, the great tower rose aloft in pre-eminent grandeur: this was in the simple style of the early Pointed architecture. In each side three remarkably pointed windows, and the same number above, but of a shorter proportion, gave an original character to the tower, with an air of great lightness and beauty. This was the foundation of an immense spire, of which, however, there are no accurate representations; for though Dugdale gives a view of the church in its entire state, yet this could not have been taken by him from personal inspection, neither does he mention any authority; and we may observe, that the style of the spire there exhibited is evidently not authentic. At each angle enormous arched buttresses, the irregular additions of various repairs, had been erected to secure the declining tower. The rest of the building, eastward of the transept, remained in its original form, a fabric of pointed arches and flying buttresses. In the east front, the most remarkable object was the rose window, which constituted the principal ornament of the Lady Chapel.

Like other ancient religious edifices, this cathedral had numerous dependencies; some of which were, the chapter-house, an octagonal building, of a rich and elegant pointed style, and surrounded by a cloister, two stories in height, of great beauty; the *clocher*, or bell-tower, standing at the east end of the church-yard, a very ancient building, to which had been added, about the time of Henry III., a spire of timber and lead; it contained four large bells, which, with the spire and an image of St. Paul, having been staked at hazard by Henry VIII., were won and taken down by Sir Miles Partridge.

It being at length determined to erect a new cathedral, Sir Christopher Wren was nominated to the superintendence. To form a just estimate of the talents of the architect employed in conducting a work of such magnitude and national importance, it is necessary to consider those preliminary steps and contemporary opinions which must ever influence or control the proceedings of an architect. We shall, therefore, condense from his posthumous collection, the *Parentalia*, an account of the formation of the design of the present church.

Before the great tax upon sea-coal, which did not commence till May, 1670, it was expected that the expenses of the building would be defrayed by voluntary contributions alone, and therefore it seemed expedient to restrict the plans to an edifice of moderate bulk. Upon these considerations, the architect prepared a design and model of a structure, with a choir, vestibule, porticos, and a lofty dome. This was applauded by some persons as containing all that was necessary for the church of a metropolis, being of a beautiful figure, and capable of erection at an expense that might reasonably have been compassed; but being designed in the Roman style, it was not so well understood and relished by others, who thought it deviated too much from the old cathedral form; while some wished for more magnificence, and were unwilling that the principal church in London should be inferior to any similar structure on the continent. The architect, enlarging his ideas, endeavoured to gratify the connoisseurs and critics with a grand colossal design, after the best style of the Greek and Roman architecture. This being much admired by some persons of distinction, a highly-finished model in wood, with all its proper ornaments, was made, which was carefully preserved, and at length deposited in a room over the morning-prayer chapel of the present edifice. Sir Christopher always appeared to set a higher value on this design than on any other he had made; but the prevailing prejudices still interfered, and the architect finally turned his thoughts to what was called a cathedral-form, but so modified as to reconcile, as nearly as possible, the Gothic to the new mode of architecture. Thus the design of the present edifice was formed; and, being approved of by king Charles II., a warrant was issued under the privy seal for beginning the work, May 1, 1675. The first stone was laid on the 21st of June following; and the works were prosecuted with so much vigour, that, within ten years from the commencement, the walls of the choir and side aisles were finished, with the circular porticos at the north and south sides, and the great pillars of the dome, were conducted to the same height. Some difficulties now occurred in procuring funds for the prosecution of this great work, but, through the operation of the coal duties, they all vanished; and, in the year 1710, the last, or highest stone, at the top of the lantern, was laid by Mr. Christopher Wren, son of the architect. Thus, by a fortune unusual to edifices of such magnitude and labour, this church was completed in thirty-five years, under the direction of one architect; and, as it has been commonly remarked as a singular coincidence, by one master-mason, Mr. Strong; and under one bishop of London, Dr. Henry Compton.

On investigating the exterior of St. Paul's cathedral, we find the general form to be that of a Latin cross, with an additional arm, or transept, at the west end, to give length to the principal point, and a semicircular projection at the east end, for the altar; there are also at the north-east, south-east, north-west, and south-west angles of the cross, square projections, which, besides containing staircases and vestries, serve as immense buttresses to the dome. This is extremely different, both in proportion and general effect, to the plan of St. Peter's at Rome, where the cross-shape is scarcely marked externally. The first object of attention is the *western front*, which is distinguished by a portico of two orders, the Corinthian supporting the Composite of grand dimensions and rich arrangement. A noble flight of steps, of black marble, forms a basement to this portico, which is terminated at the summit by a pediment. On each side of the front is a steeple; one serving as a belfry, and the other as the clock-tower: singly considered, these may be said to want repose, but yet they are picturesque; and their springing forms not only harmonize with the cupola in the distant view, but also give effect and elevation to the western front, to which they particularly belong. Nor are they without parts of considerable beauty.

The entablature of the upper order is remarkable, from the consoles of the cornice occupying the whole of the frieze. In this, as in many other instances, we see Sir Christopher sacrificing a particular, to a general, effect; for this cornice, considered as the grand termination to the body of the building, required to be treated in a bold and striking style, rather than with that delicacy appropriate to the order. The idea of this may probably have been taken from the upper entablature of the Coliseum at Rome, where the same motives of general effect have prevailed.

The ornaments of the front are well executed; and though not remarkable for elegance, are placed with judicious frugality, so as to enrich without overloading or confusing the aspect. A very large composition in basso-relievo, representing the conversion of St. Paul, occupies the tympan of the pediment. This is said to be the best work of the artist, Francis Bird. At the apex of the pediment is placed a gigantic statue of the patron saint, while St. Peter, St. James, and the four Evangelists, occupy situations at his right and left hand.

The rest of the building is a vast fabric of a wall decorated with coupled pilasters, arranged at regular distances; the intervals below being occupied with large windows, serving to light the side aisles, and those above with niches; in the pedestals of which are singularly inserted windows, belonging to galleries and rooms over the side aisles.

In the whole surface of the walling, the joints of the stones are marked by horizontal and perpendicular channels; a simple decoration, which, while it gives a vigorous expression of strength and stability, has the advantage of defining and rendering conspicuous the pilasters and entablatures.

The entrance doors of the transepts are adorned by semicircular porticos; objects equally beautiful, whether considered separately or in connection with the total mass of the building, which they adorn and diversify, by the contrast of curves and straight lines, and of insulated columns, with engaged pilasters.

At the centre, formed by the crossing of the nave and transept, rises an ample cupola, which is the most magnificent feature of the building. The basement of this part of the fabric is an octagonal wall, pierced through each side by an arcade; the two, which are in the direction of the nave, are open to the top, as are also the two in the direction of the transept: the other four have an intermediate arch, which supports the continuation of the dado or panelling above the entablature. The spandrels of the arches are spherical, and form a complete circle at the level of the summit of the arches. Upon the archivolt of the arches is placed a corbelled cornice of considerable projection, the upper side forming the floor of the whispering-gallery; from the floor of the whispering-gallery rises a cylindrical wall, called by the French, *tour du dome*, for which we have no technical expression. This is surrounded by a Corinthian peristyle, so placed as to conceal the projecting buttresses of the cupola; and thus, by a happy combination of profound skill and exquisite taste, a construction adapted to oppose, with insuperable solidity, the enormous pressure of the dome, the cone, and the lantern, is converted into a decoration of the most grand and beautiful character. The idea of this arrangement was, doubtless, taken from the interior of the Pantheon at Rome, to which it bears a striking resemblance.

On the exterior side of the building, the general disposition is divided into eight parts by piers, containing staircases, with two columns attached to the angles of each. The spaces between the piers form eight recesses, having in each two columns, which, at a distance, to a hasty observer, appear to be insulated; but they are in fact joined to the dome-tower, by walls, serving as counterforts. All these buttresses are, however, pierced with arcades, so as to leave a free communication round this part of the cupola. The columns being of a large proportion, and placed at regular intervals, are crowned with a complete entablature, which, continuing without a single break, forms an entire circle, and thus connects all the parts into one grand and harmonious whole. Above the colonnade, but not resting upon it, rises an attic story, with pilasters and windows, from which springs the exterior dome, of a bold contour, well adapted to the rising form of the lofty and elegant lantern by which it is crowned. It has been said, with some justice, that the columns of the cupola are too high in proportion to the body of the building, as they are indeed little less than those of the lower order, but higher than the columns of the upper order. This incongruity would not have existed, had circumstances allowed the architect to construct the main edifice of a single order. extending the whole height of the building; but being baffled in this his original intention, it would have been too great a sacrifice to relinquish the peristyle, the noblest feature of the building, or to materially diminish the cupola.

Comparing the cupolas of St. Peter's and St. Paul's, we shall find that, though the latter has, in a great degree. been the model of the former. there is a material difference in the decorative part, though the general idea of the construction is the same. In St. Peter's the buttresses of the dome-tower, though decorated each with two engaged columns and pilasters projecting from the cylindric wall. destroy the continuity, and render the effect disagreeable. The dome is likewise pierced with three ranges of little dormer-windows, which are suffered to spot and break the surface for the paltry consideration of lighting the interior staircases. The idea, originated in St. Paul's, has been prosecuted in the church of St. Geneviève at Paris, where the appearance of a peripteral temple is completely obtained, as the columns surrounding the tambour are all insulated; but, it is to be lamented, that the dome itself should be so deficient in grandeur of dimensions, and grace of proportions, as to destroy the effect of this beautiful decoration.

Beginning the examination of the interior of St. Paul's at the west end, we find the body of the building, as to the general form, entirely upon the plan of the ancient cathedrals; an edifice of three aisles, divided by piers and arches, and covered with vaulting.

Sir Christopher Wren has not only adopted the form of building practised by the architects of the middle ages, but he has imitated their mode of construction; for the lofty vault of the middle aisle is supported by flying buttresses concealed by an enormous screen wall. The architectural detail is in the Roman style, simple and regular.

"The Romans," says Sir Christopher, "though they sometimes used a hemisphere, as in the exhedræ of the baths, of the tribunes, of the temples, and basilicæ, yet, generally, they used a *plain cylindrical vaulting* where the walls were parallel, or cross-vaulting where the two cylinders intersected in diagonals, as in the Temple of Peace, and in all the theatres, in the passages under the steps. The moderns, whose arches are not circular, use commonly another sort, where the spandrels, resting upon the pillars, spring every way round as their arch rises in sections of circles, parallel to the horizon; that is, in four quadrants described from the angles of a square, and terminated by its sides; and, at the summit, these quadrants come in contact in the middle of the sides, the four curves forming a quadrilateral, each side being convex towards the centre; and the space thus included is filled with tracery work, which gives them great opportunity of divers variations, which I need not insist on. Another way, (which I cannot find used by the ancients, but in the latter Eastern empire, as appears at St. Sophia, and by the examples of all the mosques and cloisters of the Dervises, and everywhere at present in the East, and of all others the most geometrical,) is composed of hemispheres and their sections only; where, as a sphere may be cut in all manner of ways, and that still into circles, it may be accommodated to lie in all positions of the pillars. Let A B C D be a cupola, or hemisphere, resting upon four pillars, from whence arise the four *vertical* arches; to which the sections, being semicircles, must join on all sides, whether A B be equal to B C or not: cut the hemisphere again horizontally, the section will be an entire circle, touching in the keys of the arches, and G, H, K, L will be the spandrels, resting upon the pillars, yet still are parts of the hemisphere; and if the horizontal circle be taken away, you may build upon that circle an upright wall, which may bear a cupola again above, as is done in St. Sophia and St. Peter's, and in all the churches in Rome. I question not but those at Constantinople had it from the Greeks before them. It is so natural, and is yet found in the present seraglio, which was the episcopal palace of old; the imperial palace, whose ruins still appear, being farther eastward. Now, because I have, for just reasons, followed this way of vaulting of the church of St. Paul's, I think it proper to show that it is the lightest manner, and requires less butment than the cross-vaulting, as well as it is of an agreeable view."

We shall now proceed with the description of the other parts of this edifice.

It appears that these domes are of considerable antiquity, and, from the reasons here given from the *Parentalia*, that Sir Christopher Wren was justified in his choice in their adoption; their form is beautiful; and, when investigated, it is truly geometrical. Each wing forms a flat dome, supported by four spandrels; a rich wreath of foliage encircles the base, while the centre and the spandrels afford spaces well adapted, and probably intended, to receive ornamental paintings. The western transept is a beautiful part of the building; here insulated columns and screens of iron-railing separate from the aisles, on either side, the morning-prayer chapel, and the consistory.

In the progress of examination, we come to the intersection of the nave and the transept; and here, instead of four openings, eight are produced, which afford striking and picturesque views in various directions; and, in this respect, St. Paul's differs from every church with which we are acquainted, the cathedral of Ely only excepted. On the other hand, the junction of the aisles with the central area presented difficulties, which have caused various defects and mutilations in the architecture. The central area, as before observed, is an octagon, supported by eight piers, with as many apertures; four of which, terminating the middle aisles, are forty feet wide, while the others are only twenty-eight feet; but this disparity only exists as high as the first order of pilasters; at which height the smaller openings are expanded so as to make the main arches all equal. Spandrels between the arches form the area into a circle, which is crowned by a large cantiliver cornice, partly supporting, by its projection, the whispering-gallery. At this level commences the interior tambour of the dome, consisting of a high pedestal and an order of pilasters, the intervals of which are occupied by twenty-four windows and eight niches, corresponding with the intercolumniations and piers of the exterior. All this part is inclined forward, so as to form the frustum of a cone. From a double plinth above the cornice of the pilasters, springs the interior dome.

The choir is of the same form and architectural style as the body of the church, and is terminated by a semicircular apsis. The stalls, an enclosure, though not remarkable for elegance of design, are valuable for their ornamental carving, which is by the masterly hand of Gibbons.

In surveying the decorative parts of the interior of St. Paul's, it must be acknowledged that the general impression is that of simplicity bordering upon meanness and nudity, a defect which implies no censure on the great architect, who has left his work in that state to receive the ornament of painting and sculpture, which the frugality of following times have withheld.

The few ornaments which exist are, in general, well executed, and disposed with judgment: The soffits of the grand arches, under the cupola, are in the best style of simple and appropriate decoration. The dome is painted by Sir James Thornhill, who has deformed this beautiful vault with an absurd, heavy, and fictitious architecture, serving as a frame to eight pictures, representing so many actions of the patron saint. It is to be lamented, that instead of placing historical paintings in a situation where the spectator can distinguish nothing but the most obvious and general effect, some other system of decoration had not been adopted.

The design of the cathedral of St. Paul has been charged with various defects, the chief of which are the following: A want of proportion between the cupola and the body of the building; the divison of the exterior into two stories, of orders of columns and pilasters nearly equal; and the coupling of the columns in the western front:

In the interior, the omission of the architrave and frieze of the order, in the spaces between the great pilasters of the nave, for the purpose of raising the summits of the arches above the level of the architrave; the circumstance of the tambour of the dome being inclined forward out of the perpendicular; and, lastly, the awkward junction of the side aisles and mutilated arches.

With respect to the general division of the body of the building into two orders of architecture, we have the authority of the architect himself, as expressed in the *Parentalia* and exhibited in his favourite model, in favour of the single order; but, with regard to this, he was obliged to yield to circumstances, as the Portland quarries could not afford stones of the required dimensions; this necessity led to another, viz., the coupling of the order.

On an inspection of the ground plan of the building, it will be seen, that the exterior pilasters are placed at intervals corresponding to the interior piers, an arrangement which could not be deviated from. As to the omission of the architrave of the order, above the arches of the interior, we are informed in the *Parentalia*, that, in this respect, Sir Christopher Wren "always insisted that he had the ancients on his side; and that, in the Temple of Peace, in the great halls of the Baths, and in all the great structures of three aisles, this is done, and for this reason, that in these wide intercolumniations, the architrave is not supposed to lie from one column to another; but, from the column to the wall of the aisle, so that the end of it only will appear upon the pillar of the inside of the great navis." This is a sufficient answer to those rigorous critics, who would subject the composition of a cathedral to the strict rules which limited the Grecian temples; and it shows that the architect had studied those antique models, which, if not in the purest taste in point of ornament, were yet the most analogous, in general form, to the edifice he had to construct. But, though this was the ostensible excuse, it was not the real reason; for, upon referring to the section of St. Paul's, it will be seen, that Sir Christopher has made the pilasters of the interior a little higher than the exterior columns, which could not be much without incongruity; and, wishing to give the arches, opening to the aisles, as much elevation, and consequently lightness, as the design admitted, he chose to encroach on the entablature of the order; and thus, by a single alteration from general rules, he improved the effect of his building.

According to the large plan, published by Gwyn, the external length of the building, from east to west, exclusive of the projection of the portico, appears to be 502 feet; from north to south, excluding the two circular porticos, 244 feet; the breadth of the western front, 177; the diameter of the octagonal area, at the crossing of the nave and transept, 107; the diameter of the tambour of the dome, 112; and the diameter of the dome itself, 102. The total height, from the pavement of the church-yard, to the top of the cross, is 370 feet. The total expense of the building amounted to £747,954. 3s. which was defrayed by a duty on coals imported into London; but not less than £126,604. 6s. 5d. was furnished by voluntary contributions, chiefly from the clergy. See *The Fine Arts of the English School*, edited by John Britton, F. S. A.

Sir Christopher was architect of no less than fifty-one parish-churches in the metropolis, besides the cathedral and other public buildings, but of these we cannot speak particularly, we can only mention such as are more deserving of notice.

St. Stephen's, Walbrook, is looked upon by some as Wren's master-piece, not even excepting St. Paul's, and the interior certainly is worthy of much praise both for taste and proportion, although by no means faultless. The exterior of the church, like those of the greater number of his churches, has no pretensions to beauty, being plain even to ugliness, if we except the steeple.

The interior, which approaches a parallelogram in plan, is divided into three aisles, and a cross aisle by four rows of Corinthian columns raised on pedestals; these support the roof, which is divided into compartments. The central portion of the church is covered by a dome, which is finely proportioned and divided into small compartments, decorated with great elegance, and crowned with a lantern. On the sides, under the lower roofs, are circular windows, but those which light the upper roof are small arched ones; and at the east end are three larger arched windows. The dimensions of the building are:—length 75 feet, breadth 36 feet, height to roof 34 feet, and to lantern 58 feet.

Of the remaining churches, those most worthy of notice are St. Bride's and St. Mary-le-Bow, and these are remarkable more especially for their steeples, a feature introduced by Wren into his churches, and one on which he bestowed his principal care, many of his churches being in other respects little worthy of the praise that has been bestowed upon them.

The steeple of St. Bride's is certainly a very excellent composition. The spire is placed on a lofty tower, is octagon in plan, and consists of four similar octagonal stories placed one above another, and decreasing in dimension as they rise, so as to present a pyramidal appearance. Each tier comprises a single order, having a semicircular-headed aperture on each side of the octagon, and a pilaster at each of its angles, the two lower stories being of the Tuscan order, the third Ionic, and the fourth Composite. Above these is a smaller story, which is surmounted by a small spire. The present height of this steeple is 226 feet, but it was originally eight feet higher, the difference having been deducted after an accident by lightning in 1764.

The spire of St. Mary-le-Bow rises in a similar manner from a lofty square tower; from a stylobate, on the top of which rises a circular peristyle surmounted by entablature and balustrade. Upon this rises above each column a kind of buttress assuming in profile a curve of double curvature, and falling inwards towards the summit, so as to diminish the horizontal area. Above this is another peristyle with entablature and buttresses of a similar form above, supporting a small spire which carries the vane. This steeple is deservedly admired.

We must pass by Wren's other churches, and content ourselves with enumerating some few of his other works, amongst which the most conspicuous in this style are—Greenwich Hospital, Theatre at Oxford, College of Physicians, and Temple Bar.

Of all Wren's pupils, only one attained to any great eminence, and this was Nicholas Hawksmore, one of whose churches, that of St. Mary, Woolnoth, is of considerable merit; this church is thus described by Mr. Godwin. Speaking of the interior, he says—"It is nearly square, and on the model of a Roman atrium. Twelve well-proportioned Corinthian columns, placed three in each angle, at a distance from the outer walls, equal to about one-sixth of the whole width of the church, support an entablature and a clere-story above it, which latter presents a large semicircular window on each of the four sides. The ceiling of the square area enclosed by the clere-story walls, as well as the soffit of the aisles formed by the columns, is profusely decorated with panels and carved mouldings. A ponderous but elegantly ornamented gallery, is introduced on three sides of the church with so much skill, that it does not mar the general effect, as is often, nay, with some few exceptions, always the case.

"The general effect of the interior is rich and beautiful, and the proportions of the plan and section good; the columns are admirably arranged, and every part displays talent; the whole design is nevertheless somewhat crowded in detail, and overlaid with ornament, and, according to our view of the case, wanting fitness for its purpose, is less deserving of applause than it would be, were the building otherwise appropriated than it is." St. George's, Bloomsbury, is another church by the same architect.

The next architect of any note practising this style, was James Gibbs, the architect of St. Martin's-in-the-Fields, and St. Mary-le-Strand, both which churches present many good features; the portico to the former is much admired. Gibbs introduced a practice of placing the spire over the body of the church, so that it appears as if rising out of the roof; this is decidedly objectionable.

Passing by many architects of less note, we arrive at Sir William Chambers, who greatly excelled his cotemporaries and many of his predecessors in this style of building; his greatest work is Somerset House, which we must not pass by without a short description. "This building," says Mr. Bury, "stands on an area of 800 feet in width, by 500 feet in depth, and is disposed on the four sides of a rectangular court, the interior length of which is 319 feet from north to south, and 224 feet in breadth: the façade towards the Strand is 133 feet long, and consists of three stories: nine arches are assigned to the basement, whereof the three in the centre are open, and lead to the great court, besides having entrances to the apartments of this wing; the other rusticated arches are occupied by windows, decorated with pilasters, entablatures and pediments. Above this story are two tiers of windows of which those in the lower tier have entablatures supported by Ionic columns; the upper windows are square, and are surrounded by square architraves. Between these windows, the walls are ornamented with three-quarter columns of the Corinthian order, standing on pedestals, and extending the height of the two stories; the height of the order without the pedestals is 23 feet, and that of the entablature is 5 feet. Over the three central compartments of this façade, is an attic-story, with oval windows and statues in front: the entire height from the ground is 62 feet."

The vestibule contains a carriage-way and two foot-ways, separated by two ranges of coupled Doric columns, which with their entablature support the vaults.

The inner front of this division of the building, facing the court-yard, is similar to that in the Strand, with the exception that pilasters are employed in the place of columns.

The east and west sides of this quadrangle are similar to those already described, with the exception of those portions between the extremities and the central division, in which the windows are of a less ornamented description, being rectangular, and without architraves. The central divisions are crowned by urns surmounting the entablatures, and have each a small clock-tower above the roof. The south façade is similar to the east and west sides, but its central compartment is more highly enriched, the entablature being supported by four columns and four pilasters, both of the Corinthian order, and the windows between the columns being recessed. Above the roof is a lofty cupola, partially screened by an angular pediment.

"The front towards the river Thames, is 350 feet long, and presents a magnificent appearance. Its arrangement corresponds with that of the quadrangle, but a superior boldness of character has been adopted in its centre wings, where disengaged columns with pilasters are introduced. The centre part of this building is crowned by a cupola, as above stated. Before this façade is a terrace 50 feet wide, supported by a lofty arcade, and protected by a balustrade. In the centre is one great semicircular arch, and near each extremity is a water-gate of similar form, the piers of which are ornamented with rusticated columns."

We must now turn to a class of structures which have risen up of late, and to which this style of building is peculiarly applicable,—we allude to Club-houses. Some of these edifices are of very elegant design, and of magnificent appearance, their general treatment being borrowed from the palatial edifices of Italy: they are in our opinion the most favourable examples of Italian architecture in England, and are far preferable to the ecclesiastical edifices built in this style; a fact which arises, as we imagine, not so much from the merit of the architects employed, as from the circumstance that the style is adapted to the one class of edifice, and not to the other.

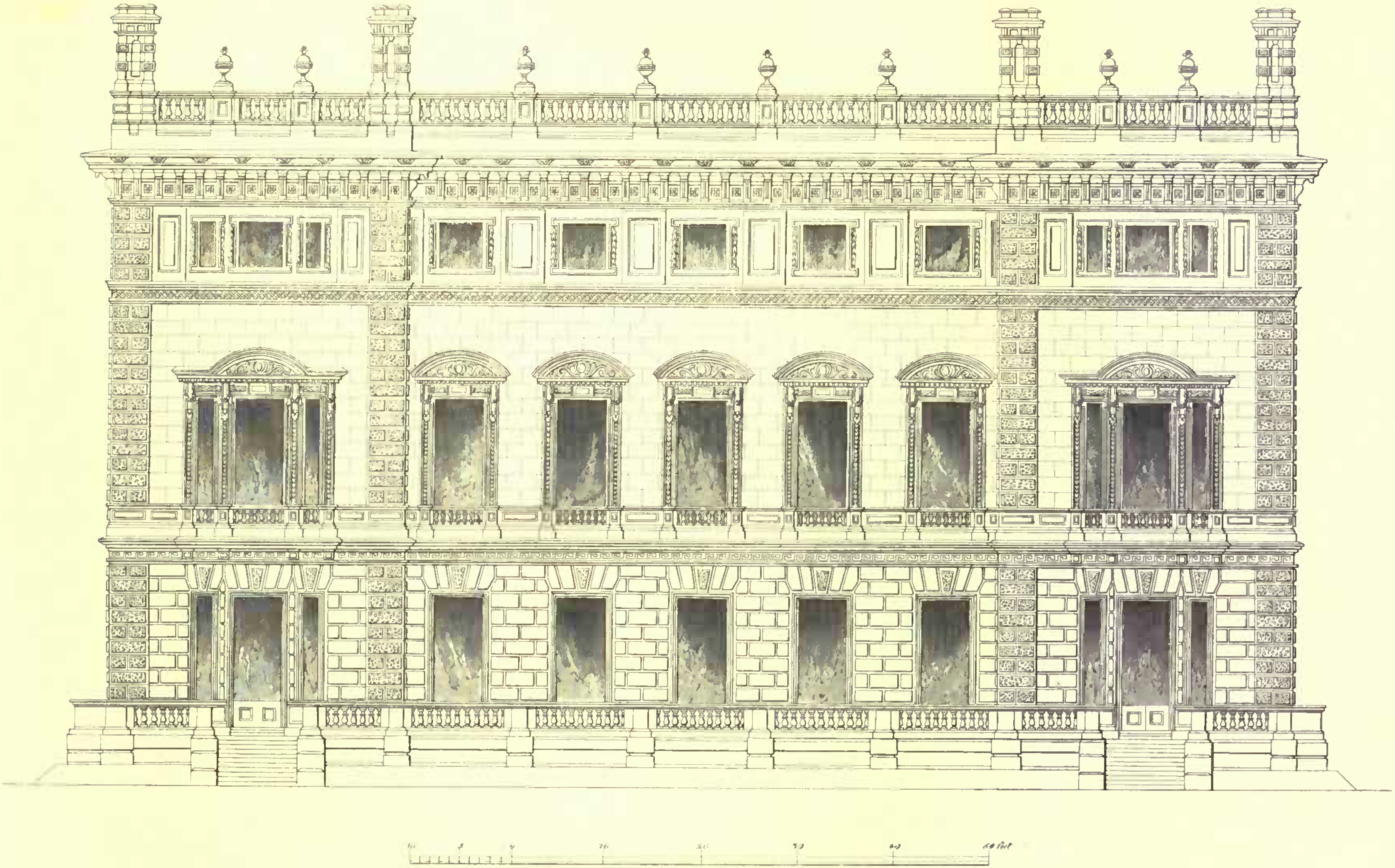
Of the clubs, all of which are of considerable merit, a full account has been given under the article Club-House, to which we beg to refer. We can here only call especial attention to the Reform, the Traveller's, the Carlton, the Army and Navy, and the Conservative. The dignified repose of the first, the simple and unpretending elegance of the second, and the lightness and magnificence of the rest, are subjects all equally worthy of the young architect's attentive study.

The same style has been applied on a somewhat less magnificent scale, yet with equal success, to many other buildings, amongst which fire and life insurance-offices stand pre-eminent. We can here only allude, in passing, to those of the Sun, Imperial, and Globe Societies. This style has also recently been adopted for private mansions, an example of which is afforded us in Bridgewater House, the mansion of the Lord Ellesmere, now erecting under the able superintendence of Mr. Barry, to whom we are indebted for some of the most beautiful and recent erections in this style, amongst which stand pre-eminent the Reform and Traveller's club-houses. We conclude this article with a description of this last, and not least, beautiful example of Mr. Barry's taste, and trust that this may be only a commencement of a new class of town residences for the nobility of this country.

The plan of this mansion is nearly square, the north front being 142 feet 6 inches from east to west, and the west front, shown in our engraving, 122 feet from north to south. The west elevation consists of three stories, separated from each other by ornamental flat-bands and cornices, and is divided into a centre and two wings, which, however, project but slightly. The lower story is rusticated with vertical and horizontal channels, and comprises seven windows, of which five, belonging to the central portion of the building, are plain rectangular apertures, with projecting key-stone, but without architrave. The two outer ones are of a similar character, but are of three lights, the central one being of the same description as the others, and the side ones a little narrower. Above the cornice of this story is a podium, pierced with balusters opposite each window, and having projecting plinths under the architraves. The same number and arrangement of windows occur in this story, but they are of a much more elaborate description, having a highly enriched architrave, and being surmounted by a segmental pediment, supported on projecting corbels, and having the tympanum enriched with sculpture. The triplets in the wings are similarly ornamented, but have a segmental pediment over the central light only, the upper mouldings being continued horizontally, with the corniee over the side lights. The upper story has the same number of square lights with moulded architraves, the spaces between them being panelled: the triple arrangement in the wings is preserved in this story. The entire building is surmounted by a bold cornice supported on consoles, the spaces between which are ornamented with roses, and the corona with dolphins' heads, one over each console. Above the cornicione is a balustrade, the dies of which are surmounted by roses. The angles of the building are finished with coins, which are enriched with reticulated rustication, and, being of considerable width, impart a very rich effect to the façade; the chimneys are brought up at the angles, and are made to form architectural features. A balustrade runs along in front of the lowermost story.

The south elevation is very similar to the west, having a series of nine windows, exactly the same as those in the central portion of the western façade, but having no projecting wings, the extreme angles only being rusticated. The entrance porch is in the centre, and is surmounted by vases similar to those above the balustrade.

IVORY, the name given to the substance composing the tusks of the elephant and the walrus, and to the horn of the narwhal, or sea unicorn. Ivory is extensively used in the arts, for making and embellishing numberless small articles of ornament and use. Tables, cabinets, &c., are frequently inlaid with ivory.



A. Gilbert del.

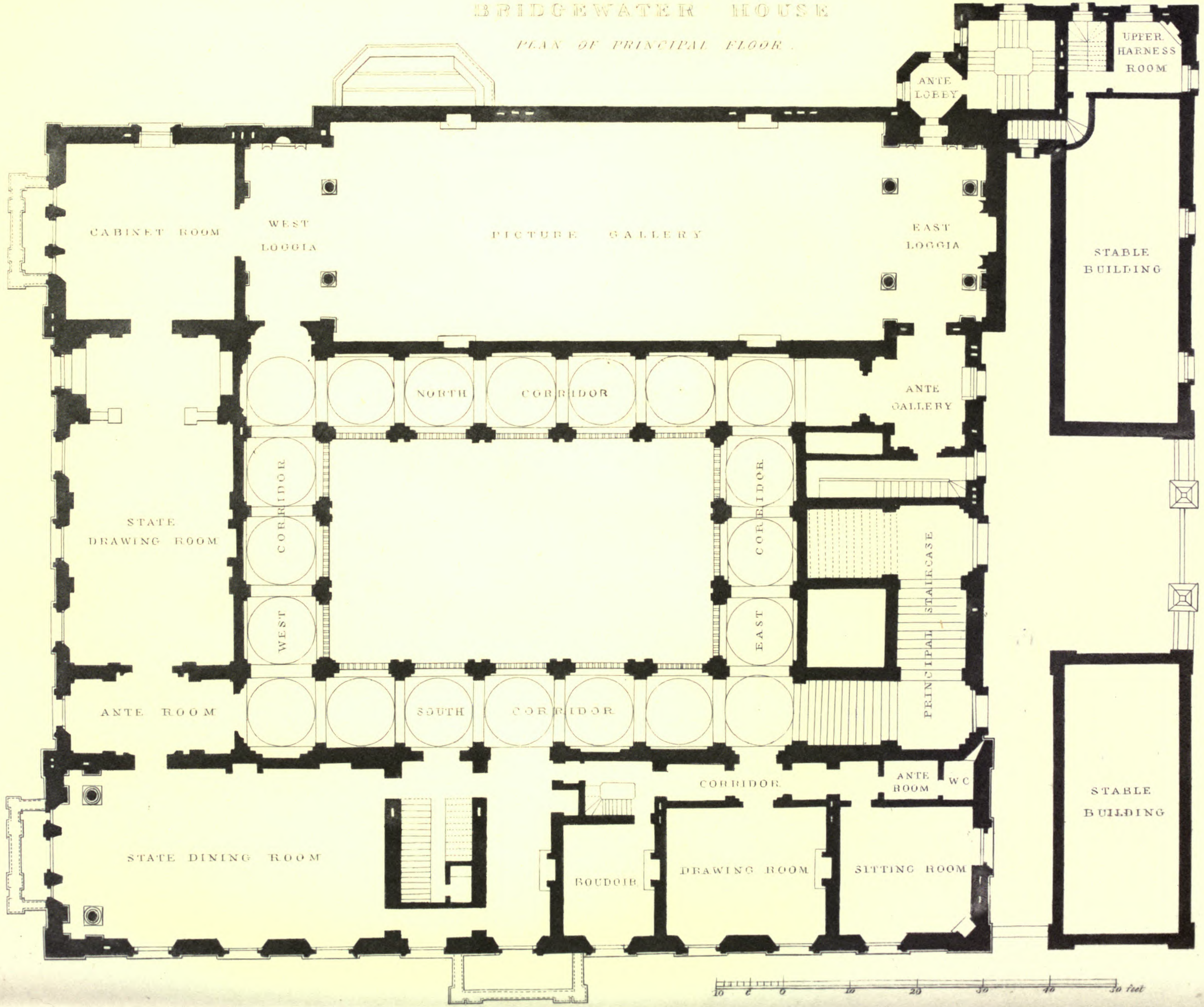
R. Thew sc.

BRIDGEWATER HOUSE

ELEVATION OF WEST FRONT.

BRIDGEWATER HOUSE

PLAN OF PRINCIPAL FLOOR.



R. Thew.

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JACK, Lifting Jack, in mechanics, a portable machine for raising great weights through a small space. It consists of a rack and pinion inclosed within a strong wooden case, and the power is applied by means of a winch or handle fixed upon the axis of the pinion; the upper end of the rack is formed into two horns, to take the better hold of the article to be elevated; and from the end two prongs project laterally through a longitudinal groove in the case, which are used upon occasions when there is not room to introduce the jack beneath the load. To prevent the labourers being overpowered, there is a racket wheel and pall on the axis of the pinion.

Jack Arch, an arch of only one brick in thickness.

Jack in the Box, a large wooden solid screw, turning in a hollow one, which forms the upper part of a wooden box, shaped like the frustum of a pyramid; it is used by means of levers, passing through holes in it, as a press in packing, and for other purposes.

Jack Plane, a plane about 18 inches in length, used for taking off the rough of the saw, or the irregularities of the axe, and planing off any inequalities, to prepare the stuff for the trying plane.

Jack Rafter, a short rafter, such as those which are fixed to the hips.

Jack Ribs, in a groin, or in a polygonal domic ceiling, are the ribs that are fixed upon the hips.

Jack Timber, any timber that is interrupted in its whole length, or cut short.

Jak Wood, a coarse-grained wood brought from India, sometimes used in cabinet-work and turnery.

JAMBS (French) the sides of an aperture, which connect the two sides of the wall.

Jamb Lining, the two vertical linings of a door-way or aperture, which connect the two walls.

Jamb Posts, such as are sometimes introduced on the side of a door, in order to fix the jamb linings. They are particularly used when the partition is of wood.

It having been noticed by Mr. T. N. Parker how rapidly the lower ends of door posts decayed where they were exposed to wet, he contrived a cast-iron socket for them, which is much used in Shropshire, and might be generally introduced with advantage. These sockets are cast by the Colebrook-dale company; they weigh only 7lbs. the pair, and cost about 2½d per pound.

Jamb Stones, in stone walls, such as are employed in building the sides of an aperture, in doing which, every alternate stone ought to be inserted the whole thickness of the walls.

JANTU, a machine used in Hindostan for raising water for the purpose of irrigating lands.

JAPANNING, the art of painting and varnishing, after the manner practised by the natives of Japan, in the East Indies. It is employed for the purpose of preserving and beautifying various articles, usually of wood and metal, as well as paper, leather, and cloth, when they are properly prepared for the purpose. Those articles we most commonly find japanned, are pieces of household furniture, cabinet-work, boxes of all kinds, trays, screens, &c., and, very generally, those articles made of any of the above-mentioned or similar materials, which it may be desired to preserve from moisture. This it is admirably adapted to effect, from its drying very hard, and being impervious to water at all moderate temperatures, even to boiling in some cases; but it may be employed on any dry substance that is sufficiently inflexible to prevent the japan from being cracked or forced off.

JERKIN HEAD, the end of a roof that is not hipped down to the level of the opposite adjoining walls; the gable being carried higher than the level of the said walls.

JET D'EAU, (French) a fountain, or ornamented jet, throwing up a stream of water to some height in the air. *See* Fountain.

JETTEE, Jetty, or Jutty, (French) the border made around the stilts under a pier, consisting of piles and planks, stones filling up the interstices, to secure the whole foundation.

Also the projecting portion of a building, such as the overhanging story of ancient timber houses.

JIB-DOOR, a door so constructed as to have the same continuity of surface with that of the partition in which it stands. The use of a jib-door is to preserve the symmetry of an apartment, where only one door is wanted, nearer to one end of the partition than the other. Instead of a jib-door, a real door and a false one may be used. Where jib-doors are used, it is obvious that they must be concealed as much as possible.

JOGGLE, the joint of two bodies, so constructed as to prevent them from sliding past each other, by the application of a force in a direction perpendicular to the two pressures by which they are held together. The struts of a roof are joggled into the truss-posts and into the rafters; when confined by mortise and tenon, the pressure which keeps them together is that of the rafter and the re-action of the truss-post. The same is also applied to the step and platform stones of a geometrical stair.

Joggle Piece, the truss-post in a roof, when formed to receive a brace or strut, with a joggle.

JOINER, the workman who joins wood for the finishing of buildings.

JOINERY, in civil architecture, the art of framing or joining wood together, for internal and external finishings of houses; thus the coverings and linings of rough walls, or the coverings of rough timbers, and the construction of doors, windows, and stairs, are joiners' work.

Joinery requires much more accurate and nice workmanship than carpentry; the latter consists only of rough timbers, used in supporting the various parts of an edifice: joinery is therefore used by way of decoration, and being always near to the eye, and consequently liable to inspection, requires that the joints should be fitted together with the utmost care, and the surfaces made smooth.

The wood used is called *stuff*, and is previously formed by the pit-saw into rectangular prisms, which are denominated *battens*, *boards*, or *planks*, according to their breadths. Battens run from two to seven inches wide; boards from seven to nine inches wide; and planks from nine inches to any greater breadth that can be cut out of a piece of wood.

The operations of joinery consist of forming surfaces of various kinds, also of grooving, rebating, and moulding, and of mortising and tenoning; and lastly, of joining two or several pieces together, so as to form a frame or solid mass

Surfaces, in joinery, are either plane or curved, but most frequently plane. All kinds of surfaces are first formed in the rough, and finally brought to a finish by means of appropriate tools.

Grooving consists in taking away a part of a rectangular section from a piece of wood, so as to form a channel of equal breadth throughout, with three surfaces, one parallel, and the other two perpendicular, to that of the wood; which channel is called a *groove;* and thus the piece that would fill the cavity, or which would restore it to its original form, is a square prism.

Rebating consists in taking away a part from a piece of wood of a rectangular section, so as to leave only two sides, one perpendicular, and the other parallel, to the surface of the wood; the cavity thus formed is called a *rebate.* From this definition it is manifest, that a rebate can only be formed by reducing the piece of wood to be rebated at the angle itself, and may therefore be considered as a semi-groove; and thus the piece which would restore the whole to its original form is a square prism, as in grooving.

A mortise is a cavity recessed within the surface of a piece of wood, with four sides perpendicular to the surface, and to each other. The act of making a mortise is called *mortising.*

A tenon is a projection formed on the end of a piece of wood with four plane sides, at right angles to each other, and to a plane, from which it projects, called *the shoulder of the tenon.*

In the following, all pieces of wood whatever are supposed to be rectangular prisms, and the length in the direction of the fibres; two of the sides of every mortise perpendicular, and the other two parallel, to the fibres; and the four sides of every tenon in the direction of the fibres, unless otherwise described: likewise, if two of the surfaces of a piece of wood be of greater breadth than the other two, the latter are called *the edges*, and the former *the sides;* while each line of concourse, formed by two adjacent sides, is called *an arris.*

Moulding consists in forming the surface of a piece by plane or curve surfaces, or by both, in such a manner that all parallel sections may be similar and equal figures.

The first thing to be done in joinery is to select the stuff or boards, which ought to be well seasoned for every purpose in joinery, and then line it out; and if the stuff be not already at the size, as is most frequently the case, it must be ripped out with the ripping-saw, or cross cut with the hand-saw, or both, as may be wanted. The next thing is the planing of the stuff, first upon a side, then the edge squared, and afterwards gaged to a breadth and thickness, should either or both be found necessary.

Two or more pieces of stuff may be fastened together, in various ways, by pins of wood, or by nails; but in work prepared by the joiner for building, the pieces are more frequently joined together by making their surfaces planes, and plastering them over with a hot tenacious liquid, called *glue*, then rubbing the surfaces until the glue has been almost rubbed out, and one piece brought to its situation with respect to the other. The best work is always joined by this method.

When boards are required of a greater breadth than common, several primitive boards must be fastened together edge to edge, either by nailing them to pieces extending across the breadth, or by gluing them edge to edge, or by joining pieces transversely together with small boards, tongued into grooves excavated in the edges.

Two pieces of stuff are joined together at right or oblique angles by a mortise and tenon adapted to each other, and fastened together with glue.

When a frame, consisting of several pieces, is required, the mortises and tenons are fitted together, and the joints glued all at one time, then entered to their places, and forced together by means of an instrument called a *cramp.*

A frame of wood in order to contain a panel, and surround it completely, cannot be made of less than three pieces, unless one or more of them be curved, because less than three straight lines cannot contain a space.

The operation of forming a given surface, by taking away the superfluous wood, is called *planing*, and the tools themselves *planes.*

The first tools used by joiners are *bench planes*, which generally consist of a *jack plane*, for taking away the rough of the saw and the superfluous wood, only leaving so much as is sufficient to smooth the surface; the *trying plane*, to smooth or reduce the ridges left by the jack-plane, and to straighten or regulate the surface, whether it be plane or convex; the *long plane*, when the surface is required to be very straight; and the *smoothing plane*, in smoothing, as its name implies, and giving the last finish to the work.

Besides the bench planes, there are others for forming any kind of prismatic surfaces whatever, as *rebating planes*, *grooving planes*, and *moulding planes:* but for a more particular description of these and the bench planes, we shall refer to the article PLANE.

The tools employed in boring cylindric holes are a *stock* with *bits*, of various descriptions and sizes, *gimlets*, and *bradawls* of several diameters.

The tools used in paring the wood obliquely, or across the fibres, and for cutting rectangular prismatic cavities, are in general denominated *chisels;* those for paring the wood across the fibres are called *firmers*, or *paring chisels*, and those for cutting mortises are called *mortise chisels.* The sides of all chisels, in a direction of their length, are straight, and the side of a chisel which contains the cutting edge at the end is of steel. The best paring chisels are made entirely of cast steel. Chisels for paring concave surfaces are denominated *gouges.*

Dividing wood, by cutting away a very thin portion of the material of equal thickness throughout, to any required extent, by means of a thin plate of steel with a toothed edge, is called *sawing*, and the instruments themselves are called *saws*, which are of several kinds; as the *ripping saw*, for dividing boards into separate pieces in the direction of the fibres; the *hand saw*, for cross cutting, or for sawing thin pieces in the direction of the grain; the *panel saw*, either for cross cutting, or cutting very thin boards longitudinally; the *tenon saw*, with a thick iron back, for making an incision of any depth below the surface of the wood, and for cutting pieces entirely through, not exceeding the breadth of that part of the plate without the iron back; likewise a *sash saw*, and a *dovetail saw*, used much in the same way as the tenon saw. From the thinness of the plates of these three last saws, it is necessary to stiffen them by a strong piece of metal, called the *back*, which is grooved to receive the upper edge of the plate that is fixed to the back, and which is thereby secured and prevented from crippling. When it is required to divide boards into curved pieces, a very narrow saw without a back, called a *compass saw*, is used; and in cutting a very small hole, a saw of a similar description, called a *key-hole saw*, is employed. All these saws have their plates longer and thinner, and their teeth finer, as they succeed each other in the order here mentioned, excepting the two last, which have thicker plates, and coarser teeth than either the sash or dovetail saws. The external and internal angles of the teeth of all saws are generally formed at an angle of 60 degrees, and the front edge teeth slope backward in a small degree, but incline or recline from the straight line drawn from the interior angle perpendicular to the edge in the plane of the plate, as the saw may be employed in ripping or in cross cutting, or cutting perpendicular to the fibres. The teeth of all saws, except turning and key-hole saws, are alternately bent on contrary sides of the plate, so that all the teeth on the same side are alike bent throughout the length of the plate, for the purpose of clearing the sides of the cut made by it in the wood.

Of all cutting tools whatever, the saw is the most useful to the joiner, as the timber or wood which he employs can be divided into slips or bars of any size, with no more waste of stuff than a slice, the breadth of which is equal to the depth of the piece to be cut through, and the thickness equal to the distance of the teeth between their extreme points on the alternate sides of the saw, measured on a line perpendicular to them: whereas, without the use of the saw, cylindrical trees could only be reduced to the intended size by means of the axe; in the use of which there would not only be an immense consumption of stuff, but also much greater labour would be required to reduce it to a straight surface.

Joiners use a small axe, called a *hatchet*, for cutting off the superfluous wood from the edge of a board, when the waste is not of sufficient consequence to be sawed.

The above are what are commonly denominated *edge tools*, but there are others required to regulate the forms. All angles whatever are formed by other reversed angles of the same number of degrees; as an exterior angle by an interior one, and the contrary. The instrument for trying right angles is called a *square*, and those for trying oblique angles are called *bevels*. The two sides which form the edge of a square are always stationary, but those of bevels are generally moveable, one leg upon the other, round a joint. In some cases, where a great number of pieces are required to be wrought to the same angle, a stationary bevel, called a *joint-hook*, is used.

When it is required to reduce a piece of stuff to a parallel breadth, an instrument called a *gauge* is used, which consists generally of a square piece, with a mortise in it, through which runs a sliding bar, at right angles, called the *stem*, furnished with a sharp point, or tooth, at one extremity, projecting a little from the surface, so that when the side of the gauge, next to the end which has the point, is applied upon the vertical surface of the wood, with the toothed side of the stem upon the horizontal surface, and pushed and drawn alternately by the workman from and towards him, the tooth will make an incision from the surface into the wood, at a parallel distance from the upper edge of the vertical side on the right hand. This line marks precisely the intersection of the plane which divides the superfluous stuff from that which is to be used.

When a mortise is required to be cut in a piece of wood, a gauge with two teeth is used. The construction of this instrument is the same as the common gauge, except that the stem has a longitudinal slider with a tooth projecting from its end, so that both teeth may be brought nearer, or removed farther from each other, at pleasure; and also to any distance, from the face of the head or guide, within the reach of the stem.

If, when a piece of wood has been planed, it is required to be sawed across the fibres; to keep it stationary during the operation, and to prevent the sides or edges from being bruised, a flat piece of wood with two projecting knobs on opposite sides, one at each end, called a *side-hook*, is used. The vertical side of the interior angle of one of the knobs is placed close to the vertical side, and the under side upon the top of the bench; then the wood is pressed against the knob which projects from the upper surface while it is cutting. But the use of two side-hooks is better, as they keep the piece more steady.

When it is required to cut a piece of wood to a mitre with one side—that is, to half a right angle—joiners use a trunk of wood with three sides, like a box without ends or a top, the sides and bottom being parallel pieces, and the sides of equal heights; through each of the opposite sides is cut a kerf, in a plane perpendicular to the bottom, at oblique angles of 45° and 135° with the planes of the sides; and another kerf is made with its plane at right angles to the two former: this trunk is called a *mitre-box*. When the wood is to be cut, the mitre-box is fixed steady against two side-hooks, and the piece, which must always be less than the interior breadth of the mitre-box, is laid in it, and pressed against its farther interior angle, with the side downwards, to which the saw-kerf is intended to be perpendicular, and in this position it is to be cut. The two kerfs in the sides of the mitre-box are requisite, in order to form the acute angle on the right or left-hand side of the piece, as may be required.

When a piece of wood is required to be made straight in one direction, joiners use a slip of wood straightened on one edge, and thence called a *straight edge*. Its use is obvious; as by its application it will be seen whether there is a coincidence between the straight edge and the surface.

When it is required to know whether the surface of a piece of wood is in the same plane, joiners use two slips, each straightened on one edge, with the opposite edge parallel, and both pieces of the same breadth between the parallel edges: each piece has therefore two straight edges, or two parallel planes. Therefore, to find whether a board is twisted, or its surface plane, the workman lays one of the slips across the one end, and the other across the other end of the board, with one of the straight edges of each upon the surface; then he looks in the longitudinal direction of the board, over the upper edges of the two slips, until his eye and the said two edges are in one plane; or otherwise, the intersection of the plane passing through the eye and the upper edge of the nearest slip, will intersect the upper edge of the farther slip. If it happen as in the former case, the ends of the wood under the slips are in the same plane; but should it happen as in the latter, they are not. In this last case, the surface is said to *wind;* and when the surface is so reduced as for every two lines to be in one plane, it is said to be *out of winding*, which implies its being an entire plane; from the use of these slips they are denominated *winding-sticks*.

Before we proceed to the method of bringing a rough surface to a plane, it is necessary to show how to make a straight edge. And here the joiner must not lose sight of the properties of a straight-line, viz., that which will always coincide with another straight line, however they may be applied together.

The operation of making the edge of a board straight is called by joiners, *shooting*, and the edge so made is said to be *shot*.

Straight edges may be formed by planing the edges of two boards, and applying them together, with their superficies or faces in the same plane; if there be no cavity in the joint, the edges will be straight; if not, the faces must be applied to each other, the edges brought together, and planed and tried as before, until they coincide.

Another mode is by having a plane surface given Plane:—the dges of a board as straight as the eye will admit of, apply the face of it to that of the plane, and draw a line by the edge of the board; turn the board over with the other side upon the plane, bring the planed edge to the line drawn before, and the extremities of the edge to their former places, and draw another line; then, if all the parts of this line coincide with the former, the edge is already straight, but if not, repeat the operation as often as may be necessary.

Another mode is to plane the edge of a board as straight as can be done by the eye, then plane the edge of another board until it coincides with the former; plane the edge of a third board in like manner, to coincide with the edge of the first, and apply their edges together; then, if they coincide, the operation is at an end, but if not repeat till they do.

By any of these methods, the superficies of the boards to be shot are supposed to be parallel planes, not very distant from each other; for if the faces be not parallel, or if the thickness be considerable, the operation will be more liable to error.

To reduce the rough surface of a body to a plane.—This will not be very difficult, when it is known that a plane will everywhere coincide with a straight line.

The most practical methods are the following:—Provide two winding-sticks, and apply them as before directed, making the ends out of winding, if they are not found to be so; then, if all the parts of the surface on which the edges of the winding-sticks were placed are straight, it is evident that the whole surface must be plane. If the surface is hollow between the said lines, one of the ends, or both, must be planed lower, until the surface acquires a small convexity in the length; and then, if straightened between the straight lines at the ends, it will be a perfect plane.

Another mode of forming a plane, supposing the surface to be of a quadrilateral form. Apply a ruler along the diagonals, then, if they are straight, they are in a plane; but if they are both hollow, or both round, the surface to be reduced is either concave or convex, and must be straightened in these directions accordingly.

Lastly, if, by trying across the diagonals with the straight edge, it be found that the one is hollow and the other round, the surface of the board winds. In this case, bring down the protuberant part of the convex diagonal, so as to be straight with the two extremities; then straighten the concave diagonal, by planing either of the two ends, or both of them, according as the thickness of the board may require. Both diagonals being now straight, traverse the wood—that is, plane it across the fibres, until all the protuberant parts between the diagonals are removed; then smooth it by working in the direction of the fibres.

To join any number of planks together, so as to form a board of a determinate breadth, the fibres of each running longitudinal to those of any other.—Shoot the two edges that are to be joined; turn the sides of the boards towards each other, so that the edges that are shot may be both uppermost; spread these edges over with strong glue of a proper consistence, made very hot; one of the boards being fixed, turn the other upon it, so that the two edges may coincide, and that the faces may be both in the same plane: rub the upper one to and fro in the direction of the fibres, till the glue is almost out of the joint; let these dry for a few hours: then proceed to make another joint; continue to join as many boards or planks in the same manner, till the whole intended breadth be made out. If the boards, or planks of which the board is to be composed, be very long, the edges that are to be united will require to be warmed before a fire; and, for rubbing and keeping the joints fair to each other, three men will be found necessary, one at each extremity, and one at the middle. Boards glued together with this kind of cement will stand as long as the substance of the deals or planks composing them, if not exposed to rain or intense heat, provided the wood has been well seasoned beforehand, and the grain be free and straight, and interrupted with few or no knots. When a board which is to be exposed to the weather is to be made of several pieces, the cement to be used for uniting them should not be of skin glue, but of white-lead ground up with linseed-oil, so thin that the colour may be sensibly changed into a whitish cast; this kind of glue will require a much greater time to dry than skin glue. Boards to be exposed to the weather, when their thickness will admit, are frequently tongued together: that is, the edges of both boards are grooved to an equal distance from the faces, and to an equal depth; and a slip of wood is made to fit the cavity made in both: this slip should be made to fill the grooves, but not so tight as to prevent the joint from being rubbed with proper cement.

To glue any two boards together forming a given angle.—This may be accomplished, either by shooting the edge of one board to the whole of the given angle, keeping the face of the other straight; and then, by applying the two surfaces together, and rubbing as before, they will form the angle required; or, if the two edges, being shot to half the given angle, be applied together, and rubbed and set as before, their faces will form the angle required. In both these methods, when only one side of the board is to be exposed to sight, which is most commonly the case, pieces of wood, called *blocks*, are fitted to the inside of the angle, and the sides glued across the joint or legs of the angle, being previously planed for that purpose.

To form wooden architraves for apertures, by giving longitudinal pieces together.—Architraves are sometimes formed of solid pieces, but a better and more economical mode is that of gluing longitudinal pieces together. See ARCHITRAVE. Architraves of the Grecian form, for doors and windows, generally consist of one or two faces in parallel planes, one of which recedes only in a small degree from the other, while the outer edge is terminated with one or several mouldings, which have a very prominent projection. In this case, make a board of sufficient thickness, and in breadth equal to the breadth of the architrave: prepare a slip of wood of a sufficient thickness and breadth for the mouldings on the outer termination of the architrave, and glue it upon the face, close to the edge of the board, with the outer edge flushed therewith. In this operation, two men, at least, will be required to rub the slip to a joint with the board; and as it often happens that the side of the slip, which is to comply with the surface of the board, is considerably bent, it must be nailed down to the board; previously to this, small square pieces of wood, called *buttons*, must be bored with holes, one in each, and a nail put through the hole to the head; then the slip is also to be bored with a bradawl, and the nails, with the pieces thus described, are entered and driven home as far as the buttons will permit. These buttons may be about three-quarters of an inch thick, and the other two dimensions each equal to, or something more than the breadth of the slip. Sometimes the slip is grooved; and the edge of the board tongued, glued, and inserted into the groove, instead of the above method. Or, the two faces may be made of different boards, tongued together at their joining, and the whole afterwards stuck into mouldings.

To form the surface of a cylinder with wood, whose fibres are in planes perpendicular to the axis of the cylinder, such as may be used in a circular dado, or the soffits of wisdom.

METHOD I.—When the dimension of the cylindric surface, parallel to the axis, is not broader than a plank or board. This may be done by bending and gluing several veneers together; the first upon a mould, or upon brackets, with their edges in the surface of the proposed cylinder, parallel to its axis.

This may be accomplished by means of two sets of brackets, fixed upon a board, with a hollow cylindric space between them, of sufficient thickness for taking in the veneers, with double wedges for confining them. If this operation be carefully done, and the glue properly dried, the wedges may be slackened, and the work will stand well; but it must be observed, that, as the wood has a natural tendency to unbend itself, the curved surface, upon which it is glued, should be somewhat sharper than that intended to be made, to allow for this tendency.

Some workmen form a hollow cradle, and bending the veneers into it, confine their ends with wedges, which compress them together; and by a very small degree of rubbing, with a hammer made for the purpose, the glue will be forced out of the joint.

METHOD II.—Form a cradle, or templet, to the intended surface, and lay a veneer upon it; then glue blocks of wood upon its back, closely fitted to its surface, and the other joints to each other, the fibres of the blocks corresponding to those of the veneer.

METHOD III.—Make a cradle, and place the veneers upon it, confining one end of them; spread the glue between the veneers with a brush, and fix a bridle across, confining its ends either by nails or by screws; open the veneers again, put glue a second time between each two, and fix another bridle across them; and in this manner proceed to the other extremity.

METHOD IV.—Run a number of equidistant grooves across the back of the board, at right angles to its edges, leaving only a small thickness towards the face; bend this round a cradle, with the grooves outwardly, and fill the grooves with slips of wood, which, after the glue is quite dry, are to be planed down to the surface of the cylindric board, which may be stiffened by gluing canvass across the back.

Instead of using a grooving-plane, workmen frequently make kerfs with the saw; but this mode is not so strong when finished, as the uncertainty of the depths of the kerfs, and the difficulty of inserting the slips, will occasion a very unequal curvature.

To bend a board, so as to form the frustum of a cone, or any segmental portion of the frustum of a cone, as the soffit of the head of an aperture.—Find the arch-form of the covering, as shown under the article ENVELOPE; cut out a board to this form, and run a number of equidistant grooves across it, tending to the centre: this being fixed to a templet made to the surface of a cone, finish it in the manner shown in the last method for a cylinder.

To bend boards so as to form a spheric surface.—Make a mould to the covering of a given portion of the sphere in plano, as shown under the article DOME; complete the number of staves by this mould; make a templet or mould to a great circle of the sphere; groove each of the staves across, at right angles to a line passing through the middle, and bend it round the templet; put slips in the grooves; shoot the edges of the staves, so as to be in planes tending to the centre of the sphere; and these staves, being glued together, will form a spheric surface.

To glue up the shaft of a column, supposing it to be the frustum of a cone.—Prepare eight or more staves, as the circumference may require, in such a manner that if the column be fluted, the joints may fall in the middle of the fillets, which disposition will be stronger than if they were to fall in the middle of the flutes.

Now, suppose eight pieces to be sufficient to constitute the shaft of a column: describe a circle to the diameter of each end; about each circle circumscribe an octagon; from the concourse of each angle draw a line to the centre; then draw an interior concentric octagon, with its sides parallel to those of the circumscribing one, the distance between any two parallel sides, on the same side of the centre, being equal to the thickness of stuff intended: and thus the sections of the staves will be formed at each end, and consequently the bevels will be obtained throughout the whole length; any two pieces when joined together having the same angle, though the staves are narrower at one end than at the other.

In order to join the column, glue two pieces together, and when quite dry, glue in blockings to strengthen them: join a third piece to the former two, and secure it also by blockings. In this manner proceed to the last piece but one.

In fixing the last, the blockings must be glued to the two adjacent staves, and their surfaces, on which the last stave is intended to rest, must be all in the same plane, that its back may rest firmly upon them. In closing up the remaining space, the part of the column that is glued together should be kept from spreading, by fixing it in a kind of a cramp, or cradle, while driving the remaining stave to close the joints.

Instead of this mode, some glue up the column in halves, and then glue them together.

When it is necessary to have an iron core, to support the roof or floor, the column must be glued up in halves; in this case, the two halves are to be dowelled together, and the joints filled with white-lead. Instead of a cramp, a rope is used, twisted by means of a lever. In the act of bringing the two halves together, the percussive force of the mallet must be applied upon the middle of the surface of one half, while an assistant holds something steady against the middle of the other, that the opposition may be equal; and by this means, the surfaces will be brought into contact, and form the joint as desired. In this operation pieces of wood ought to be inserted between the rope and column.

To glue up the Ionic and Corinthian capitals for carving.—The abacus must be glued in parts, so that their joints may be in vertical planes. The leaves and caulicoles of the Corinthian capital may be first made of rectangular blocks, and fixed to the vase.

To make a cornice round a cylindric body of the least quantity of wood, when the body is greater than a half-cylinder, and when the members will nearly touch a right line applied transversely.—Draw a section of the cylinder through its axis, and let the section of the cornice be represented upon the cylindric section. Draw a transverse line, touching the two extreme members of the cornice; and parallel to it draw another line within, at such a distance from the former, as may be necessary for thickness of stuff; produce the latter line, till it meet the line representing the axis of the cylinder, and the junction will either be above or below, according as the cornice is applied to the convex or concave sides of the cylinder. This meeting is the centre of two concentric circles, whose radii are the distances between the nearest and farthest extremes of the section of the cornice. This is evidently an application of the method of finding the covering of a cone. When mouldings are got out in this manner, viz., by a piece which does not occupy the space, when set to the place represented by the height and breadth, they are said to be sprung.

When a cornice is to have much projection, the corona, or middle part, is got out of a solid piece, and the parts above and below, or one of them, as may be found necessary, only set to the spring, and supported by brackets.

Another method is to bend veneers round the cylindric surface or surfaces; then work them to their form with moulding planes.

Raking mouldings depend principally upon the nature of a solid angle, properly called *a trihedral*. In a trihedral angle, with two of its planes at right angles to the third, let these two former make an obtuse angle; then suppose a moulding placed in the concourse of the two planes which form the obtuse angle of the solid, and another in the concourse of the two planes which form one of its right angles;

and supposing the section of the moulding which stands in the line of concourse of the obtuse angle to be given, it is required to find the section of the other, so as to mitre in a plane bisecting the remaining right angle of the solid. The trihedral will thus consist of three plane angles, two of which are right angles, and the other obtuse.

Make an angle equal to that formed by the sides of the obtuse-angled plane of the solid; let one of the legs be called the *mitre-line*, and the other the *raking-line;* draw the position of the moulding at the point of concourse in respect of the mitre-line without the angle; take any number of points in the curve of the moulding; through these points draw lines parallel to the mitre-line: also draw lines through the same points parallel to the raking-line: draw a line perpendicular to the mitre-line, cutting the other parallels at right angles; take the perpendicular, thus cut into several portions by the parallels of the mitre, and transfer it upon any part of the raking-line, marking all the points of section: through the points of section, draw lines at right angles to the raking-line, to cut its respective parallels; through the points of section of the parallels and perpendiculars of the raking-line, draw a curve which will be the section of the moulding.

The raking-mouldings in pediments depend upon this. The raking-line is the top of the tympanum; the mitre-line, the angle of the building; and the line of concourse of the obtuse angle of the solid, the level returning cornice, at right angles to the tympanum, or plane of the front of the building.

The same is also applicable to a hollow trihedral, such as the inside of a room, of which the two vertical planes are at right angles to each other, the legs of the one plane forming a right angle, and those of the other an obtuse angle; and consequently the ceiling, which is the third side of the trihedral, will be inclined to the horizon, like the exterior side of a pediment, or triangular roof, with this difference, that the surface of the former is opposed to the floor, and the latter to the sky. Open pediments are not now in use, otherwise it might be shown how the return mouldings were to be formed: if, however, the above general description is well understood, the reader cannot be at a loss to apply the principle to finding the section of such return moulding in an open pediment also. This, however, will be noticed under the article MOULDING.

In a trihedral solid, with two of its planes at right angles to the third, as in the preceding case, let the two planes make an acute angle instead of an obtuse one; then the other two angles of the solid will be both right angled, as also each of the planes forming the acute angle: now supposing one moulding to be placed in the line of concourse of the acute angle of the solid, and another in the line of concourse of one of the right angles; then if these mitre together upon a plane, passing along the line of concourse of the planes which form the remaining right angle of the solid, they will show the principle of the formation of the angle-bars of a bow-window, consisting of three or more vertical planes. As the angle-bar stands in the concourse of two of the vertical planes, suppose those two planes to be cut by a third plane at right angles to their line of concourse, and the solid thus formed again divided in halves by a plane passing along the concourse of the two vertical planes, bisecting the angle-bar, or the angle of their inclination, two equal trihedrals will be formed, each having one acute angle and two right angles: and the mouldings formed on the two legs of the front plane will be those required to mitre together. One of these mouldings will be half of the angle-bar, and the other half of the horizontal-bar.

The section of the horizontal-bar being given, to find that of the angle-bar.—Lay down the horionztal side of the trihedral, viz., that side which is contained by the acute angle; then calling one of the legs *the mitre-line*, and the other *the sash-line;* draw half the section of the horizontal bar perpendicular to the sash line, with the surface of the moulding opposed to the mitre line; take any number of points in the curve of the moulding, and draw lines through them perpendicular to the sash-line, cutting it in as many points; take the length of the intercepted line between the extreme points, and transfer it upon a line perpendicular to the mitre-line, with the several points of division from the mitre-line towards the section of the horizontal-bar; through the several points of division in the said perpendicular, draw lines parallel to the mitre-line; again, through the several points of division in the curve of the section of the horizontal-bar, draw lines parallel to the sash line, cutting the respective lines parallel to the mitre-line, and the points of intersection will give the section of half the angle-bar, by drawing a curve through them. The counter part being drawn on the other side of the mitre-line, the whole section of the angle-bar will be complete.

The reader will perceive that this principle is similar to the former, both depending upon the trihedral, or solid angle, consisting of three plane angles. The mitre passes through one of the lines of concourse, and a moulding along each of the two others. In both cases, that which is perpendicular to the other two is laid down.

A circular sash-frame in a circular wall, is a solid of double curvature; its formation, therefore, depends upon the section of a cylinder, and the covering of any portion of the cylinder.

The gluing up of the arcular bars depends upon the development of any portion of a cylindric surface.

The radial bars are portions of different elipses, which intersect each other in one common line of concourse, or conjugate axis, being the sections of a cylinder at different inclinations, all passing through a line at right angles to the axis.

Two of the sides of these bars are plane surfaces, and the other two curved surfaces are cylindrical; consequently they terminate the plane surfaces in curved lines, which are portions of elliptical figures.

The head of the sash is generally got out of the solid in halves, or in four pieces, according to the size of the window; and when put together, ought to be so formed, that one concave surface may saddle upon a cylinder of a radius equal to that of the inner circle, which forms the plan, while the outer surface is everywhere equidistant from the cylindric surface; and that the other concave surface may coincide with the convex surface of another cylinder, whose radius is equal to that required to describe the interior curve of the sash-head, while the outer surface is everywhere equally distant from the cylindric surface.

An enlarged or diminished cornice has its parts, in height and in projection, of the same proportions as those of another, already given. Here it is only necessary to suppose the height or projection given; thus, take one of them as the height to be given, and find a fourth proportional to the following three measures, placed in order, viz., the height of the given cornice, the height of the required cornice, and the projection of the given cornice; then divide the height of the required cornice in the same proportion as the height of the given one, and the projection of the one required, in the same proportion as the projection of that given.

The drawing of the flutes of a diminished pilaster, with curved sides, depends also upon the division of a line in the same proportion as one already divided: thus, a line equal to, or longer or shorter than the breadth of the pilaster, may contain the aggregate breadths of the number of flutes and fillets, in just proportion; then drawing several equidistant lines parallel to the base on the surface of the pilaster to be fluted, divide each of these equidistant lines in the same proportion; then a curve being drawn through each set of corresponding points will be the terminations of the flutes and fillets. For this purpose, an equilateral triangle, with one of its sides divided into the number of flutes and fillets, is sometimes used; for if lines be drawn to the point of concourse of the other two sides, any line parallel to the base will be divided in the same proportion as the base, which must be equal to, or greater than, the breadth of the pilaster at the bottom. The same may also be conveniently done in the following manner: divide a straight line, equal to, or shorter, than the breadth of the pilaster at top; through the points of division draw lines parallel to each other, making any angle with the divided line: then if this series of parallels be intersected by a line drawn in any direction, such line will be divided in the same proportion as the given line. Suppose, therefore, the parallels to be at right angles to the given line: to divide any line on the surface of the pilaster, take the extension of the line, and apply one end of it from any point in one of the extreme parallel lines as a centre, and describe an arc cutting the most remote of the parallel lines; then a line drawn from the centre to the intersection of the arc and the remote parallel, will be divided in the same proportion, equal to the breadth of the pilaster at the place required; then transfer the line so divided, upon the line on the surface of the pilaster. In like manner, may every other line on the surface of the pilaster be divided, and the curve drawn as before.

The method of diminishing and giving a graceful swell to the shaft of a column, depends upon the parabolic or sinical curve; both of which are easily described. The concoid of Nicomedes is also sometimes employed for this purpose; but the instrument required to describe it is very cumbersome, and the curve produced is not of a better form than that of the parabola, or figure of the sines.

Of joining boards.—A simple board, in its original state from the saw, is in one piece. A compound board is formed of several boards.

Boards may be joined together at a given angle, in various ways; by nails or pins, or by mortise and tenon, or by indenting them together; the latter mode is called *dovetailing*, from the sections of the projecting parts, and those of the hollows, being formed to that of a dovetail.

Dovetailing is of three kinds, viz., common, lap, and mitre: common dovetailing shows the form of the pins or projecting parts, as well as of the excavations made to receive them. Lap dovetailing conceals the dovetails, but shows the thickness of the lap in the return side, which appears like the edge of a thin board. Mitre dovetailing conceals the dovetails, and shows only a mitre on the edges of the planes at their surface of concourse; that is, the edges in the same plane, the seam or joint being in the concourse of the two faces, making the given angle with each other. Dovetailing is used in fixing very wide boards together, where the seam or line of junction is in the concourse of the two faces, and the fibres of the wood of each board are perpendicular to a plane passing through such line.

Concealed dovetailing is particularly useful where the faces of the boards are intended to form a saliant angle; but where the faces form a re-entrant angle, common dovetailing will best answer the purpose, as it is not only stronger and cheaper, but is entirely concealed, the dovetails only showing upon the saliant angle.

Indeed, where the faces form a re-entrant angle, and each board is to be fastened to a wall, the two boards may be fixed together by means of a groove in the one and a tongue in the other; and if well nailed previous to their being brought to their situation, so that the nails may not be seen in the faces, this will answer as good a purpose as dovetailing.

When several simple boards are glued together, to form a broad face, they are sometimes strengthened by fixing another simple board across the end, or across each end, as may be required, by means of a groove and tongue, or by mortise and tenon, and reducing the face of the whole compound board to a plane; the transverse pieces are called *clamps*, and the compound board is said to be *clamped*.

In simple and compound boards, where the faces are required to form an angle, and where the fibres of the wood are required to be parallel to the line of concourse of the two planes or faces which form the angle, the two boards are fastened together by tonguing the edge of one of them the whole of its length, and running a groove in the face of the other next to the edge to receive it, so that when the two boards are joined together, the re-entrant angle shows only a line at the concourse of the two surfaces, but the saliant angle shows a line parallel to the line of concourse, which is the intersection of the inner surface of one board produced to meet the external surface of the other; so that to form the saliant angle, the thickness of one board must be added to the breadth of the other, and thus the face of the one is lapped upon the edge of the other the whole of its thickness.

The most common way of joining boards with the fibres thus disposed, in respect of the line of concourse of their inclination, is by lapping the face of one upon the edge of the other, and fastening them together with nails, driven through the lap into the substance of the other.

Besides what has now been treated of, as principles on which the practice of joinery depends, many particulars relating to the art, the definitions of the terms, and several articles which require long description, and a reference to plates, will be found under the following alphabetical order viz.:

Blockings
Boarded Floors
Bolt
Boxing of a Window
Brackets for Shelves
Brackets for Stairs
Brads, in Joinery
Butt-Hinges
Butt-Joint, in Hand-Railing
Cap, in Joinery
Cased Sash-Frames
Casements
Casting, in Joinery
Centre of a Door
Chamfering
Cheeks of a Mortise
Circular
Circular Work
Clamp
Clamping
Cloak-Pins and Rail
Communicating Doors
Curtail Step
Cut Brackets
Cut Standards
Cylindrical Work
Deal
Description
Diminished Bar
Diminishing Rule
Dog-legged Stairs
Doors, framed
Double-hung Sashes
Dovetail
Dovetailing
Draw-bore
Draw-bore Pins
Dressings
Elbows of a Window
Face-Mould
Falling Mould
Feather-edged Boards
Fence
Fillet
Flaps
Floor
Folding Doors
Folding Joint
Folds
Fox-tail Wedging
Frame, in Joinery
Franking
French Casements
Frieze Panel
Frieze Rail
Furniture

Gluing up of a Base refers to Base; Bridge-Board refers to Notch-Board; Curtail Step refers to the article Stair; Dog-legged Stairs refers to Staircasing; and Inlaying refers to Marquetry and Veneering. Among the foregoing articles, Boarded Floor, Floor, Boxing of a Window, and Description, are of considerable length; Hand-Railing and Hinging are complete articles, accompanied with plates.

Anything omitted in the foregoing catalogue will be explained in the subsequent part of this article.

Mouldings.—The names of moulding in joinery, according to their situation and combination, in various pieces of joiners' work.

Figure 1, edge, said to be rounded.

Figure 2, quirked bead, or bead and quirk.

Figure 3, bead and double quirk, or return bead.

Figure 4, double bead, or double bead and quirk.

Figure 5, single torus.

Figure 6, double torus. Here, it is to be observed, that the distinction between torus mouldings and beads, in joinery, is, that the outer edge of the former always terminates with a fillet, whether the torus be double or single, whereas in beads there is no fillet on the outer edge.

Figure 7, 8, 9, single, double, and triple reeded mouldings; semi-cylindric mouldings are denominated *reeds*, either when they are terminated by a straight surface equally protuberant on both sides, as in these figures, or disposed longitudinally round the circumferance of a shaft; but if only terminated on one side with a flush surface, they are then either beads or torus mouldings.

Figure 10, reeds disposed round the convex surface of a cylinder.

Figure 11, 12, 13, fluted work. When the flutes are semicircular, as in *Figure* 11, it is necessary that there should be some distance between them, as it would be impossible to bring their junction to an arris; but in flutes, whose sections are flat segments, they generally meet each other without any intermediate straight surface between them. The reason of this is, that the light and shade of the adjoining hollows are more contrasted, the angle of their meeting being more acute than if a flat space were formed between them. See *Figures* 12 and 13.

Figure 14, simple astragal, or half round bar, for sashes.

Figure 15, quirked astragal bar.

Figure 16, quirked Gothic bar.

Figure 17, another form of a Gothic bar.

Figure 18, double ogee bar. This and the preceding forms are easily kept clean.

Figure 19, quirked astragal and hollow. Bars of this structure have been long in use.

Figure 20, double reeded bar.

Figure 21, triple reeded bar.

Figure 22, base moulding of a room, with part of the skirting. When the base mouldings are very large, they ought to be sprung, as in this diagram.

A. The base moulding.

B. Part of the plinth.

In order to know of what thickness a board would be required to get out a moulding upon the spring, the best method is to draw the moulding out to the full size, then draw a line parallel to the general line of the moulding, so as to make it equally strong throughout its breadth, and also of sufficient strength for its intended purpose.

Figure 23, a cornice. The part A forming the corona, is got out of a plank.

B. A bracket.

C. The moulding on the front spring.

D. A cover board forming the upper fillet.

E. A moulding, sprung below the corona.

F. A bracket.

Shutters to be cut must first be hung the whole length, and taken down and cut: but observe that you do not cut the joint by the range of the middle bar, but at right angles to the sides of the sash-frame; for unless this be done, the ends will not all coincide when folded together. In order to hang shutters at the first trial, set off the margin from the bead on both sides, then take half the thickness of the knuckle of the hinge, and prick it on each side, from the margin so drawn towards the middle of the window, at the places of the hinges, put in brads at these pricks, then putting the shutter to its place, screw it fast, and when opened, it will turn to the place intended.

Mouldings are mitred by means of a templet, which is a small piece of wood, moulded in a reverse form to the mouldings that are to be mitred, so that the surface of the templet may coincide with that of the surface of the moulding, and to a portion of the plane surface of the framing, both on the face and on the edge adjoining: the ends of the templet are cut to an angle of 45 degrees in a plain perpendicular to the face, the one end forming a right angle with the other.

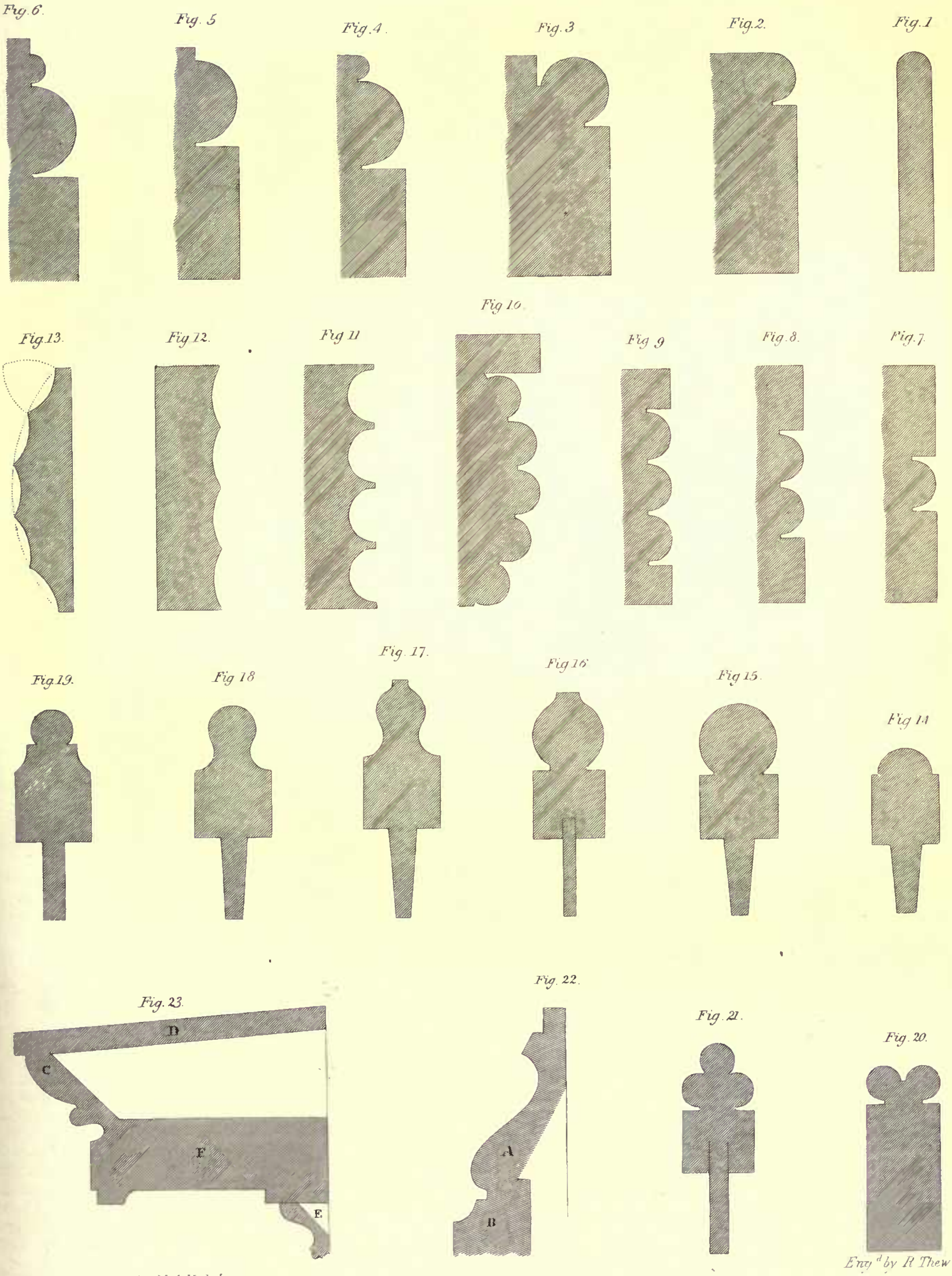
To scribe one piece of board or stuff to another.—When the edge end, or side, of one piece of stuff is fitted close to the superficies of another, it is said to be scribed to it. Thus the skirting boards of a room should be scribed to the floor. In moulded framing, the moulding upon the rails, if not quirked, are scribed to the styles, and muntins upon rails.

To scribe the edge of a board against any uneven surface.—Lay the edge of the board over its place, with the face in the position in which it is to stand, with a pair of stiff compasses opened to the widest part, keeping one leg close to the uneven surface, move or draw the compasses forward, so that the point of the other leg may mark a line on the board, and that the two points may always be in a straight line, parallel to the straight line in which the two points were at the commencement of the motion: then cut away the wood between this line and the bottom edge, and they will coincide with each other.

To rebate a piece of stuff.—When the rebate is to be made on the arris next to you, the stuff must be first tried-up on two sides: if the rebate be not very large, set the guide of the fence of the moving fillister to be within the distance of the horizontal breadth of the intended rebate; and screw the stop so that the guide may be something less than the vertical depth of the rebate from the sole of the plane; set the iron so as to be sufficiently rank, and to project equally below the sole of the plane; make the left-hand point of the cutting-edge flush with the left-hand side of the plane: the tooth should be a small matter without the right-hand side. Proceed now to gauge the horizontal and vertical dimensions of the rebate: begin your work at the fore end of the stuff; the plane being placed before you, lay your right hand partly on the top hind end of the plane, your four fingers upon the left side, and your thumb upon the right, the middle part of the palm of the hand resting upon the round of the plane between the top and the end; lay the thumb of your left hand over the top of the fore end of the plane, bending the thumb downwards upon the right-hand side of the plane, while the upper division of the fore-finger, and the one next to it, goes

JOINERY.

PLATE. I.



Drawn by M. A. Nicholson

Eng^d by R. Thew

obliquely on the left side of the plane, and then bends with the same obliquity to comply with the fore end of the plane; the two remaining fingers are turned inwards; push the plane forward, without moving your feet, and a shaving will be discharged equal to the breadth of the rebate; draw the plane towards you again to the place you pushed it from, and repeat the operation: proceed in this manner until you have gone very near the depth of the rebate, move a step backward, and proceed as before, go on by several successive steps, operating at each one as at first, until you get to the end; then you may take a shaving or two the whole length, or take down any protuberant parts.

In holding the fillister, care must be taken to keep the sides vertical, and consequently the sole level: then clean out the bottom and side of the rebate with the skew-faced rebate plane, that is, plane the bottom and side smooth, until you come close to the gauge-lines: for this purpose the iron must be set very fine, and equally prominent throughout the breadth of the sole.

If your rebate exceed in breadth the distance which the guide of the fence can be set from the right side of the plane, you may make a narrow rebate on the side next to you, and set the plough to the full breadth, and the stop of the plough to the depth: make a groove next to the gauge-line: then with the firmer chisel cut off the wood between the groove and the rebate level with the bottom; or should the rebate be very wide, you may make several intermediate grooves, leaving the wood between every two adjacent grooves of less breadth than the firmer chisel, so as to be easily cut out; having the rebate roughed out, you may make the bottom a little smoother with the paring chisel; then with a common rebate plane, about an inch broad in the sole, plane the side of the bottom next to the vertical side, and with the jack plane take off the irregularities of the wood left by the chisel: smooth the farther side of the bottom of the rebate with the skew rebate plane, as also the vertical side: with the trying plane smooth the remaining part next to you, until the rebate is at its full depth. If anything remain in the internal angle, it may be cut away with a fine-set paring chisel; but this will hardly be necessary when the tools are in good order.

When the breadth and depth of the rebate is not greater than the depth which the plough can be set to work, the most expeditious method of making a rebate, is by grooving it within the gauge-line on each side of the arris, and so taking the piece out without the use of the chisel: then proceed to work the bottom and side of the groove, as before. By these means you have the several methods of rebating when the rebate is made on the left edge of the stuff: but if the rebate be formed from the right-hand arris, it must be planed on two sides, or on one side and an edge, as before; place the stuff so that the arris of the two planed sides may be next to you. Set the sash-fillister to the whole breadth of the stuff that is to be left standing, and the stop to the depth, then you may proceed to rebate as before.

To rebate across the grain.—Nail a straight slip across the piece to be rebated, so that the straight edge may fall upon the line which the vertical side of the rebate makes with the top of the stuff, keeping the breadth of the slip entirely to one side of the rebate; then having set the stop of the dado grooving plane to the depth of the rebate, holding the plane vertically, run a groove across the wood; repeat the same operation in one or more places in the breadth of the rebate, leaving each interstice or standing-up part something less than the breadth of the firmer chisel: then with that chisel cut away these parts between every two grooves, but be careful, in doing this, that you do not tear the wood up; pare the bottom pretty smooth, or after having cut the rough away with the chisel, take a rebating plane with the iron set rather rank, and work the prominent parts down to the aforesaid grooves nearly. Lastly, with a fine-set screwed rebating plane, smooth the bottom next to the vertical side of the rebate. The other parts of the bottom may be taken completely down with a fine-set smoothing plane: in this manner you may make a tenon of any breadth.

Stairs.—Are one of the most important things to be considered in a building, not only with regard to the situation, but as to the design and execution: the convenience of the building depends on the situation, and the elegance on the design and execution of the workmanship. A staircase ought to be sufficiently lighted, and the head-way uninterrupted. The half paces and quarter paces ought to be judiciously distributed. The breadth of the steps ought never to be more than 15 inches, nor less than 10, the height not more than 7, nor less than 5; there are cases, however, which are exceptions to all rule. When you have the height of the story given in feet, and the height of the step in inches, you may throw the feet into inches, and divide the height of the story in inches by the height of the step; if there be no remainder, or if the remainder be less than the half of the divisor, the quotient will show the number of steps: but if the remainder be greater than the half of the divisor, you must take one step more than the number shown by the quotient; in the two latter cases, you must divide the height of the story by the number of steps, and the quotient will give the exact height of a step: in the first case you have the height of the steps at once, and this is the case whatever description the stairs are of. In order that people may pass freely, the length of the step ought never to be less than 4 feet, though in town-houses, for want of room, the going of the stair is frequently reduced to 2½ feet.

Stairs have several varieties of structure, which depend principally on the situation and destination of the building.

Geometrical stairs are those which are supported by one end being fixed in the wall, and every step in the ascent having an auxiliary support from that immediately below it, and the lowest step, consequently, from the floor.

Dog-legged stairs are those which have no opening or well-hole, the rail and balusters of both the progressive and returning flights fall in the same vertical planes, the steps being fixed to strings, newels, and carriages, and the ends of the steps of the inferior kind terminating only upon the side of the string, without any housing. For farther particulars, *see* Dog-Legged Stairs.

Bracket stairs are those that have an opening or well, with strings and newels, and are supported by landings and carriages, the brackets mitering to the ends of each riser, and fixed to the string-board, which is moulded below like an architrave.

The same methods must be observed as to taking the dimensions of bracket stairs, and laying down the plan and section, as in dog-legged stairs. In all stairs whatever, after having ascertained the number of steps, take a rod, the height of the story from the surface of the lower floor to the surface of the upper floor: divide the rod into as many equal parts as there are to be risers, then if you have a level surface to work upon below the stair, try each one of the risers as you go on, this will prevent any excess or defect, which even the smallest difference will occasion; for any error, however small, when multiplied, becomes of considerable magnitude, and even the difference of an inch in the last riser being too high or too low, will not only have a bad effect to the eye, but will be apt to confound persons not thinking of any such irregularity. In order to try the steps properly by the story-rod, if you have not a level surface to work from, the better way will be to lay two rods or boards, and level their top surface to that of the floor, one of these rods being placed a little within the string, and the other near or close to the wall, so as to be at right angles to the starting line of the first riser, or, which is the same thing, parallel to the plan of the string; set off the breadth of the steps upon these rods, and number the risers; you may set not only the breadth of the flyers, but that of the winders also. In order to try the story-rod exactly to its vertical situation, mark the same distances on the backs of the risers upon the top edges, as the distances of the plan of the string-board and the rods are from each other.

[The methods of describing the scroll and all ramps and knees, are described geometrically in the articles Hand-Railing and Staircasing.]

As the internal angle of the steps is open to the end, and not closed by the string, as in common dog-legged stairs, and the neatness of workmanship is as much regarded as in geometrical stairs; the balusters must be neatly dovetailed into the ends of the steps, two in every step; the face of each front baluster must be in a straight surface with the face of the riser; and as all the balusters must be equally divided, the face of the middle baluster must of course stand in the middle of the face of the riser of the preceding step and the face of the riser of the succeeding one. The risers and treads are all glued and blocked previously together; and when put up, the under side of the step nailed or screwed into the under edge of the riser, and then rough-bracketed to the rough-strings, as in dog-legged stairs, the pitching-pieces and rough-strings being similar to those. In gluing up the steps, the best method is to make a templet, so as to fit the external angle of the steps with the nosing.

Geometrical stairs.—The steps of Geometrical stairs ought to be constructed so as to have a very light and clean appearance when put up: for this purpose and to aid the principle of strength, the risers and treads, when planed up, ought not to be less than 1⅛ inch, supposing the going of the stair, or length of the step, to be 4 feet; and for every 6 inches in length you may add ⅛ part more; the risers ought to be dovetailed into the cover, and when the steps are put up, the treads are screwed up from below to the under edges of the risers: the holes for sinking the heads of the screws ought to be bored with a centre-bit, and then fitted closely in with wood, well matched, so as to conceal the screws entirely, and to appear as one uniform surface without blemish. Brackets are mitered to the riser, and the nosings are continued round: in this mode, however, there is an apparent defect, for the brackets, instead of giving support, are themselves unsupported, depending on the steps, and are of no other use, in point of strength, than merely tying the risers and treads of the internal angles of the steps together; and from the internal angles being hollow, or a re-entrant right angle, except at the ends, which terminate by the wall at one extremity, and by the brackets at the other, there is a want of regular finish. The cavetto or hollow is carried all round the front of the slip, returned at the end, returned again at the end of the bracket, thence along the inside of the same, and then along the internal angle of the back of the riser.

This is a slight imitation of the ancient mode, which was to make the steps solid all the way, so as to have everywhere throughout its length a bracket-formed section. This, though more natural in appearance, and much stronger, would be expensive and troublesome to execute, particularly when winders are used.

The best mode of constructing geometrical stairs, is to put up the strings, to mitre the brackets to the risers as usual, and finish the soffit with lath and plaster, which will form an inclined plane under each flight, and a winding surface under the winders. In elegant buildings, the soffit may be divided into panels. If the risers are got out of two-inch stuff, it will greatly add to the solidity.

In order to get a true idea of the twist of the hand-rail, the section of the rail, by a plane passing through the axis of the well-hole or cylinder, is everywhere a rectangle; that is, the plum or vertical section tending to the centre of the stair. This rectangle is everywhere of an equal breadth, but not of an equal vertical dimension in every part of the rail, unless that the risers and treads are everywhere the same from the top to the bottom: the height is greatest above the winders, because the tread is of less breadth, and less above the flyers; the tread being there the greatest. If you cut the rail, after squaring it, perpendicular to any of its curved sides, the section will not then be a rectangle, three of the sides will at least be curved. Hence two falling-moulds laid down in the usual way, will not square the rail, though in wide openings they may do it sufficiently near. Nor in squaring the rail can the square ever be applied at right angles to any one of the four arrises, for the edge of the stock will not coincide with the side of the rail, being curved; this would be easily made to appear by making a wreathed part of a rail of unusual dimensions, and cutting it in both directions. Therefore, to apply the square right, keep the stock to the plumb of the stair; and to guide the blade properly, the stock ought to be very thick, and made concave to the plan, so as to prevent the possibility of its shaking or turning from side to side; as a little matter up, or a little down, in the direction of the blade, would make a great difference in the squaring of the rail.

All this might easily be conceived from the cylinder itself, for there is no direction in which a straight line can be drawn on the surface of a cylinder but one, and this line is in a plane passing through the axis of the cylinder, and as the two vertical surfaces of the rail are portions of cylinders, there can be no straight line upon such surface but what must be vertical: all others, from this principle, are curves, or the sections of the rail are bounded by curves, or by a curve on that side.

In gluing up a rail in thicknesses, it will be sufficiently near to get out a piece of wood to the twisted form by two falling-moulds, provided the well-hole be not less than one foot diameter. The thickness of this piece, as is there stated, must be equal to the thickness, or rather the horizontal breadth of the rail, together with the thickness which the number of saw-kerfs will amount to, and also the amount of the substance taken away by planing the veneers. We are now supposing the plan of the rail to be semicircular, with two straight parts, one above and one below, a plan more frequently adopted from motives of economy, than from any property of elegance.

The first thing to be done is to make a cylinder of plank to the size of the well-hole. Draw two level lines round the surface of this cylinder at the top and bottom; upon each of these lines set off the treads of the steps at the end next the well-hole. Draw lines between every two corresponding points at the head and foot, and these lines will be all parallel to the axis of the cylinder. Upon each of the springing lines, and also upon a middle line between these two lines, set the heights of the winders, and the height of one of the flyers above and below, or as much as is intended to be taken off the straight of the rail. Take a pliable slip of wood, straight on one edge, and bend it round; keep the straight edge of it upon the three corresponding points, at the height of the last riser of the flyer; then draw the tread of the first

JOINERY.

Fig. 24.

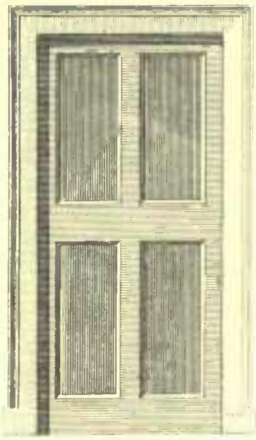


Fig. 25.

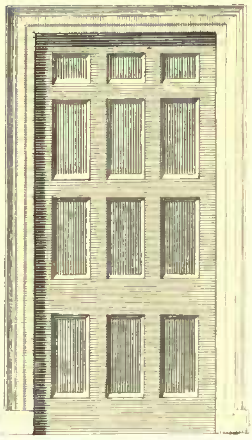


Fig 26

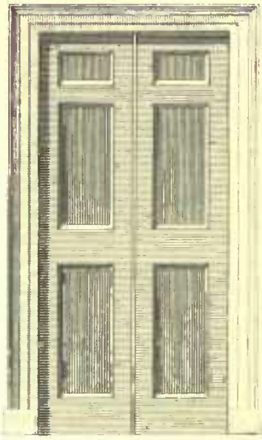


Fig. 27.

Fig 28.

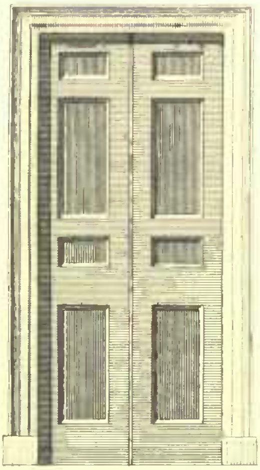


Fig. 29.

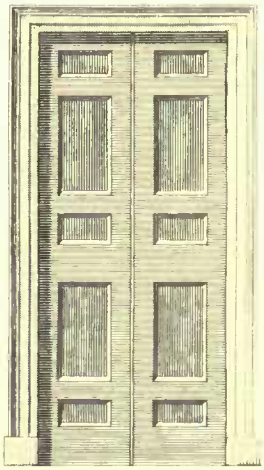


Fig. 30.

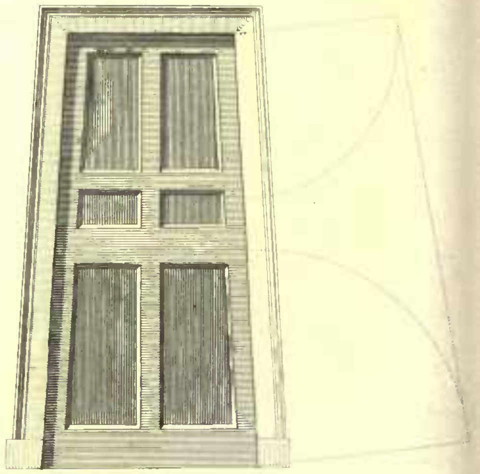


Fig. 31.

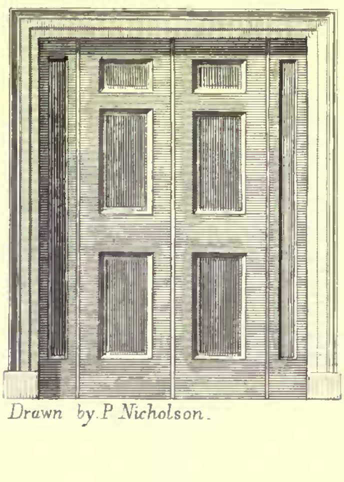


Fig. 32.

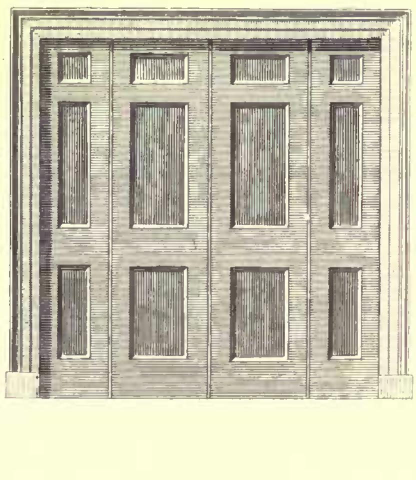
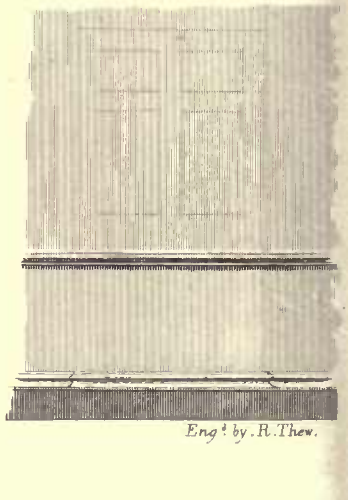


Fig. 33.



Drawn by P. Nicholson.

Engd. by R. Thew.

winding step by the straight edge, from the line where the cylindric part commences, to the first perpendicular line on the curved surface; take the next three points higher, and draw a line between the second and third perpendicular lines, proceed in like manner with the next three higher points, and draw a line between the next two adjoining cylindric lines, and the lines so drawn between each three points will be the section of the treads of the succeeding winding-steps.

Having thus gone through the cylindric part, draw a step at the top, and another at the bottom, and thus the sections of the steps will be completed; draw the hypothenusal or pitch lines of the flyer on the lower part, and that of the upper part, and whatever difference you make in the height of the rail between the flyers and the winders, you must set it up from the nosings of the steps of the winders upon two of the perpendicular lines: draw a line through the two points by bending a straight-edged slip round the cylinder, the straight edge of the slip coinciding with these points: this line will represent the top of the rail over the winders, and the hypothenusal lines at the bottom and top, that of the flyers; then curve off the angles at the top and bottom where the rail of the winding parts meets that of the flyers above and below, and a line being drawn parallel to this, will form the falling-mould. The reason of making the vertical elevation of the rail more upon the winders than the flyers, is, that the sudden elevation of the winders diminishes the height of the rail in a direction perpendicular to the raking line, and by this means persons would be liable to fall over it.

To lay the veneers upon the cylinder, if bed-screws or wedges are used, you may try the veneers first upon the cylinder, screwing them down without glue; prepare several pieces of wood, to lie from 6 to 12 inches apart, according to the diameter of the well-hole, with two holes in each, distant in the clear something more than the breadth of the rail. Then having marked the positions of the places of these pieces on the cylinder, pierce the cylinder with corresponding holes on each side, of the depth of the rail. If the cylinder be made of plank 2 inches thick, it will be sufficient for the screws: but if of thinner stuff, it will be convenient to set it on end upon stools, to get underneath, confining the top with nuts. Unscrew one half, three men being at work, one holding up all the veneers, another gluing, and the third laying them down successively one after the other, until all are glued: screw them down immediately. Unscrew the other half and proceed in like manner, and the rail will be glued up. The glue that is used for this purpose ought to be clear, and as hot as possible; the rail ought likewise to be made hot, as otherwise the glue will be liable to set before all the veneers are put down, and ready for the screws: this operation should therefore be done before a large fire, and the veneers thoroughly heated previous to the commencement, in order that the heat may be as uniformly retained as possible throughout the process. The glue in the joints of the rail will take about three weeks to harden in dry weather.

Doors.—When a board is made to fit an aperture in a wall, for the purpose of preventing ingress or egress at pleasure, it is called *a door*, or *closure.*

Doors are seldom constructed of one entire board, from the difficulty of procuring a simple board of sufficient size; neither are they often constructed of simple boards joined edge to edge, to form a compound board, without having transverse pieces fastened to one side, or being clamped at the ends; as, without such appendages, the door of this construction would be liable to break in the direction of the fibres, or be subject to crack or split, if not entirely seasoned, or when the texture is unequal in consequence of knots, or the resin not being uniformly disposed.

The most common kind of doors are constructed of several simple boards, not fixed with glue, or any tenacious substance, but by nailing transverse pieces upon the back of the boards, laid edge to edge. The transverse pieces, thus nailed, are called *ledges*, or *bars*, whence the door is said to be *ledged*, or *barred.* In this case, one of the edges, at every joint, is beaded on both sides, or at least on the face which is the outside, the ledges being placed to the inside.

Doors of this description are generally employed in the cottages of the poor, or in the out-houses of superior buildings.

Where doors are required to combine strength, beauty, and durability, a frame, joined by mortise and tenon, must be constructed, with one or more intermediate openings, each of which must be entirely surrounded by three or more parts of the frame, which have grooves ploughed in the edges, for the reception of boards to close the openings. When any parts of the framing are intended to lie in an horizontal position, after the door is hung, or fixed upon its hinges, they are called *rails;* if there are more than two rails, the extreme rail next to the floor is called *the bottom rail*, and that next to the ceiling, *the top rail.* Doors are seldom framed with less than three rails; in which case the middle one is called *the lock rail;* but most doors have two intermediate rails, of which the one next to the top rail is called *the frieze rail.* When there are more than two intermediate rails, those between the lock and frieze rails have no particular name. The extreme parts of the frame to which the rails are fixed, are called *stiles*, and the intermediate parts, *mountings*, from their vertical position. The boards by which the interstices are closed, are called *panels.* The stiles are first defined, on account of some doors being made narrower at the top than at bottom, in the manner of ancient doors.

Figure 24.—A four equal-panelled door; this form is only used in common work, and frequently without mouldings.

Figure 25.—A nine-panelled door, with square panels at the top.

Figure 26.—A six equal-panel pair of folding doors, two panels in breadth and three in height.

Figure 27.—A double margin or folding-door, with three panels in height, and two in breadth; being all equal.

Figure 28.—A double margin, or pair of folding-doors, with four panels in height and two in breadth, and with two lying panels below the top rail, and two above the lock rail.

Figure 29.—A ten-panelled pair of folding-doors, five in height and two in breadth, with two lying panels under the top rail, two above the bottom rail, and two in the middle: of this form is the ancient door of the Pantheon at Rome.

Figure 30.—An ancient door, narrower at the top than at the bottom: of this form is the door of the temple of Vesta, at Rome, and that of Erechtheus, at Athens. This construction may be useful for causing the door to rise as it opens, in order to clear a carpet, or to make it shut of itself.

Figures 31 and 32.—Doors of communication, or such as shut out of the way of the floor. *Figure* 31, folds round upon the partition, by means of hanging styles: *Figure* 32, is made to shut occasionally in the partition, so as to be entirely concealed. The two middle parts open, like ordinary folding doors, upon hinges fastened to the extreme parts.

Figure 33.—A jib-door, which when shut may be as much concealed as possible. Jib-doors are used to preserve the uniformity of a room, or to save the expense of a corresponding door.

Doors ought to be made of clean good stuff, firmly put together, the mitres or scribings brought together with the greatest exactness, and the whole of their surfaces perfectly smooth, particularly those made for the best apartments of good houses; in order to effect this, the whole of the work ought to be set out and tried up with particular care; saws and all other tools must be in good order; the mortising, tenoning, ploughing, and sticking of the mouldings, ought to be correctly to the gauge lines; these being strictly attended to, the work will of necessity, when put together, close with certainty; but if otherwise, the workman must expect a great deal of trouble in paring the different parts before the work can be made to appear in any degree passable: this will also occasion a want of firmness in the work, particularly if the tenons and mortises are obliged to be pared.

In bead-and-flush doors, the best way is to mitre the work square, afterwards put in the panels, and smooth the whole off together, then marking the panels at the parts of the framing they agree to, take the door to pieces, and work the beads on the styles, rails, and mountings.

If the doors are double-margin, that is, representing a pair of folding-doors, the staff stile, which imitates the meeting stiles, must be entered to the top and bottom rails of the door, by forking the ends into notches cut in the top and bottom rails.

Of hanging doors.—Having treated fully on the various kinds of hinges under the article Hinging, we shall here make a few observations upon, and give some rules for, hanging of doors, so as to clear the ground or carpet.

First, Raise the floor under the door as much as may be necessary, according to the thickness of the carpet, &c.

Secondly, Make the knuckle of the bottom hinge to project beyond the perpendicular of the top hinge about one-eighth of an inch: this will throw the door off the floor.

Note.—The centre of the top hinge must project a little beyond the surface of the door, if the hinge is let equally into the door and into the jamb; otherwise, if the centre lie in the surface of the door, it ought to be placed at the very top, which is seldom done, except when hung with centres.

Thirdly, Fix the jamb, on which the door hangs, out of the plumb line, so that the top of the jamb may incline to the opposite jamb about one-eighth part of an inch: this will contribute to the effect of clearing the door from the floor.

Fourthly, Make the door, when shut, to project at the bottom towards the inside of the room, about one-eighth of an inch, which may be effected by giving the rebate the quantity of inclination requisite.

Note.—Although any of the above methods, properly applied, will make a door swing sufficiently clear of the floor, yet as each one separately will require to be done in so great a degree as to offend the eye, I do not recommend it in nice work, but would rather advise a combination of them all to be used, thus:

Raise the floor about one-eighth of an inch under the door; make the jamb on which the door hangs incline to the opposite jamb about one-quarter of an inch; make each rebate that stops the door project at the bottom one-eighth part of an inch to that side of the room on which the door opens. Now these several methods practised in the above small degrees, which will not be perceptible, will throw the door sufficiently out of the level when opened to a square; that is, it will be at least half an inch when the height of the door is double its width.

Fifthly, Rising hinges, which are made with a spiral groove winding round the knuckle, answer a similar end; this construction of hinge requires that the door should be beveled at the top next to the ledge or door-catch, as much as the hinge rises in one quarter of its revolution.

Sixthly, This may also be effected by adopting a door in the form of the antique doors; that is, the bottom to be wider than the top, the jambs having the same inclination.

Mouldings of Doors.—The different denominations of framed doors, according to their mouldings and panels, and framed work in general. The figures in the Plates, to which these descriptions refer, are sections of doors, through one of the stiles, taking in a small part of the panel; or they may be considered as a vertical section through the top rail, showing part of the panel.

Figure 34, the framing is without mouldings, and the panel a straight surface on both sides: this is denominated *doors square and flat panel on both sides.*

Figure 35, the framing has a quirked ovolo, and a fillet on one side, but without mouldings on the other, and the panel flat on both sides: this is denominated *doors quirked ovolo, fillet and flat panel, with square back.*

Figure 36, differs only from the last in having a bead instead of a fillet, and is therefore denominated *quirked ovolo, bead and flat panel, with square back.*

Figure 37, has an additional fillet on the framing to what there is in *Figure* 36, and is therefore denominated *quirked ovolo, bead, fillet, and flat panel, with square back.*

Note.—When the back is said to be square, as in *Figure* 35, 36, 37, the meaning is, that there are no mouldings on the framing, and the panel is a straight surface on one side of the door.

Figure 38, the framing struck with quirk ogee and quirked bead on one side, and square on the other; the surface of the panel straight on both sides; this is called *quirked ogee, quirk bead and flat panel, with square back.*

Figure 39, differs from the last only in having the bead raised above the lower part of the ogee, and a fillet. This is therefore denominated *quirked ogee, raised bead, and flat panel, with square back.*

Figure 40, is denominated *cove, raised bead, and flat panel, with square back.*

Figure 41, is denominated *quirked ovolo, bead, fillet, and raised panel on front, with square back.* The rising of the panel gives strength to the door, and on this account they are often employed in street doors, though the fashion at present is discontinued in the inside of buildings.

Figure 42, the framing is the same as the last, but the panel is raised in front, and has an ovolo on the rising. This is therefore denominated *quirked ovolo, bead, and raised panel, with ovolo on the rising on front of door, with square back.*

Figure 43, is denominated *quirked ogee, raised panel, ovolo and fillet on the rising, and astragal raised on the flat of panel and square back.*

Note.—The raised side of the panel is always turned towards the street.

Figure 44, is denominated *quirked ovolo, bead, fillet, and flat panel, on both sides.* Doors of this description are used between rooms, or between passages and rooms, where the door is equally exposed on both sides. When the panels are flat on both sides, or simply chamfered on one side and flat on the other, and the framing of the door moulded on the side which has the flat panels: such doors are employed in rooms where one side only is exposed, and the other never but when opened, being turned towards a cupboard or dark closet.

Figure 45, is denominated *bead, but, and square,* or more fully, *bead and but front, and square back.* In bead and but work, the bead is always struck on the outer arris of the panel, in the direction of the grain.

Figure 46, is denominated *bead and flush front and*

Fig. 34.

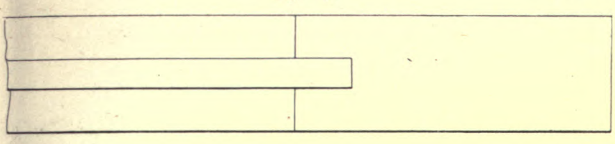


Fig. 35.

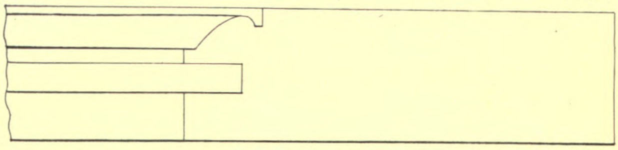
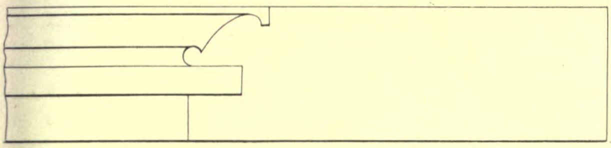


Fig. 36.



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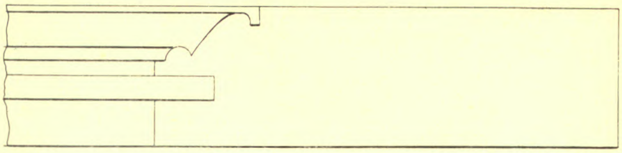


Fig. 38.

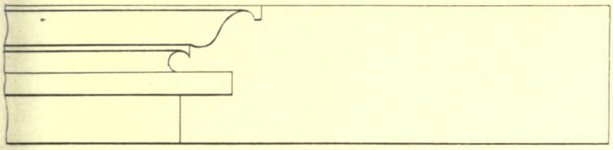


Fig. 39.

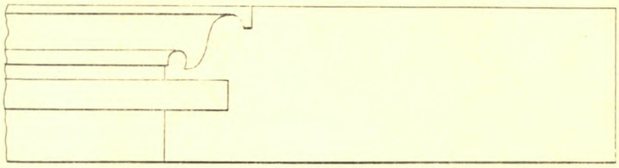


Fig. 40.

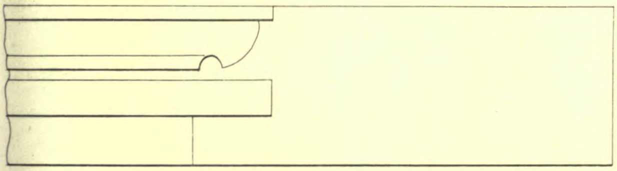


Fig. 41.

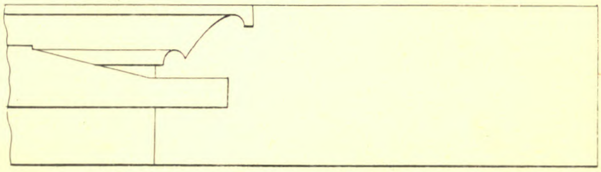


Fig. 43.

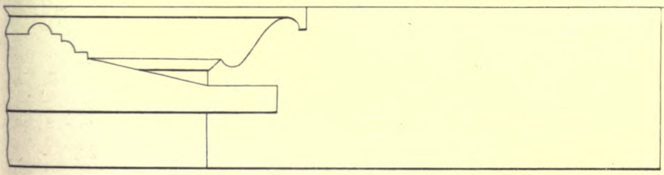


Fig. 42.

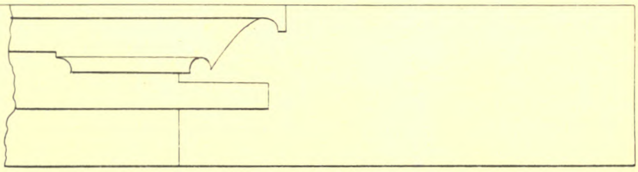


Fig. 44.

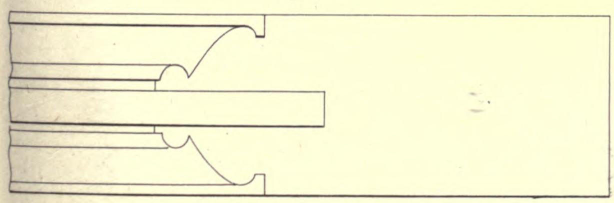


Fig. 45.

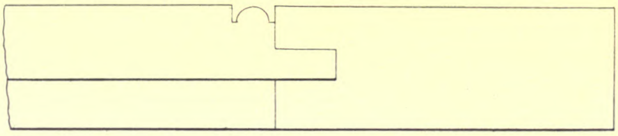


Fig. 46.

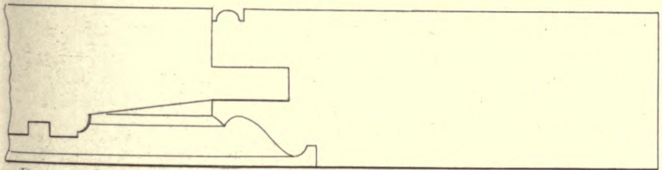
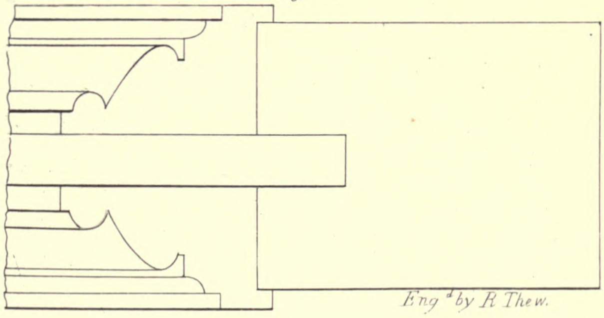


Fig. 47.



Designed by P. N.
Drawn by M. A. Nicholson.

Eng^d by R. Thew.

Fig 48

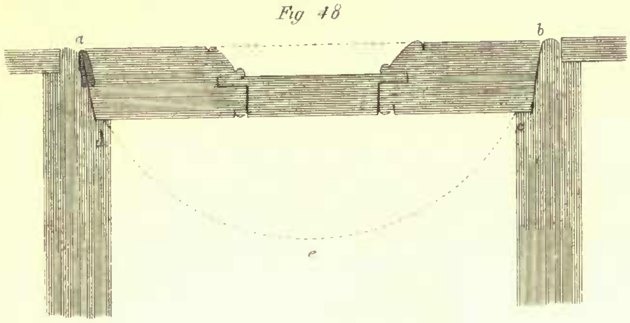


Fig 49

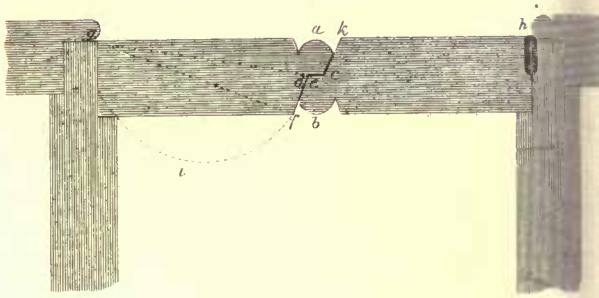


Fig 50.

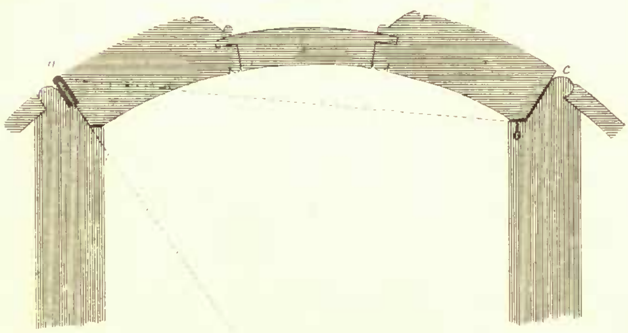


Fig 51

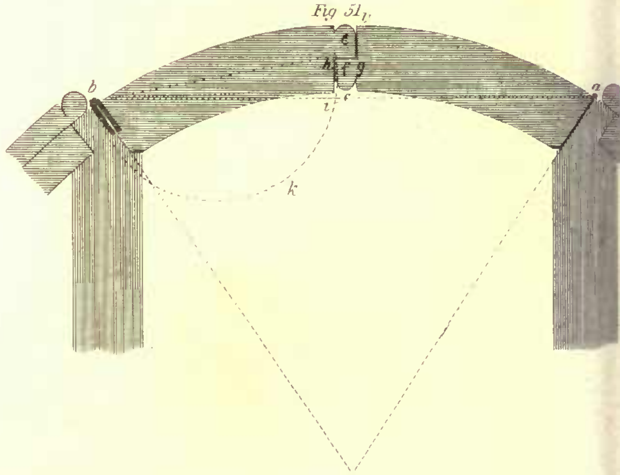


Fig 52

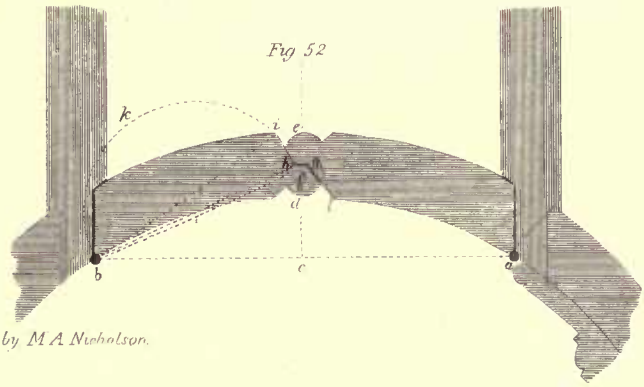
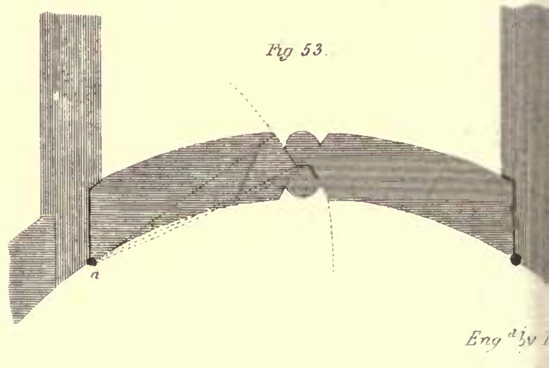


Fig 53.



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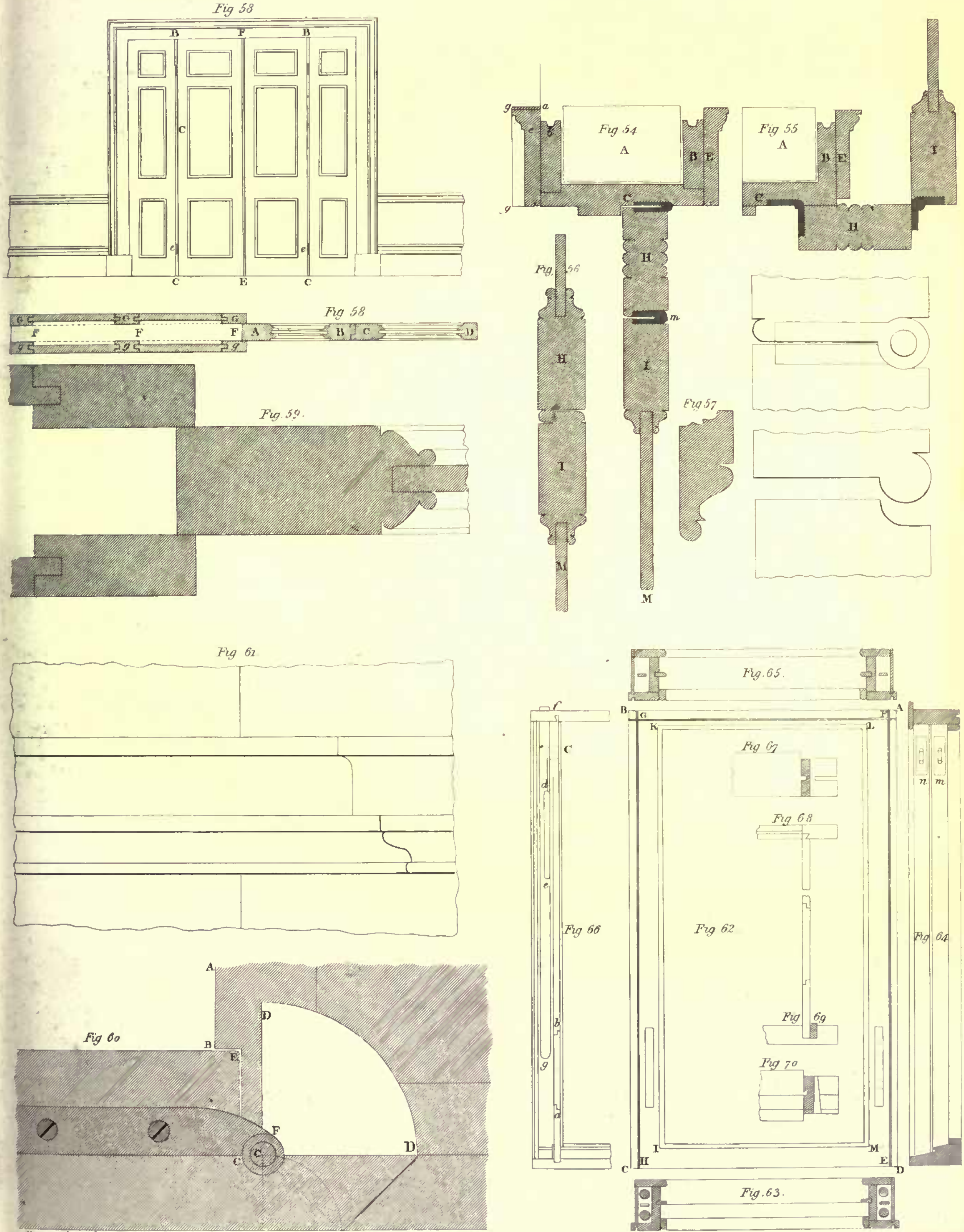
Eng^d by

JOINERY.

PLATE V



Drawn by M.A. Nicholson

Eng^d by R. Thew.

quirked ogee, raised panel, with ovolo on the rising, grooved on flat of panel, on back. Bead and flush, and bead and but work, are always used where strength is required. The mouldings on the inside are made to correspond with the other passage or hall doors.

Figure 47, is a collection or series of mouldings, the same on both sides, and project in part without the framing on each side. The mouldings are laid in after the door is framed square and put together. If bradded through the sides of the quirks, the heads will be entirely concealed; but observe, that the position of the brads must not be directed towards the panels, but into the solid of the framing. The mouldings of doors which thus project are termed *belection mouldings;* belection-moulded work is chiefly employed in superior buildings.

Geometrical Descriptions in Joinery.

To find the true bevel for hanging any door.

Figure 48.—Let *a* be the centre of the hinge; on *a b* the width of the door, describe a semicircle, *b c e d a*, cutting the other side of the door at *c* and *d*. Join *a d* and *b c*, which will be the proper edges of the door, in order to make it open freely.

Note.—The bevelling on the side *a d* is of no other consequence than to make the sides uniform.

To find the joint for a pair of folding doors.

Figure 49.—Let *h* and *g* be the centre of each hinge; bisect *h g* by a perpendicular, *a b*, cutting the thickness of the door at *a* and *b;* bisect *a b* by the perpendicular *c d* at *e;* make *e c* and *e d* each equal to half the thickness that you intend the rebate to be. Suppose you intended the flap, *g a c d f*, to open, draw a line from *d* to the centre of the hinge at *g;* on *d g* describe a semicircle *d f i g*, cutting the other side of the door at *f;* join *f d*, and through *c* draw *c k* parallel to *d f;* then *k c d f* will be the proper joint.

Note.—If you put a bead at the joint, it ought to be equally on each side of the points *a* and *b*.

To find the bevel on the edge of a door, when it is executed on a circular plan, and the door to turn towards the space on the convex side of the circle.

Figure 50.—With regard to the circular door, all that is required is to make the angle *a b c* either a right angle or greater than a right angle (for a right angle is the least that any door will admit of) formed by the edge of the door, and a line drawn from the centre of the hinge to the opposite angle.

For the folding-doors.

Figure 51.—Let *a* and *b* be the centres of the hinges; join *a b*, and bisect it by the perpendicular *c f e*, cutting the door in *c* and *e;* bisect *c e* by the perpendicular, *g f h;* make *f h* and *f g* each equal to half the thickness of the rebate: join *h b;* on it describe the semicircle *h i k b*, cutting the concave side of the door, *i;* join *i h;* through *g* draw *g l* parallel to it; then will *l g h i* be the joint required.

To find the meeting joint of folding doors when the hinges are placed on the concave side of the doors.

Figure 52.—Let *a* and *b* be the centre of the hinges; join *a b*, and bisect it by a perpendicular, *c d e*, at *c*, cutting the thickness of the door at *d* and *e;* bisect *d e* by a perpendicular, *g f h*, cutting *d e* at *f;* make *f h* and *f g* each equal to half the thickness of the rebate; join *b h;* on it describe a semicircle, *h i k b*, cutting the other side of the door contrary to the hinge at *i;* join *i h*, and through *g* draw *g l* parallel to *i h*, cutting the concave side of the door at *l;* then will *i h g l* be the joint sought.

Demonstration.—Let the door *a l g h i* remain in its place; now the angle *b i h* being a right angle, consequently the perpendicular *b i* will be the shortest line that can be drawn from the point *b* to the line *i h;* then suppose the half door to be turned round the hinge at *b;* the point *i* will then describe a circle, whose centre is the hinge at *b;* then will *i h* be a tangent to that circle at *i;* therefore the angle at *i* will touch no other part of the edge of the other door, but at *i*.

If round the centre of the door which opens as *Figure* 53, you describe circles on each side of the rebate, and the edges of each door be made circular, it is plain it will also open in this case.

The plan of the doors here shown, are two or three times thicker than those used in practice, in order to show the principle clearly.

Figure 54, a section of the jamb-post, jamb-linings, grounds, and architraves, with part of the plan of a door.

B *b*. Sections of the grounds, flush, or in the same plane with the plaster.

E *e*. Outside and inside architraves.

g g g g. Line of the plinth.

C. Jamb-lining.

H. Hanging style.

I. Door style hung to the hanging style H, by means of the hinge *m*.

Figure 55, half of the plan: showing the door folded back; the parts in this having the same references as those in Figure 54.

Figure 56, meeting styles.

Figure 57, the moulding of the door, shown to a larger size.

This method is advisable where you have no opportunity of making the doors slide into the partition, as is shown in Figure 32; but whenever that opportunity offers, it should be preferred, as no door can be seen when shut into the partition, which not only keeps them entirely out of the way, but makes the most complete appearance.

Elevation of a pair of folding-doors, to be shut quite out of the way, in order to open a communication between two rooms, or to throw both into one on any occasion.

Figure 58, plan of half the door to a small size.

A. Plan of the outside style.

B, C. Plans of the hanging styles.

D. One of the meeting styles.

G O G, *g g g*. Framed partitions, distant from each other, in the clear, the thickness of the door.

F F F. The space or cavity for the door to work in, which must be made sufficiently wide to receive one half of the door entirely within, or nearly so: doors of communication for general uses may be constructed in this larger door, in which case the middle doors may be hung to the flaps, on the flanks, so that they will open like any other common folding-door; this method, therefore, combines utility and convenience, and is a complete deception. The first leaf of the door must run in a groove at the top, to make it steady.

Figure 59, a section of the style next to the partition, to a large size, with part of the plan of the bottom rail, showing a small part of each partition.

Note. In setting out work of this kind for practice, one half of the plan ought to be completely drawn out.

To find the joint of a jib-door, so that it shall open freely at the hanging side, and the joint to be a plane surface.

Figure 60.—Let C, the centre of the hinge, be in the same plane with the dado, and placed within the substance of the lining, in order to give strength to the jamb.

C E. The thickness of the door at the joint, which produce till it cut the opposite side of the base moulding at A; make A B equal to A C; join B C, and from B draw B D perpendicular to B C; then will B D be the true line through which the surbase-moulding must be cut in a plane perpendicular to the floor. The shadowed part shows a part of the jamb-lining cut out sufficient to let the surbase-moulding move in it.

Note.—If the centre of the hinge had been placed in the plane of the side of the rebate, parallel to the jamb-lining, a deep cavity through the jamb would have been brought into view in the opening of the door, the exposure of which would have been very unsightly.

If the upper part of the door be hinged, the axis of the hinge should be in a straight line with the axis of the centre below, and both the axis of the hinge and the axis of the centre should be in the plane of the face of the door, so that the joint upon the hanging side will always be close.

Figure 61, the elevation of the surbase at the joint.

The construction of a sash-frame, and the manner of putting the several parts of it together.

Figure 62, the elevation of the sash-frame.

A B C D. The outer edge of it.

The dark perpendicular lines E F, G H, are grooves whose distances from the edges L M and K I of the sash-frame, are equal to the depth of the boxing, together with three-eighths of an inch allowed for the margin between the shutters and the bead.

Figure 63, horizontal section of the sides, showing also the plan of the sill.

Figure 64, a vertical section of the sill and top, showing the elevation of the pulley-style *m* and *n*, the pulleys let into the pulley-piece.

Figure 65, the horizontal section of the sides, showing also a plan of the head of the sash-frame.

Figure 66, the elevation of the outer side of the sash-frame: the outside lining being taken away in order to show the work within the sash-frame.

f g, the parting strip fastened by a pin: *e d*, one of the weights connected with the sash by means of a line going over the pulley *c;* the other end fixed to the edge of the sash.

Note.—The weight *d e* is equal to half the weight of the sash.

Figure 67, part of the head of the sash-frame before put together.

Figure 68, the edge of *Figure* 67.

Figure 69, the edge of the bottom, showing the manner of fixing the styles.

Figure 70, the plan of *Figure* 69.

Figure 71 and 72, sections of window-sills, with sections of the under-rail of the sash, showing the best modes of constructing them in order to prevent the weather from driving under the sash-rail.

A. Section of the bottom-rail of the sash.

B. Section of the bead tongued into the sill.

C. Section of the sill.

Figure 73, sections of the meeting-rails, with the side elevations of the upright bars.

C. Rebate for the glass.

D. A square.

E. F. An astragal and hollow moulding.

G. Fillet.

Note.—The small letters denote the same parts of the under-sash.

Figure 74, section of an upright bar, with the plans of two horizontal bars, showing the franking or manner in which they are put together, so as to keep the upright bars as strong as possible. The thickness of the tenon in general comes about one sixteenth of an inch to the edge of the hollow of the astragal, and close to the rebate on the other side.

h h. A dowel to keep the horizontal bars still firmer together.

Note.—The same parts in this have the letters of reference the same as *Figure* 73.

Note also. There is no rebate made for the glass on the inside of the meeting-bar; a groove being made to answer that purpose.

Figure 75.—*Section of common shutters and sash-frame.*

A. Section of the architrave.

B. Ground for the architrave.

F. Back lining of the boxing, tongued into the ground B, and into the inside lining G, of the sash-frame.

G. The inside lining of the sash-frame.

H. The inside bead.

I. The pulley-style.

K. The parting bead.

L. Outside lining.

M. Back lining.

C C C. The front-shutter hung to the inside lining of the sash-frame, G, by means of the hinge *a*.

D D D. Back flap or shutter hung to the front shutter by means of the hinge *b*.

E E E. Another back flap hung to D D D, by means of the hinge *c*.

As in a window, the whole of the light should be shut out, the principle of setting out the shutters is, that each boxing should contain as many shutters as will cover one half; the horizontal breadth of which is from the axis of the hinges to the central vertical line of the windows.

O P Q R. Plan of the lower sash.

O. Rebate of the glass.

P. A square.

Q. An astragal moulding

R. A small square or fillet.

Figure 76, the method of hinging two back flaps together, showing the manner of placing the hinge, when room is scanty in the boxings.

Elevation and plan of half a window, adapted, when the wall of the building is not sufficiently thick to admit of room for boxing.

Figure 77, elevation of half the window.

Figure 78, plan of the window to double the size of the elevation, in order that the parts may be more distinctly seen.

E L. The breadth of the shutter, which is hung to a hanging style G, and the hanging style G is hung to the sash-frame by the hinge at *h*.

The whole breadth of the shutter E L, together with the breadth of the hanging style at G, that is, *i h*, ought to cover exactly half the breadth of the window; viz., from the axis of the hinge at *h*, to the central vertical line of the window.

H. Architrave.

I. Back-ground.

K. Back lining.

The panel A B C D, *Figure* 77, represents the shutter, of which E F, *Figure* 78, is the breadth. The hanging style and shutter are hung together by means of a rule-joint, as before described, under the article HINGING.

Under the shutter A B C D, is a bead R, which is continued across the sash-frame to serve for a capping; P is a vertical bead continued in a line with the edge, at D, of the rule-joint.

O and N. Sub-plinth of window, flush with the bead P.

M. Plinth, or skirting-board.

Figure 79.—A. Architrave-moulding.

B. Ground.

C C C. Back lining.

Fig. 75.

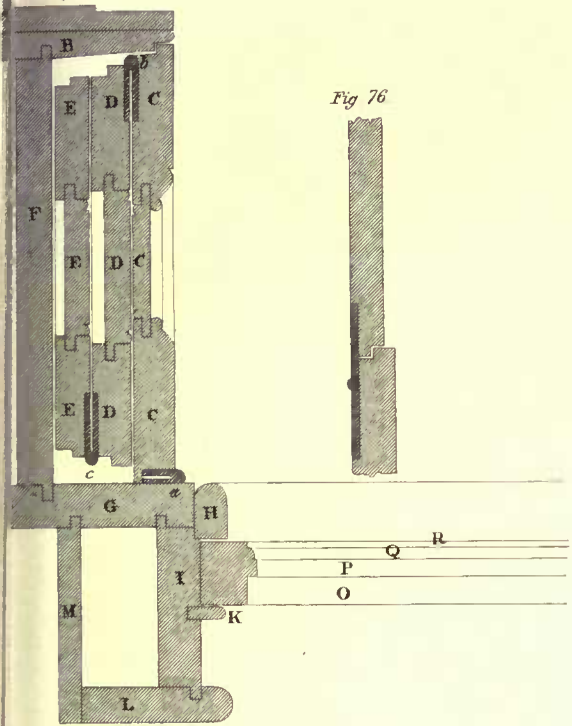


Fig 76

Fig. 72.

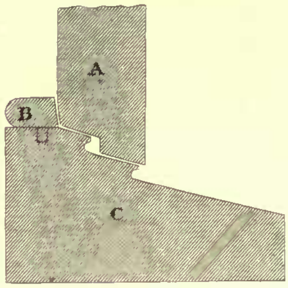


Fig 71.

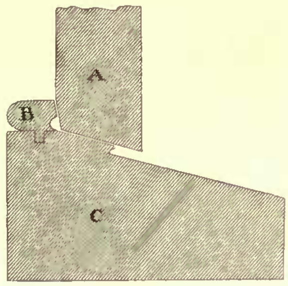


Fig. 74.

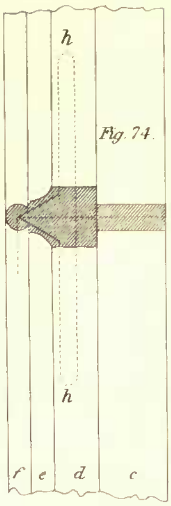


Fig 73

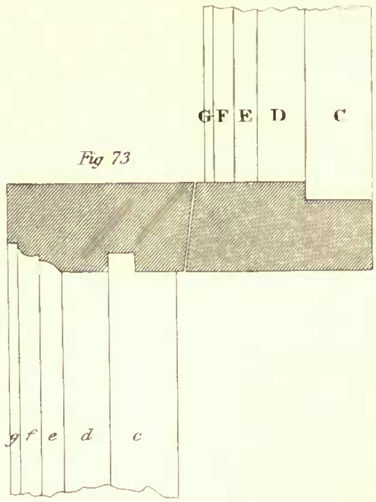


Fig. 79.

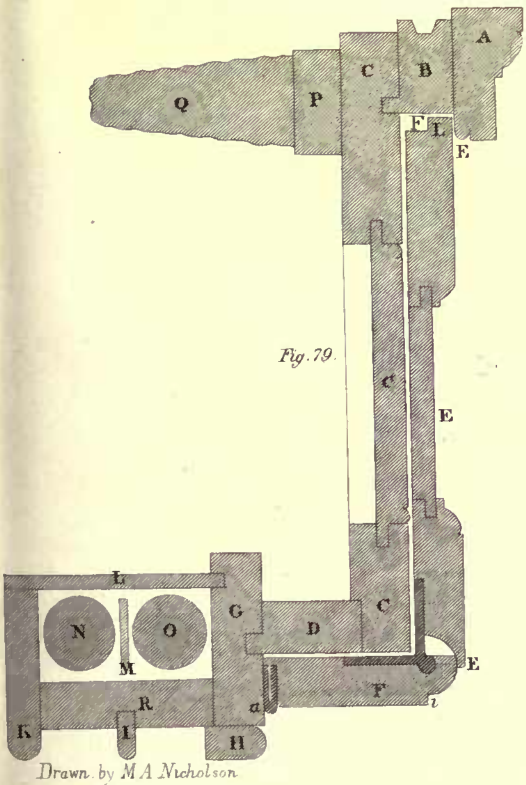


Fig. 77.

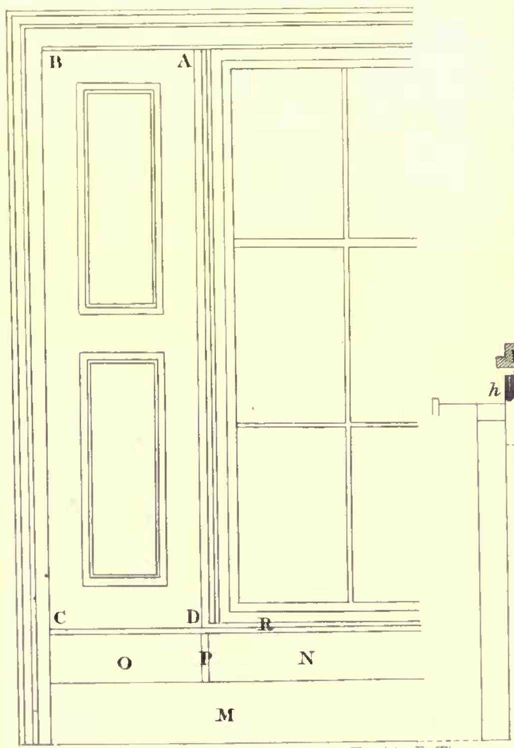
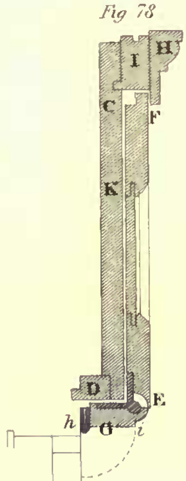


Fig 78



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Engd. by R. Thew

JOINERY.

PLATE. VII.

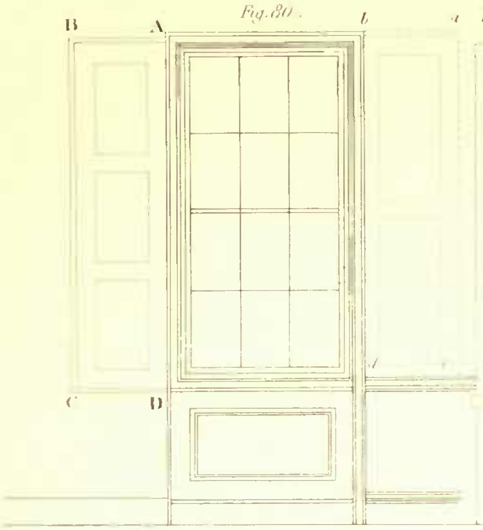

Fig. 80.

Fig. 81.

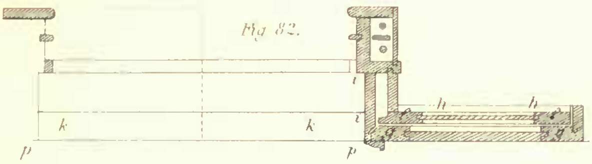

Fig. 82.

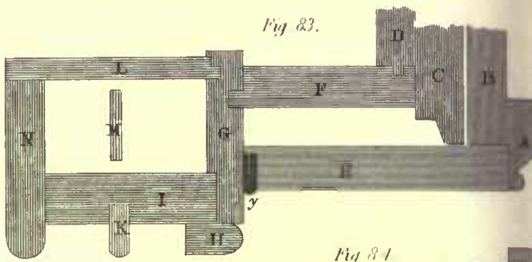

Fig. 83.

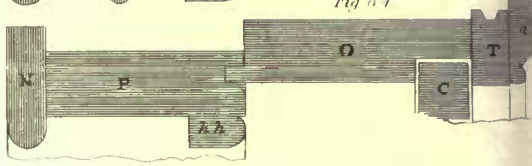

Fig. 84.

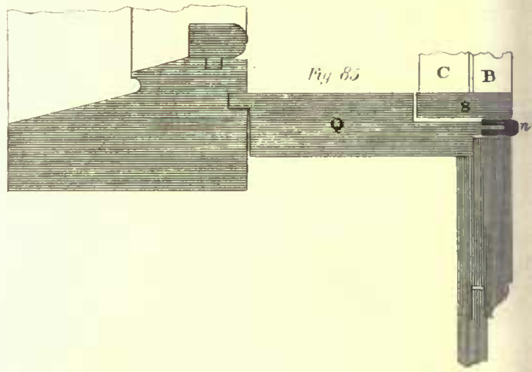

Fig. 85.

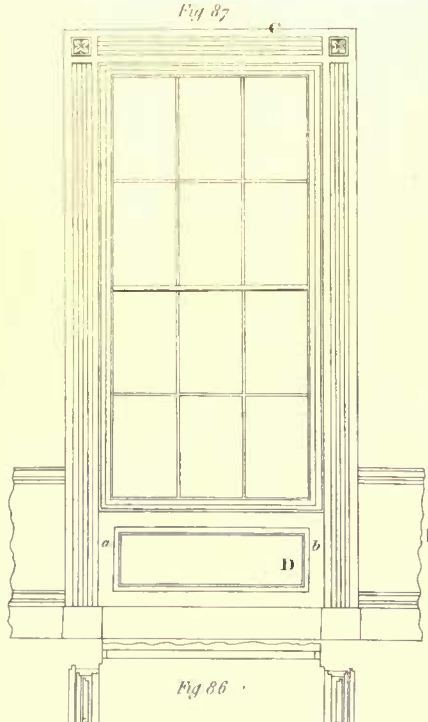

Fig. 87

Fig. 86

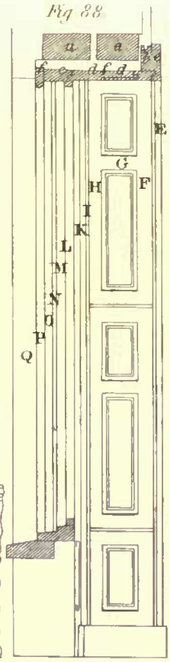

Fig. 88.

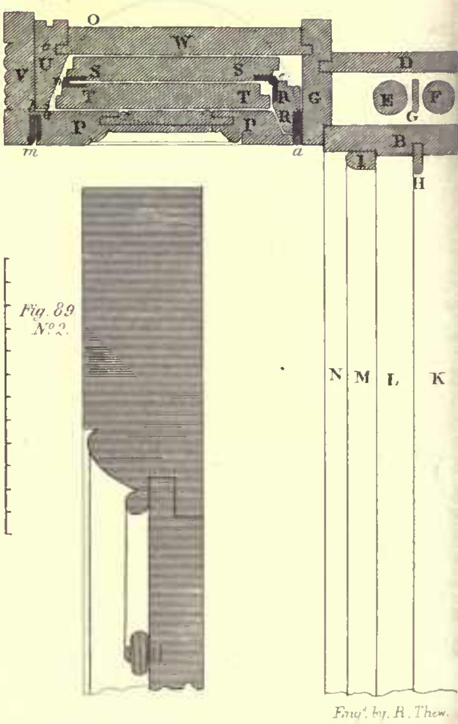

Fig. 89

Fig. 89 N°. 2.

D. The lining, or return of the window.
E E E. The shutter hung to the hanging style, F, which is hung to the sash-frame by the hinge at *a*.
G. The inside lining of the sash-frame.
H. Inside bead.
I. Parting bead.
K. Outside bead.
L. Back lining.
M. The parting slip for the weights N and O.
N and O. Weights.
P. Ground fixed upon the plug, Q.
Q. The plug for securing the finishings.
R. Pulley-style.

The plan, front, side elevation, and section of a window proper for a building where the walls are not thick enough to admit of room for boxings, which will show the same finish as if the shutters folded into boxings.

Figure 80, front elevation of the window.

The dotted lines *a b d c*, represent a piece of framing.

The other side, A B C D, represents a sliding shutter in the wall.

The framing is supposed to be removed, in order to show the shutter.

Figure 81, the side elevation and section, supposing the shutter removed.

a. An architrave-moulding.
b. Soffit.
c. Top of the sash-frame.
d. Capping, tongued into the sash-frame sill.

Figure 82, horizontal section and plan of the window, twice the size of the elevation.

g g. Section of the framing, as shown by *a b c d*, *Figure* 80, by dotted lines.
h h. Plastering on the wall.
i i. A shutter hung to the sash-frame.
f f. Section of the sliding shutter, which runs on rollers.
k k. A flap, which is let into a rebate and hinged at the edge *p p*, so that when the flap is turned round, the hinges out of the rebate, and the shutter *i i* turned to the face of the window, there will be a clear passage for the shutter *f f* to run out.

Note.—Although there is only a stop for the back of the shutter at the bottom, yet it is quite sufficient, as it is stopped on both sides at the top, and as the edge of the shutter should never be entirely out of the boxing.

This is more clearly shown by the parts drawn larger in the next plate.

Different sections of the foregoing Plate.

Figure 83, horizontal section through the side of the window.

A. Architrave moulding.
B. Part of a piece of framing.
C. Part of the shutter.
D. Plaster or rendering upon the wall.
E. The front shutter hung to the sash-frame at *y*.
F. Back lining.
G. Inside lining of the sash-frame.
H. Inside bead of the sash-frame.
I. Pulley-piece.
K. Parting bead.
L. Back lining of the sash-frame.
M. Parting stripe.
N. Outside lining.

Figure 84, vertical section through the top of the window.

a. Architrave moulding.
T. Ground over the window.
C. Section of part of the shutter.

O. Soffit.
P. Top of the sash-frame.
N. Horizontal outside bead.
h, h. Inside horizontal bead.

Figure 85, vertical section through the sill of the window.

B. Edge of the framing.
C. Edge of the shutter.
Q. Capping, rebated out at S, and tongued into the sash-frame sill.
S. A flap hung to Q, by means of the hinge at *n*; then by turning the front shutter upon the window, and by turning up the small flap, S, there will be a clear passage for the shutter, C, to run in.

Plan, elevation, and section, of a window with shutters, which will show uniform and complete, whether the shutters are in the boxings, or closing the aperture of the window.

Figure 86, plan or horizontal section at *a b*.

Figure 87, elevation or front of the window.

Figure 88, vertical section at C, D, *Figure* 87, and side of the window.

E. Thickness of the pilaster or architrave.
F. A bead stuck on its edge, parting the edge of the pilaster from the shutter.
O. The breadth of the shutter.
H, I. A bead and square to correspond to the thickness of the architrave and bead, so as to show the same finish on each edge of the shutter: one edge of this finishes against the sash-frame above, and the same edge below finishes against the back of the window down to the plinth.
K. Another square, equal to the projection of the capping.
L. Bead of the sash-frame.
M. Thickness for the under sash to run in.
N. Parting bead.
O. The thickness for the upper sash to run in.
P. Outside lining and bead.
Q. The breadth of the reveal or outer brick-work. This is farther explained in another figure, where the principal sections are shown to a larger scale. *a a*. Lintels, made of strong yellow deal or oak.
b. The top of the ground.
c. The architrave fixed upon the ground *b*.
d d. The soffit tongued into the top of the sash-frame *e*, and on the other edge into the head architrave C.
f f. A hollow space between the soffit *d d*, and the lintels *a a*; the under edges of the lintels *a a*, are generally about four inches and a half above the camber of the outside of the window; but it may be less when there is any necessity for it, as, for example, when very narrow grounds are used, it may come down within a quarter of an inch of the soffit.

The face of the pulley-style of every sash-frame ought to project beyond the edge of the brick-work about three-eighths of an inch; that is, the distance between the face of each pulley-style ought to be less by three-quarters of an inch than the width of the window on the outside, so that the face of the shutters ought to be in the same plane with the brick-work on the outside.

Parts of the foregoing at large.

Figure 89. Plan of the shutters.

A. The outside lining.
B. The pulley-style.
C. Inside lining.
D. Back lining.
E, F. Weights.
G. Parting slip of weights.
H. Parting bead of sashes.
I. Inside bead.
K L M N. Plan of the sash-frame.

K L. Sill of the sash-frame.

M. Plan of the inside bead.

N. Plan of the capping.

R R. Hanging style, hung to the sash frame at *a*.

S S. A shutter, hung to the hanging style at *e*.

T T. Another shutter, hung to S S at *n*, if necessary.

P P. A door, hung to the architrave at *m*, falling upon the hanging style R R by means of a rebate.

Note. The door must fall in a rebate at top and bottom.

U. A ground to fix the architrave upon.

V. The architrave fixed upon the ground.

W. Back lining.

When the aperture is shut, the door P P must be turned round the hinge *m*, parallel to the face of the sash-frame: then the shutters R R, S S, T T, being drawn out and turned on the hinge *a*, and on the hinges *e* and *n*, will cover that part of the window for which they were intended. The door P may then be closed, and the whole will have a uniform and neat appearance.

To find the splay of the ground b c.—Draw a line from the centre of the hinge at *a* to the edge of the ground at *b*; on *a b*, as a diameter, describe a circle cutting the back lining of the boxing at *o*; join *c b*, and it will be the bevel required.

Front and two side elevations of a window, the sash-frame being out of the square, or an oblique-angled parallelogram: showing how to construct the sides of the window, so that the shutters shall make an equal margin round the edge of the sash-frame, when the window is shut: and also to fit their boxings.

Figure 90. Elevation of the window. A B C D being the edge of the sash-frame next to the bead, and E F G H the margin between the shutters and the inside beads.

The difficulty of fitting up a window of this kind may be surmounted if the following observations are attended to: the points K and I, *Figure* 91, being taken at the distance E F, *Figure* 90, and the point R, *Figure* 91, being made to correspond to K, *Figure* 90, the middle of the meeting rails; then make the angle R K L, *Figure* 91, equal to the angle K E H, *Figure* 90; through R and I draw R S and I M parallel to K L; then K I M L will be the front shutter, and R S the parting bead, in case the shutters are to be cut.

Figure 92, is constructed in the same manner as *Figure* 91; that is, by making the angle T O P equal to the angle L H E, *Figure* 90; the points O, T, N, being previously made to correspond to the points H, L, G, as on the other side.

In *Figures* 91 and 92, A and B are lintels.

C. The top of the sash frame.

D. The soffit.

G. Sash-frame sill.

F. Stone sill.

Plan and elevation of the shutters to the foregoing example; showing the manner of hanging and cutting the shutter when the sash-frame is an oblique-angled parallelogram, or out of the square, as workmen call it.

Let *Figure* 93, be the plan of the window, and let A B and D C, *Figure* 94, be the bottom and top ends of the shutters parallel to each other; now, in order that the shutters may fit close into their boxing, and also close into the window-frame, the centres of the hinges to each flap must be set in lines perpendicular to D C or A B.

To set out the shutters.—Make A *e* and D *f*, *Figure* 94, equal to the breadth of the front shutter, and draw the line *f e*; then will A D *f e* represent the front shutter, and *f e* the edge on which the flap will join to it; then if the angle D *f e* be not a right angle but obtuse, from *f* draw *f g* perpendicular to D C; then will *f g* be the line of the hinges. In the same manner, B C *q r* will represent the shutter on the other side; B *r q* being the obtuse angle, and *r s* a perpendicular to A B for the line of the hinges: the two extreme joints being made, all the other joints, *h i*, *k l*, *m n*, and *o p*, ought to be all perpendicular to the ends D C and A B of the shutters: then will the centres of the hinges be parallel to, or in the same line with, the joint.

To find the breadth of the flaps which hang to the front shutters, so that they may be as wide as possible.—From the points A and C, the obtuse angles, draw A *v* C *u* perpendicular to A B and D C, the ends of the shutters; make *v a* and A *b* equal to the breadth of the rebate; and from the point *f*, and in the line of hinges, make *f c*, *f h*, and *g d*, *g i*, respectively, equal to *f a*, *f v*, and *g b*, *g* A; then will *e f h i* be the flap required; and it is plain, from the nature of this window, that the other flap, *o q r p*, must be the same figure as the flap *e f h i*, but inverted.

The other flaps may be filled in as the width of the window will admit.

Note.—We have given this example because the method is general, and will apply to all cases; the workman ought never to trust to the sash-frame being absolutely square, for they seldom are; and if the variation be ever so small, there will be a very considerable error in the ends of the shutters when enclosed in the boxings. Such distorted examples as the above generally occur in old buildings; in such this method must be adopted: but also, for the above reason, it ought not only to be employed in old work, but even in new, where the shutters are cut, so that the ends of the shutters may not only coincide when folded, but also with the sill and top of the sash frame, and also with the meeting rail.

Customary Measures in Joiners' Work, for labour only.

Preparation of boarding by the foot super.—The different distinctions are—edges shot; edges shot, ploughed and tongued; wrought on one side and edges shot; wrought on both sides and edges shot; wrought on both sides, ploughed and tongued; boards keyed and clamped; mortise clamped; mortise and mitre clamped. The price per foot is also increased according to the thickness of the stuff. If the longitudinal joints are glued, so much more is added to the foot: and if feather-tongued still more.

Floors.—Are measured by the square, the price depending upon the surface, whether wrought or plain, and the manner of the longitudinal and heading joints, as well as upon the thickness of stuff; or whether the boards are laid one after the other, or folded; or whether the floor be laid with boards, battens, or wainscot.

Skirtings are also measured by the foot super; the price depending upon the position, whether level, raking, or ramping; or upon the manner of finishing, whether plain, torus, rebated, scribed to floor, or to steps; or upon the plan, whether straight or circular.

The price of every kind of framing depends upon the thickness, or whether the framing be plain or moulded; and if moulded, what kind of mouldings, and whether stuck on the solid, or laid in; whether mitred or scribed; and upon the number of panels in a height and breadth; also upon the nature of the plan.

The various descriptions of wainscoting, window-linings, as backs and elbows, door-linings, jambs and soffits, back-lining partitions, doors, shutters, are all measured by the foot super.

Sashes are measured by the foot super, as well as the sash-frames. The sash and frame are either measured together or separately.

Sky-lights are measured by the foot super, their price depending upon the plan and elevation.

Fig. 92.

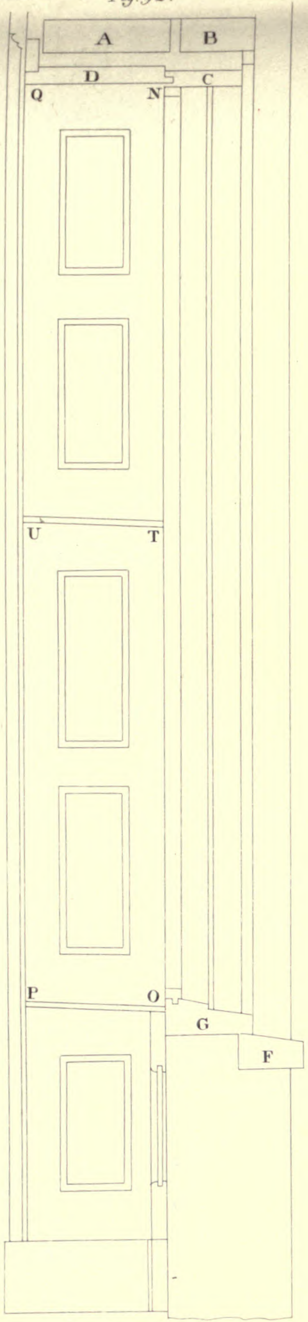

Fig. 90.

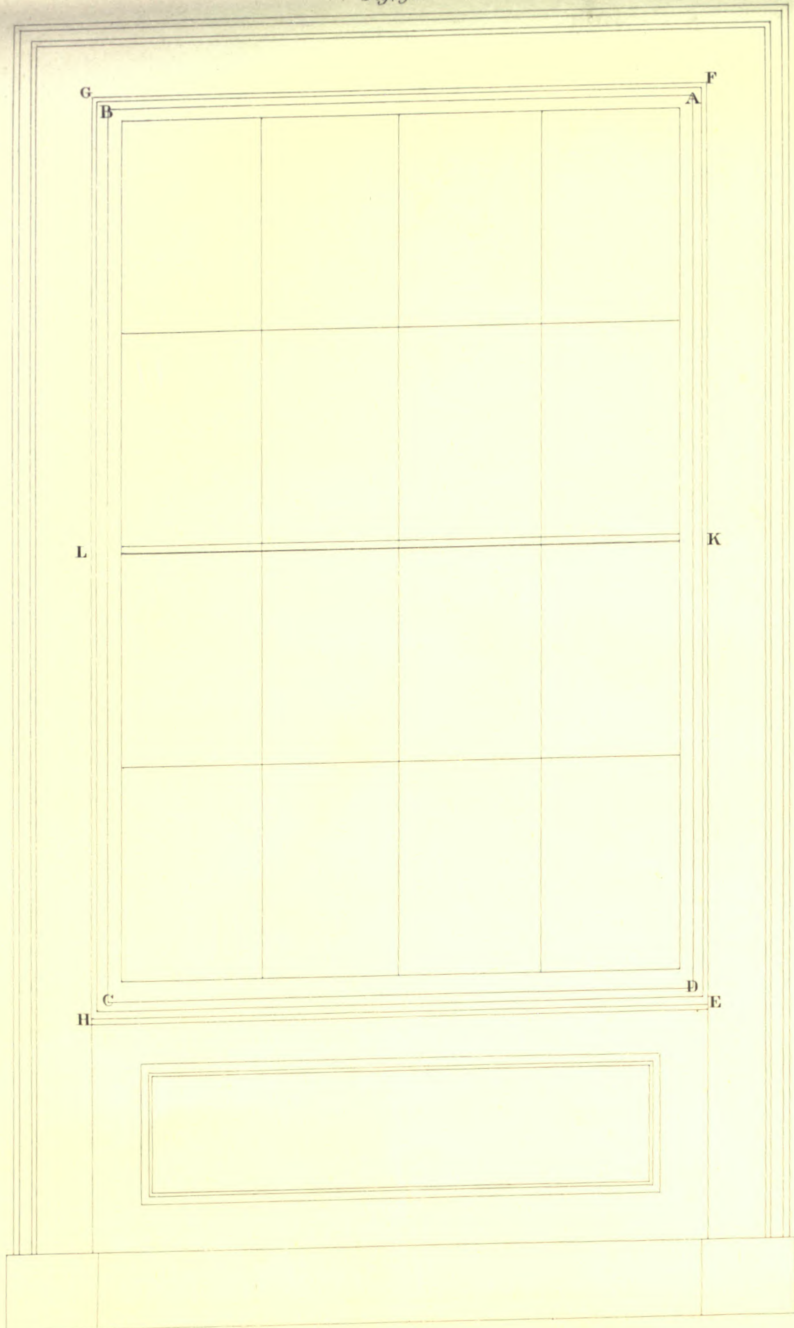

Fig. 91.

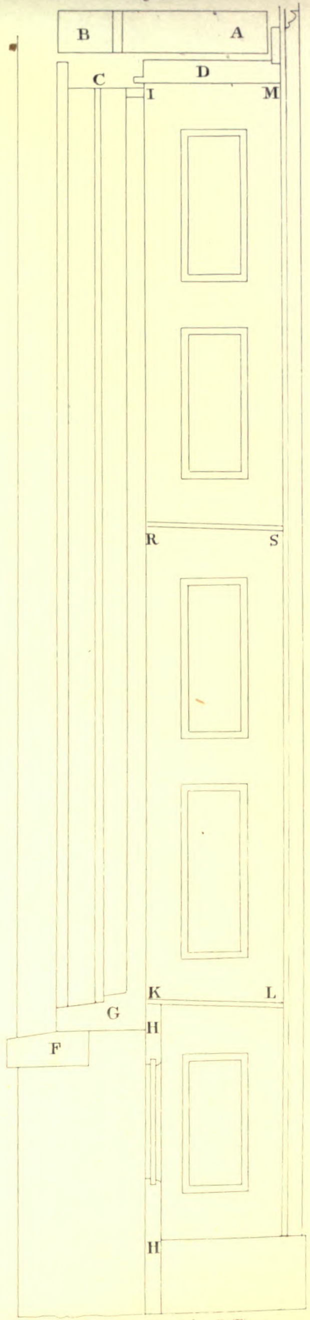

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PLATE IX.

Fig. 93.

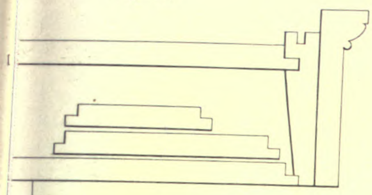


Fig. 94.

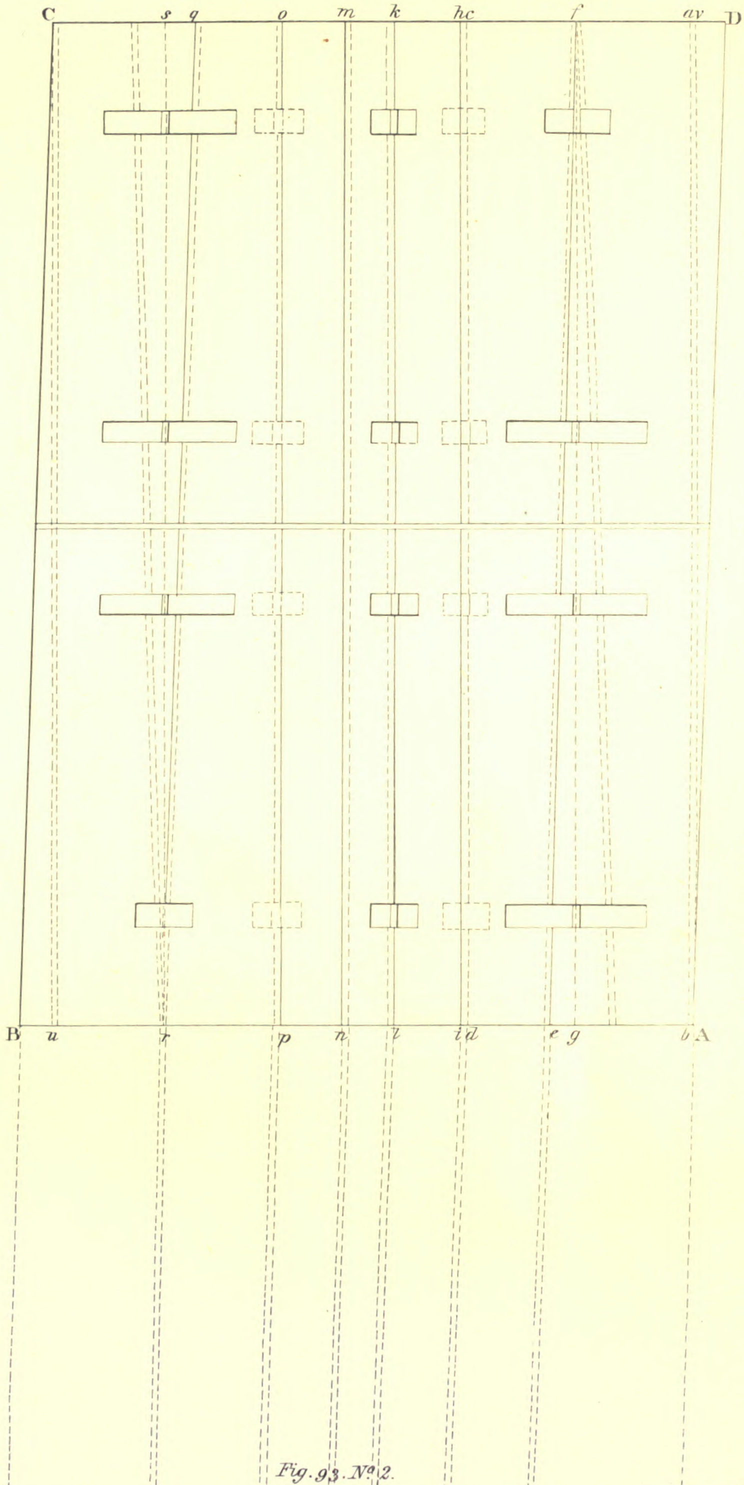
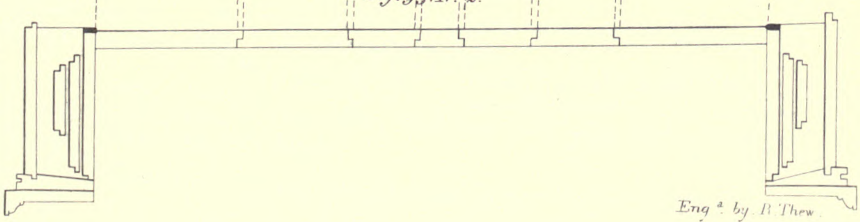
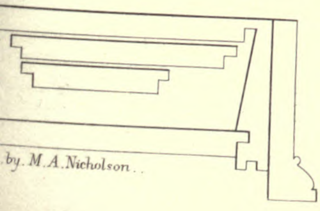


Fig. 93. No. 2.





by M. A. Nicholson.

Eng^d. by R. Thew.

Framed grounds, at per foot run.

Ledged-doors by the foot super.

Dado is measured by the foot super; the price depends upon the plan being straight or circular, or upon the elevation being level or inclined as in staircases.

In staircasing, the risers, treads, carriages, and brackets, are generally classed together, and measured by the foot super; sometimes the string-board is also included. The price must be different, as the steps are flyers or winders, or as the risers are mitred into the string-board, the treads dovetailed for balusters, and the nosings returned, or whether the bottom edges of the risers are tongued into the step. The curtail-step is generally valued as a whole. Returned nosings are sometimes valued at so much each, and if circular are double the price of straight ones.

The hand-rail is measured by the foot run; the price depending upon the materials and diameter of the well-hole, or whether ramped, swan-necked, level circular, or wreathed; or whether made out of the solid, or in thicknesses. The scroll is paid at per piece; as is the making and fixing of each joint screw; three inches of the straight part at each end of the wreath are included in the measurement.

Deal balusters are prepared and fixed at so much each; as likewise, iron balusters, iron column to curtail, housings to step and riser, common cut brackets, and brackets circular upon the plan, preparing and fixing.

Extra sinking in rail for iron balusters is charged by the foot run, the price depending on the rail being straight, circular, wreathed, or ramped.

The price of the string-board is regulated by the foot super, according to the manner in which it is moulded, or whether straight or wreathed, or the manner in which the wreath string is constructed, if properly backed upon a cylinder.

The shafts of columns are measured by the foot super, the price depending upon the diameter, or whether it be straight or curved on the side, and upon its being properly glued and blocked. If the column be fluted or reeded, the flutes or reeds are measured by the foot run, and their price depends upon the size of the flute or reed. The headings of flutes and reeds are so much each. Pilasters, straight or curved in the height, are measured in the same way, and the price taken per foot super. In the caps and bases of pilasters, besides the mouldings, the mitres must be so much each, according to the size.

Mouldings, such as double-faced architraves, base and surbase, or straight mouldings stuck by hand, are valued at per foot super. Base and surbase, and straight mouldings wrought by hand, are generally fixed at the same rate per foot, being something more than double-faced architraves. The head of an architrave in a circular wall is four times the price of the perpendicular parts, not only on account of the time required to form the mouldings to the circular plan, but on account of the greater difficulty of forming the mitres. All horizontal mouldings, circular upon the plan, are three or four times the price of those on a straight plan; being charged more as the radius of the circle is less. Housings to mouldings are valued at so much each, according to the size.

The price per foot super of mouldings is regulated by the number of quirks, for each of which an addition is made to the foot.

The price of mouldings depends also upon the materials of which they are made, or upon their running figure, whether raking or curved.

The following articles are measured by the foot run. Beads, fillets, bead or ogee capping, square angle staff rebated, beaded angle staff, inch ogee, inch quirk ogee, ovolo and bead, astragals or reeds on doors, or on shutters; small reeds, each in reeded mouldings stuck by hand up to half an inch, single cornice or architrave, grooved space to let in reeds, and grooves.

Note.—In grooving, the stops are paid over and above, and so much more must be allowed for all grooves wrought by hand, particularly in the parts adjoining the concourse of an angle; and circular grooving must be paid still more. The other running articles are, narrow grounds to skirting, the same rebated, or framed to chimneys; and rule-joints, cantalivers, trusses, and cut brackets for shelves, are rated at per piece.

Water-trunks are measured by the foot run, the rate depending upon the side of their square. These ought always to be properly pitched, and put together with white-lead, and the joints ploughed and tongued; the hopper-heads and shoes are valued at so much each; moulded weather-caps at so much each; the joints at so much each. Scaffolding, &c. used in fixing, to be paid for extra.

Flooring boards are prepared, that is, planed, gauged, and rebated to a thickness, at so much each, the price depending upon the length of each board: if more than 9 inches broad, the rate to be increased according to the additional width; each board listing at so much per list. Battens in the same way, but at a different rate.

Rates of Labour in Joiners' Work from the Bench, according to the universal Method described in pages 79 *and* 80 *of the First Volume of this Dictionary.*

The column on the left hand of the table denotes the number of panels, the middle column the species of work, and the right-hand column the rate in decimals, being the rate of the part or parts of a day required to the quantity signified at the head of the column; therefore, this rate being multiplied by the wages per day, gives the real rate of the work per foot, in shillings or pence, according as multiplied by shillings or pence.

Description of One-and-a-quarter Inch Doors.

No. of Panels.		Rate per ft. super.
2.	Both sides square	.06
4.	Both sides square	.07
6.	Both sides square	.08
2.	Quirk, ovolo, and bead front, and square back	.1
4.	Quirk, ovolo, and bead front, and square back	.11
6.	Quirk, ovolo, and bead front, and square back	.12
2.	Bead and flush front, and square back	.1
4.	Bead and flush front, and square back	.11
6.	Bead and flush front, and square back	.12
2.	Bead and but front, and square back	.09
4.	Bead and but front, and square back	.10
6.	Bead and but front, and square back	.11
2.	Quirk, ovolo, and bead, on both sides	.14
4.	Quirk, ovolo, and bead, on both sides	.15
6.	Quirk, ovolo, and bead on both sides	.16
2.	Bead and but on both sides	.12
4.	Bead and but on both sides	.13
6.	Bead and but on both sides	.14
2.	Bead and flush on both sides	.14
4.	Bead and flush on both sides	.15
6.	Bead and flush on both sides	.16

For every additional quarter of an inch in thickness, add .005 to the rate per foot super.

If the panels are raised on one side, add .002; and if on both sides .004; and if an astragal or ovolo on the rising on one side, add .003; and if on both sides .006—to the rate per foot super.

If the price of a foot of a square door, and the number of pannels, are given, and the price of a foot of a door square on one side, with the same number of panels, and with extra work on the other side; then, the price of a door with the same number of panels, and the same extra work on both sides, will be found by subtracting the rate of the first from that of the second; and adding the difference to the second, will give the rate per foot extra on both sides.

Thus the rate per foot super for 1¼-inch two panel door, square on both sides, is .06; and the rate for 1¼ inch two panel door, square upon one side, with quirk, ovolo, and bead upon the other, is .1, their difference is .04, which added to .1, gives .14, for the rate per foot of 1¼-inch two panel, with ovolo and bead on both sides of the framing.

The difference of workmanship between square-framed door-linings, backs, elbows, soffits, or wainscoting and doors that are square on both sides, supposing the panels and thickness to be alike in both cases, can only arise from planing the panels and the framing on the other side of the door: therefore if the difference of the rate per foot of a door square on both sides, and one square on one side, with any extra work on the other, be added to the rate per foot of door-linings, backs, elbows, soffits, or wainscoting, framed square, will give the rate per foot for door-linings, window-linings, or wainscoting with the same extra work.

In these rates the styles or rails are supposed without rebating. Framed linings for walls or apertures, may be made of stuff ¼ of an inch thinner than doors. In common cases, the thickness of linings may be about an inch, as they are rendered sufficiently stiff by being fixed to the wall; this, however, must depend upon the distance that the panel recedes from the face of the framing, or upon the depth which the mouldings are run in the thickness of the said framing.

No. of panels.	Framed Inch Linings.	Rate per ft. super.
1.	Square, as in backs	.051
3.	Square, as in backs and elbows, measured together	.071
4.	Square, as in backs, elbows, and soffits	.061
3.	Moulded, as in backs and elbows, together	.087
4.	Moulded, as in backs, elbows, and soffits, measured together	.077
3.	Quirk moulded, as in backs and elbows, measured together	.095
4.	Quirk moulded, as in backs, elbows, and soffits, measured together	.085

Semicircular moulded soffits in two panels, seven times the straight.

For every additional quarter of an inch, add .005 to the foot super.

In the column of panels, the backs, elbows, and soffits, are numbered 3 and 4 panels, as being classed together; though this is the case, they are intended to be framed in single panels.

One-and-quarter Inch Door Linings,

Having only one panel in height.

Rebated	.051
Rebated and beaded	.058
Double rebated, not exceeding seven inches wide	.067
Double rebated, and one edge beaded	.071
Double rebated, and both edges beaded	.075

If the plan be circular, the price will vary as the diameter is less.

Semicircular heads, straight on the plan, five times the straight.

Shutters. (Rate per ft. super.)

Inch framed, uncut, shutters or flaps, two panels in height. Mouldings, when described are understood to be laid in, but if stuck on the framing to add .012 *to the rate; for every extra panel, to add* .016 *to the rate; for any extra height, to add* .012 *to the rate; if quirked moulded, add* .008 *to the rate of moulded.*

Square	.071
Bead, but, and square	.1
Bead, flush, and square	.111
Bead, flush, and bead but	.131

Inch-and-quarter uncut shutters, two panels in height, to add for extras, as above.

Moulded and square	.1
Moulded bead and but	.111
Moulded bead and flush	.135
Moulded on both sides	.111
Ovolo and bead, or quirk ogee front, and square back	.103
Ovolo and bead, or quirk ogee front, with bead and but back	.123

One-and-quarter Inch Wainscoting,

Two panels high, including square facia, framed up to ceiling.

Square	.039
Moulded	.055
Quirked moulded	.063
Bead and but	.051
Bead and flush	.059
Bead and flush, with 3 reeds	.075

If any of them are framed with raised mouldings, add .008 to the rate; or, if framed with more panels in the height, add .006 for every additional panel.

One-and-quarter Inch Dwarf Wainscoting,

With one panel, including square skirting.

Square	.047
Moulded	.063
Quirk moulded	.071
Bead and but	.059
Bead and flush	.067
Bead and flush with 3 reeds	.083

If any of the above descriptions of dwarf wainscoting are framed with two panels in height, add .016 to the rate, as in full wainscoting.

If made raking to stairs, to be paid for extra .023, and if with raised mouldings .007.

All cappings to be measured, and paid for as in running articles.

All skirting to stairs, to be paid for separate from wainscoting.

Three-quarter Inch Deal,

From the bench, called Slit Deal.

Edges shot	.004
Wrought on one side	.016
Wrought on one side, grooved, tongued, and beaded	.028
Wrought on two sides, and edges shot	.028
Wrought on two sides, grooved, tongued, and beaded	.04
If glued joints, add per foot	.004

Inch-and-quarter Deal.

	Rate per ft. super.
Wrought on one side, and edges shot	.02
Wrought on two sides, and edges shot	.032
Wrought on one side ploughed and tongued	.036
Wrought on two sides, ploughed, tongued and beaded	.052

If glued joints, add .004 to the rate.

Inch-and-half Deal.

Edges shot	.008
Ploughed and tongued	.024
Wrought on one side, with edges shot	.02
Wrought on both sides, with edges shot	.036
Wrought on both sides, ploughed and tongued	.052

If glued joints, add .012 to the rate.

Two-inch Deal,
From the bench.

Edges shot	.02
Ploughed and tongued	.036
Wrought on one side	.028
Wrought on both sides	.044
Wrought on both sides, ploughed and tongued	.056

If glued joints, add .016 to the rate.

Two-and-a-half-inch Deal,
From the bench.

Edges shot	.028
Ploughed and tongued	.048
Wrought on one side	.048
Wrought on both sides	.063
Wrought on both sides, ploughed and tongued	.083

If glued joints, add .016 to the rate.

Three-inch Deal.

Edges shot	.032
Ploughed and tongued	.056
Wrought on one side	.056
Wrought on two sides	.08
Wrought on both sides, ploughed and tongued	.103

If glued joints, add .016 to the rate.

Inch Boarding, One Side planed.

Ploughed and tongued	.024
Glued joint	.03
Clamped	.056
Mortise-clamped	.063
Laid with straight joint in floors	.02
Dado-keyed	.044
Keyed in backs and elbows	.056

Inch Boarding, wrought on Both Sides.

Ploughed and tongued	.036
Glued joints	.04
Groove-clamped flaps to shutters, in one height	.053
Clamped flaps to shutters, in two heights	.071
Inch mortise-clamped outside shutters	.063
Ledged doors with plain joint	.044
Ledged doors, ploughed, tongued, and beaded	.056

Preparing Flooring Boards.

To be gauged to a width, and rebated to a thickness not more than nine inches wide.

Inch Deal.	Rate for each board.
Ten feet long	.063
Twelve feet long	.075
Fourteen feet long	.087

1½ Inch.	Rate for each board.
Ten feet	.071
Twelve feet	.083
Fourteen feet	.1

Battens 1¼ inch.	
Ten feet	.044
Twelve feet	.056
Fourteen feet	.075

Mouldings.

	Rate per ft. super, from the bench.
Double-faced architraves	.111
Base or surbase	.127
Above four inches girt, stuck by hand	.127

If a collection of mouldings have more than two quirks, add .016 for each.

Running Articles.

	Per foot lineal.
Beads and fillets	.004
Bead or ogee capping	.016
Inch ogee	.016
Inch quirked ogee or ovolo and bead	.023
Square angle-staff rebated	.028
Angle-staff rebated and beaded	.048
Single cornice or architrave	.048
Small reeds, in reeded mouldings stuck by hand, to half an inch	.004
Reeds above half an inch, stuck by hand, including grooved space	.008
Grooves in ornamental work	.004
Narrow ground to skirting	.011
Narrow ground to skirting, rebated or grooved	.016
Narrow grounds framed to chimneys	.032
Double-beaded chair-rail	.023

Plugging included in the above rates.

Such of the above running articles as are circular on the plan, must be rated at double the straight.

Legs, rails, and runners to dressers	.055
Rule-joints to shutters	.063

Inch and Inch-and-quarter Framed Grounds to Doors.

	Rate per run from the bench.
Both edges square	.028
One edge square, and the other rebated and beaded	.032
Rebated on one edge, and both edges beaded	.036

If framed to a circular plan with a flat sweep, the head to be three times the straight, but the less the radius the greater the price.

Stairs.

1¼ *inch nailed Steps with Carriages.*	Rate per ft. super fixed.
Flyers	.08
Winders	.111
Flyers moulded and glued with close string-board	.103
Winders moulded and glued with close string-board	.135
Moulded planceer under steps	.04

Housings to flyers, .127 each.
Housings to winders, .2 each.
Common cut brackets to flyers, .143 each.
Common cut brackets to winders, .286 each.
All fancy brackets to be paid for at per value.

Hand-Rail.

2 inches deep by $2\frac{1}{4}$ inches broad	Rate per ft. run fixed.
Deal moulded	.111
Deal moulded and ramped	.495
Deal moulded, level circular	.413
Deal moulded wreathed	1.2
Mahogany moulded straight	.263
Mahogany moulded ramped	.831
Mahogany moulded swan-neck	.927
Mahogany moulded, level circular	1.08
Mahogany moulded wreath, from 12 inches and above	1.6
Mahogany moulded wreath, under 12 inches	1.8
Mahogany moulded wreath, not less than 12 inches opening	2.8
Mahogany moulded wreath, under 12 inches opening	3.4

Mahogany moulded cap, wrought by hand, .495 each.
Mahogany moulded cap, turned and mitred, .4 each.
Mahogany scroll, 1.8 each.
Making and fixing each joint with joint screw, .231.
Making model, and fixing iron balusters, each, 2.095.
Making model, and fixing iron columns to curtail, each, 2.142.
Preparing and fixing deal bar balusters, each, .04.
Preparing and fixing deal bar balusters dovetailed to steps, .056.

Extra sinking to rail, for iron rail or balusters	.032
Extra sinking in ramp or wreath	.1

Every half rail to be measured two-thirds of a whole.

All rails to be measured three inches beyond the springing of every wreath or circular part.

All cylinders used in rails glued up in thicknesses, to be paid for extra.

Articles rated at so much each.

Clamp mitres.
Cuttings to standards.
Housings in general.
Housings to steps.
Housings to mouldings.
Each scribe of skirtings to nosings of steps.
Elbow cappings.
Curtail step.
Returned moulded nosings to steps.
Caps to hand-rails.
Scroll of hand-rails.
Making and fixing joints of hand-rails with joint-screws.
Fixing iron columns in curtails of stairs and preparing mould.
Fixing iron balusters, and preparing mould.
Preparing and fixing deal balusters.
Brackets to stairs.
Mitres of pilasters according to their size.
Headings of flutes and reeds.
Hopper-heads to water-trunks.
Shoe to water-trunks.
Moulded weather caps to water-trunks.
Joints to water-trunks.
Preparing flooring-boards.
Preparing battens for floors.
Listing boards.

Articles rated at per foot lineal.

Sinking to shelves.
All raised panels on the extremity of the raising to be charged extra.
Moulded raisings of panels.
Coping to wainscoting.
Level circular string boards to stairs.
Hand-rails.
Newels to stairs.
Moulded planceer in stairs.
Sinking to rail for iron rail or balusters.
Pilasters under 4 inches wide.
Boxings to windows.
Water-trunks.
Skeleton grounds.
Flutings to columns.
Beads or fillets.
Bead or ogee capping.
Square angle-staff rebated.
Beaded angle-staff rebated.
Inch common ogee.
Inch quirk ogee.
Ovolo and bead.
Astragals on doors.
Reeds on doors.
Reeds on shutters.

Articles rated at per foot lineal.

Single cornice.
Single-faced architrave.
Ornamental grooving.
Narrow ground for skirting.
Narrow grounds for chimneys.
Legs, rails, and runners of dressers.
Rule-joints.
Framed grounds.
Skeleton grounds.

Articles rated at per foot super.

Planing, ploughing, tonguing, beading, gluing, and clamping deals.
Skirtings.
Sash-frames.
Sashes.
Sashes and sash-frames.
Sky-lights.
Framed back linings.
Back elbows and soffits.
Shutters.
Door linings.
Doors.
Wainscoting.
Partitions.
Dado.
Steps to stairs, including carriages.
Cradling.
Double-faced architraves.
Mouldings wrought by hand.
Shafts of columns.

Articles done by the square.

Laying floors.

Articles at per value.

Belection mouldings.
All fancy-works.

The English writers who have treated upon joinery, are, Moxon, in his *Mechanical Exercises*, second edition, printed 1693; Halfpenny, in his *Art of Sound Building*, small folio, 1725; Oakley, in his *Magazine of Architecture*, folio, 1730; Price, in his *British Carpenter*, quarto, 1735; Hoppus, in his *Builders' Repository*, quarto, 1738; Batty Langley, in his *Builders' Complete Assistant*, royal octavo, 1738; Salmon, in his *London Art of Building*, third edition, small quarto, 1748; Mr. Abraham Swan, in his *Architect*, folio, 1750; Pain, in almost every one of his works, particularly in *The Carpenters' and Joiners' Repository*, *The British Paladio*, *The Practical Builder*, and in *The Practical House Carpenter;* and the author of the *Architectural Dictionary*, in *The New Carpenters' Guide*, published in quarto, 1792; in *The Carpenters' and Joiners' Assistant*, quarto, 1792; in Rees's *Cyclopædia;* and in the *Mechanical Exercises*, octavo, 1812.

From these authors we shall here collect such extracts as relate to mechanical principles, or to geometrical construction, in the order of the above list.

Moxon treats the subject merely as a manual art. The following is extracted from Halfpenny's *Art of Sound Building:* he seems to have been the first writer who considered joinery in a geometrical point of view; his knowledge, however, is entirely confined to hand-railing.

"*To find the raking arch, or mould, for the hand-rail to a circular pair of stairs, in such a manner that it shall stand perpendicularly over its base, or arch of the well-hole.*

Figure 95.—"First describe a circle equal to the breadth of the well-hole, whose diameter is U W; as also another from the same centre, whose diameter is A G, to represent the plan of the rail; and divide the circumference of the greater circle into the same number of equal parts as you would have steps once round the circle.

"This being done, take the back, or rake, of the bracket, equal to C F, in your compasses, and setting one foot in A, with the other strike the arch *h:* also take the height of one step, as A C, *Figure* 96, and setting one foot in B, with the other strike the arch *i;* and when this is done, take the distance from A to *h* in your compasses, and setting one foot in *h*, with the other strike the arch *k*, and take the height of two steps, and with one foot in C, draw the arch *l*, to intersect the arch *k*, and so on.

"The intersecting points of the arches *h i*, and *k l*, and *n o*, and *r s*, and *t u*, are all at the same distance from one another, and the lines B *h*, C *k*, D *n*, E *p*, F *r*, and G *t*, being the risings or heights of the steps, in *Figure* 96, B *h* being the height of one step, C *k* of two, D *n* of three, E *p* of four, F *r* of five, and G *t* of six. Now, if these lines are raised up perpendicular on the circle A D G, it is evident that the point of intersection of the arches *h* and *i*, will stand perpendicularly over the point B; of the arches *k*, *l*, over C; of the arches *n* and *o*, over D; of the arches *p*, *g*, over E; of the arches *r* and *s*, over F; and of the arches *t* and *u*, over G. Now, if nails be struck into the intersecting points of the said arches, and a thin rule be bent round them, you may describe the arch, A *h k n p r t*, by the edge thereof, being the mould to strike the arch of the rail with.

"*The arch or mould of the rail being found, as above, how to prepare the stuff of which the rail is to be made, and work the twist thereof without setting it up in its due position.*"

Figure 97. "First strike two circles, whose diameters are equal to U W and A G, in *Figure* 95, and next consider into how many pieces you glue the rail, which in the semicircle let be six, as in the example.

"Now divide the semicircle into six equal parts, as E F, F M, M S, S L, L D, and D K; from each of these points of division, draw lines to the centre A, as A E, A F, A M, A S, A L, A D, and A K. Then from F raise F G perpendicular to A F, and equal to the height of one step. Also, at the point M, raise M N perpendicular to A M, equal to the height of two steps; and in like manner at the points S, L, D, and R, raise the perpendiculars S T, L Y, D E, and R L, respectively equal in length to the height of three, four, five, and six steps. Then draw a line from G to R, parallel and equal to A F; as also another from N to *y*, parallel and equal to A M; another from T to W, parallel and equal to S A; another from Y to B, parallel and equal to L A; another from E to H, parallel and equal to D A; and another from L to P, parallel and equal to K A. From the point A draw the line A B, perpendicular to A E, and equal to the height of one step; also at the points R *y*, W, B, H, P, draw the lines R L, Y Z, W X, B C, H I, P O, all equal to the height of one step, and respectively perpendicular to R G, Y N, T W, Y B, E H, L P, and draw the hypothenuse E B, L G, Z N, T X, Y C, E I, L O.

"This being done, set off the width of the rail from E to *d*, G to *i*, N to *o*, T to *u*, Y to *a*, E to F, and L to *m*; and set the stem of a square on the line E B, till the blade touches the point *d*, and draw the line *c d*. Moreover, set a square on the line G L, and where it cuts the line R G, as in the point I, draw the line *h* I; and in like manner draw the lines *p o*, U N, Z *a*, *g* F, and *n m*. Then the angles E *d c*, G I *h*, N *p o*, &c. and the rest of the little black spaces, as you see in the Figure, do represent the twisting of each piece, and what must be taken off from the back at the lower end, to make the twist of the rails. The lines being drawn, you are next to consider after what manner they are to be applied in the working of the rail.

"Take the piece of timber, of which you design to make the first length, which is represented in *Figure* 98, and plane one side thereof straight, and cut it to its bevels *a c*, *b d*, answering to D R A and a D A, *Figure* 97, and both ends thereof being also cut to the raking-joint of the rail, proceed thus: Take that part of the raking-arch in *Figure* 95, which answers to the first length of the rail, as A *h* in the arch A *u*, and lay it on the upper side of *Figure* 98, from *l* to *h*, and strike the arch *l h*, then take E *c*, equal to G *h*, or N *p*, in *Figure* 97, and set it on the line *b d* from *h* to *m*, *Figure* 98, and strike a square stroke at pleasure from *m* to *g*; also take *d* equal to *h* I, or *p o*, &c., *Figure* 97, and set it on the line from *m* to *g*, and draw the line *h g*, which represents the back of the rail when it is worked, and is equal to E *d*, or G *i* or N *o*, &c., *Figure* 97. This being done, represent the lower end of the rail *h g k i* at right angles to *h g*; as also the upper end *l c o n* at right angles to *l c*, and baste out the inward arch *c m* square from the upper side *a b c d*, as *m g*; and take a thin lath, and bend it close to the side thereof, from *c* to *g*, whereon strike a line along the edge of the lath, and so the lines *l h* and *c g* are your guides in backing the rail; which, when done, turn the piece upside-down, and with the mould strike an arch equal to *l h*, from *a* to *k*, and baste out the side to the lines *l h* and *o k*; then you have one side and the back squared, which is the greatest difficulty in the formation of a twisted rail, because the two other sides are found by gauging from them.

"*Note.*—If the triangles in Figure 97. and lines whereon they stand, be supposed to be raised up perpendicularly, then will the lines A B, R L, Y Z, W X, B C, H I, and P O, join to each other, and produce one line perpendicularly over A, equal to seven risings or heights of the steps. But in working a rail of this kind, you have need of but one triangle, A B C E *d*, because they are all equal, and of but one effect in working, they being drawn only to satisfy the curious in the nature of the thing."

He finds the moulds for elliptical staircases in a similar manner, viz., by finding an arch line divided into equal parts, so that each of them may be equal to the hypothenuse of the pitch-board, and the distance of the points of division in succession respectively equal to the heights of the steps: this principle is to be understood in all staircases where the steps are equally divided at the well-hole, whatever be the form of the plan: but in elliptic staircases the degree of twist is different, and therefore requires a pitch-board to be made for every portion.

It is hardly possible to conceive any method so distant from principle as what is here shown: the squaring of the wreath is altogether guessed at, not to mention the great disadvantage in making the rail in so many pieces. If the rail were really executed, the above method would then be a property; but the moulds never can be obtained from any construction in plano upon the same consideration. It is rather astonishing that any attempt should be made at demonstration, for the support of a method so entirely destitute of principle as the above.

"*How to form the arch or mould to the hand-rail of a pair of stairs that sweeps two steps, so as to stand perpendicularly over its ground, and the manner of squaring the same, without setting it up in its position.*

"First: draw *Figure* 99, to represent the ground-work of the rail, whose arch, G C, consists of two different arches, one whereof is a quarter of a circle, the other a quarter of an oval. A B (equal to A C, equal to C D, equal to B D) is equal to one-third of a step: and D is the centre to the arch C B; also, B F is equal to two-thirds of a step, and F G is equal to one step and two-thirds; by means of which, and B F, is the arch G B described. G K represents the straight part of the rail to one step, and the arch H D is drawn by gauging from the arch G C; that is, it is drawn parallel to it, and the straight part I H is found by gauging from K G, or is drawn parallel to it.

Figure 100, "shows the manner of drawing the rake or arch of the rail, which is done thus: draw I L equal to G K of *Figure* 99, and represent the tread of the steps as before, by pricked lines. Then divide that part of the ground-work of the rail which belongs to each step into any number of equal parts, as A F into five, and F K into four. This being done, draw A B, B G, C D, in *Figure* 101, to represent the rising and tread of the steps, and continue out the line C B at pleasure, towards T, in which set the five divisions on the ground of the rail to the first step F E, of *Figure* 100, being equal to C *i* of *Figure* 101; also, E D equal to *i k*, D C to *k l*, C B to *l u*, and B A to *u* T. Then will the line C T, in *Figure* 101, be equal to the arch A F, of *Figure* 100; draw the line D T; then is the triangle C D T the bracket to the first step, according to the sweep of the rail: and as T C is the length of the ground to the first step, so is T D the length of the rail answering to it. Then from the points *i*, *k*, *l*, *u*, raise the perpendiculars *i* P, *k* Q, *l* Z, and *u* S, to C T; and take the four divisions on the second step, and set them in the line C T, from C to B, and draw the line B D; and then is B C the length of the ground to the second step, and B D the length of the rail answering to it. Draw lines through these divisions, as from F to *m*, G to *n*, and H to O, perpendicular to C B; and so your perpendiculars are found according to the compass brackets of each step, and may be pieced thus:—

"In *Figure* 101, take T S in your compasses, and with that distance, setting one foot in A, in *Figure* 100, strike the arch *m*; and take S *u* between your compasses, and with one foot in B strike another arch to intersect the arch *m*. Again: take S Z or S T in your compasses, and with one foot in the intersection of the arch *m* and this latter arch, describe the arch *n*; and take *l* Z in your compasses, and with one foot in C describe an arch to intersect the arch *n*; and thus proceed on, so that Z Q be equal to *n o*, Q P to *o p*, P D to *p q*, *q z* to B O, *z s* to *o n*, *s t* to *n m*, and *t u* to *m* D; as also *k* Q to D *o*, *i* P to E *p*, C D to *q* F, H *o* to G *z*, G *n* to H S, F *m* to I *t*, E D to K *u*, L *w* to three times A B. The points *n*, *o*, *p*, *q*, *r*, *s*, *t*, *u*, *v*, *w*, being found by the intersection of arches, as above, stick a nail into each point, and bend a thin rule about the nails, till it touches them all, then with a pencil describe an arch round the edge thereof, which will be the arch A *w*, being that of the rail to work by.

"*Figure* 102 shows the manner of squaring the rail, which is thus: first, describe A F, the square, or ground of the rail, being the same as that of *Figure* 99, and find the centres to answer to the different arches of the ground; from whence draw pricked lines to the places where you design to join the rail, as from G to B, from G to C, from H to E, and from H to *d*. Because the first step is to be joined in three equal pieces, you must take one-third of the rising or height of the step, and set it from B to I, perpendicular to B G, and draw the line M I, parallel and equal to G B. Now, from M to *n* draw a perpendicular to M I, to rise so much as the rail rakes over, which is one-third of the rising or height of the step, because that part of the rail is one-third of the length on the first step; and draw the line I *n*, by which means we shall have the first triangle I M *n*. Then from the point C, draw C *q* perpendicular to G C, and equal to two-thirds of the height of one step; and draw the line *q z* equal and parallel to C G; and from *z* raise a perpendicular, *z s*, to *z q*, equal to one-third of the height of one step, and draw the line *q s*, and you will have a second triangle. Again, from *d* draw *d* T perpendicular to H *d*, and equal to the height of one step, and draw the line T W equal and parallel to H *d*; and from W erect the line W X perpendicular to W T, and equal to the height of one step, because that part of the rail over the second step will be one piece, therefore the triangle must rise one height of the step; and draw the line T X, and so you will have a third triangle, W X T. This being done, from I in the line I M, set off I *k*, equal to the width of the rail; also set off the same from *q* to *o*, and T to *u*, and setting the stem of a square on the hypothenusal line, so that the blade thereof touches the point *k*, draw the line *k l*; and in like manner draw the lines *p o*, *u v*; and then the little triangles I *k l*, *q o p*, T *u v*, do represent what must be taken off from the lower end of each piece, to bring the rail to its true twist."

The form of the scroll is only a subject of fancy, but what has been quoted from this author, will show the difference of taste between the time when such were in use, and those of the present day. No elegant geometrical forms seem then to have been employed. As to the construction of the raking-mould for the scroll, it is done in a similar manner to the twist of the rail, before shown, and therefore equally destitute of principle.

Mr. Edward Oakley, in his *Magazine of Architecture*, has copied Halfpenny's descriptions and diagrams; to which we refer the reader.

The next work under review is *The British Carpenter*, by Francis Price. The article Joinery is almost confined to hand-railing, as in the preceding authors. Mr. Price proceeds as follows:

"*To find the proper kneeling and ramp of rails.*—In *Figure* 103 is represented a short flight of four steps, and part of a half-pace, on which are shown two balusters on a step; *a b* is the rise or height of one step, and *b c* is the newel, generally two feet four inches and a half high, and sometimes two feet six inches high, &c., and *c d* is the thickness of the rail; the kneeling, *o*, is in the middle of the first baluster; from *e* to *f* is also the height of the first step on the half-pace; and *f g* the height of the newel, agreeable to that of *b c*; and *g h* is the thickness of the rail; from *h* to *i* is generally the same as from *o* to *c*, which line, *h i*, continue at pleasure; for on it is the centre for the ramp. With your compasses find the centre, *k*, which touches the back of the rail, *n*, and the point of the ramp, *i*; find the point of touch, *n*; draw the line *k n*; describe the ramp, and also the turned part of the balusters, as may be seen by the pricked line.

"Over this is represented the alteration that ought to be made, if you place three balusters on a step; that is, that the kneeling ought to come to the back-side of the first and last balusters, as at *p* and *q*. If it be said, the method in *Figure* 103 is not fully expressed; to find the height of the ramp agreeable to the kneeling, let *Figure* 104 be the rail, the bottom is continued as by the pricked line appears at *u* and *w*; take the distance, *u t*, and set from *w* to *x*; from *x* set one rise, or the height of one step, as at *y*, and that gives the height of the ramp, and is the same as the method in *Figure* 103, notwithstanding they differ in appearance.

"In *Figure* 105 is shown the manner of fluting newels for stairs, and balusters; the newel having twelve flutes, and the balusters eight. If the stuff be large, the flutes may vary; thus the newels to have sixteen flutes, the balusters twelve."

We cannot comment any farther on the above, than that it shows the method of describing the ramp of a rail, and the difference of taste in the age of Price, from that now in use. The design, the quantity of work, and the massy parts, which characterized that time, when contrasted with the slightness and plainness of work executed in the present day, are really astonishing. Our hand-rails are very light, but very neat; when ornamental work is used, it is chiefly confined to iron, being rarely constructed in wood.

"Whatever may appear difficult in this method of forming scrolls proper for the plans of twisted rails, due application will make easy and expeditious.

"First, form a scroll with chalk, or a pencil, agreeable to the bigness of the place in which it is to stand; next resolve on the bigness of your stuff to be used for your rails, and also your mouldings on the side thereof, as in *Figure* 106

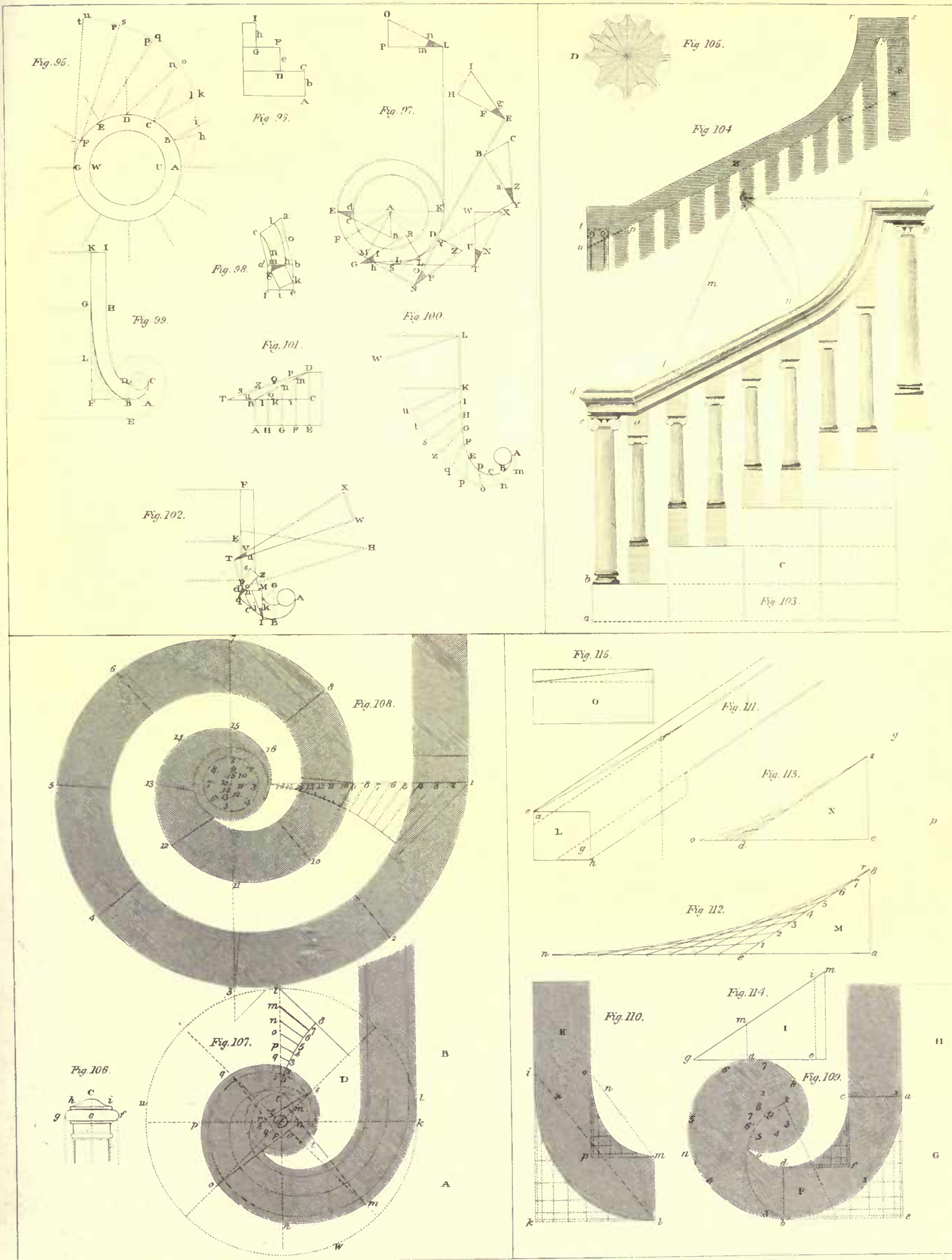


Fig. 95.
Fig. 96.
Fig. 97.
Fig. 98.
Fig. 99.
Fig. 100.
Fig. 101.
Fig. 102.
Fig. 103.
Fig. 104
Fig. 105.
Fig. 106.
Fig. 107.
Fig. 108.
Fig. 109.
Fig. 110.
Fig. 111.
Fig. 112.
Fig. 113.
Fig. 114.
Fig. 115.

Let *d* be the centre of your chalked scroll in *Figure* 107; on which describe with the projection of your mouldings from *Figure* 106, the small circle *d;* take from *Figure* 106, half the bigness of the stuff, as *eg*, or *ef*, which add to the small circle, and form the circle *h i t*, which is the bigness of the eye of the scroll: this done, take the distance from *i*, to the inside of the rail, as the supposed chalked scroll, which suppose *k;* with it, make a diminishing scale, by setting that distance up, from *t* to *l;* draw the line *k l;* place one foot of your compasses in *k*, describe the part of a circle *t* 8, which divide into eight equal parts, because here your supposed chalked scroll was to come into its eye, or block, at one revolution of a circle. (Scrolls may be made to any number of revolutions desired, by the same rule, witness that above, in *Figure* 108.)

"Place one foot of your compasses in *d*, describe the large circle *w l l u*, which always divide into eight parts, because you strike one eighth part of a circle every time, till you come into the eye, or block, *i t h;* from the said divisions on the large circle, draw lines through, for on them your sections meet, which form the scroll. It is observable in drawing your sections, that they do not end in the line drawn through the great circle, only the outside scroll; for those of the inside scroll end on a line drawn to each respective centre. I suppose A and B to be two steps; the rest, I think cannot fail of being understood, by observing the letters and figures, which show each part distinctly."

Mr. Price's advice, to make a scroll first of chalk, is altogether ungeometrical, and therefore unworthy of notice. The method of forming it is of Italian invention. A similar construction is used in describing the Ionic volute in Daviler's *Cours d'Architecture*, dated Paris, 1720. He ascribes the invention to Vignola. But, in our opinion, it is far from producing that agreeable variation of curvature required. The opening next to the eye expands too rapidly towards the extremes. A much more perfect method, and not very dissimilar in construction, is that published in the *Joiner's Assistant*, by Nicholson. *See* the Articles SPIRAL and SCROLL.

"In order to make the squaring of a twisted-rail easy, see the plan, *Figure* 109, which is the same as that in the foregoing *Figure* 107, and find the point of touch, *b*. From these curves a mould must be traced out, in order to form a sweep, which when applied on the rake, is agreeable to this of *a b*, *c d*, as that of *Figure* 110. (It is first to be observed, that you will want wood extraordinary, both on the top of the rail, as in *Figure* 111, at *e*, *a;* and also under the same, as *g*, *h*.) To find which, observe where your sweep begins, in the plan *Figure* 109, as at *a c;* also observe that *o* and *n* is the end of the twisted part. Therefore, from *a* to *n*, divide into a number of equal parts, so as to transfer them on some line, as in 112, from *a* to *n;* also divide the inside of 109, as from *c* to *o*, into equal parts, so as to transfer them on some line, as in 113, from *c* to *o;* take the distance *e a*, in 109; apply it to the pitch-board, as from *g* to *e;* take the pitch-board, 114, with its place *e* to *c*, in 113; draw the line *dg*, and make the point *s;* divide from *d* to *s* into eight equal parts, also from *d* to *o* into the same number; draw the lines, which form a sweep, whose use shall be hereafter shown.

"Likewise take the pitch-board 114, and apply *e* to *a*, in 112; draw the line *ep*, and make the point *r;* from *e* to *r* divide into eight equal parts; also from *e* to *n* do likewise; draw straight lines from each division; that curve shows how much wood is wanting on the back of the rail, as *b t*, which describe in 111, from *e* to *a;* and there describe the bigness of the rail; which shows how much wood is wanting, as may be observed by what was said above. The other part of the twist is cut out of a parallel piece, as 115; which thickness extraordinary is shown in 111, at *e a*.

"To square the twisted part of the rail, having so much wood extraordinary on the top and bottom, observe in 109, from *a* to *e*, and from *c* to *f*, must be traced as was above mentioned. Take *a e* in 109, apply it to the pitch-board 114, it shows *g i*, which length place in 110, from *k* to *i;* also, take from 109 the distance *b d*, apply it to the pitch-board 114, it shows *g m*, which length place in 110; from *l* to *m*. This done, trace out the raking-mould 110, agreeable to the plan 109, which, by inspection and a little practice, will become easy, and without which nothing is known truly. I say, the wood extraordinary being accounted for in 111 both on the top and the bottom of the rail, observe to place your stroke *f* in its true place, that is, at the beginning of the twisted part; take the raking-mould 110, set *i* to *f* in 111; there strike it by; with the angle of your pitch-board describe the pricked line *f*, by the side of the rail; then apply the mould 110 to the bottom; set *i* to this pricked line, and there describe by it, with your pencil. Lastly, cut that wood away; also, cut the remaining part of the scroll out of the block; as 115; then glue these together, and bend both moulds, 112 and 113, round the rail; strike them by that, and cut the wood away; so will the back of your rail be exactly square, and fit to work."

This method of squaring the twist of the scroll is correct; the principle is that of the section of a curved prism at right angles to a given plane, and amounts to no more than tracing a common angle-bracket. The construction, however, requires a very considerable addition to the thickness of stuff; and even this thickness will be variable, according to the place of the pitch-board. This method, though much superior to that of Halfpenny, is not to be compared with that of springing the plank, introduced by Mr. Nicholson.

Mr. Price says, that his method will apply to any twist or wreath whatever: we grant that it will; but then the stuff would require to be from 4 to 8 inches in thickness, and sometimes more. In drawing the section upon the plank, in order to be cut out, the shank of the mould is always applied parallel to the arrises; this application occasions also a great waste in the breadth as well as in the thickness. In the construction of the face-mould of the scroll, he employs the pitch-board of the flyers. He gives no example of forming a wreath over winders; but if the same principle is to be applied, recourse must be had to a development of the steps. It is unnecessary to make any farther observations, as the author of the Architectural Dictionary, Mr. Nicholson, has placed these and his own before his readers, in order to compare and point out the specific differences of each, by proper diagrams, at the end of this article.

"You are always to observe this general rule, viz., to conceive each respective paragraph, as it occurs, before you begin another; the neglect of which appears by some who cannot conceive the particulars of the foregoing Figure, although I had put it in so clear a light.

"I have here described three distinct methods of squaring the twisted part of a rail, which may be known, and the rail squared, with more ease than in the foregoing Figure. But when done, they will not have that agreeable turn in their twisted part as they would have, if done by the foregoing unerring rule, as may more clearly appear by the following explanation:—

"That of *Figure* 116, is the raking-mould, taken from *Figure* 110 (whose use and application was therein clearly shown); that of 117, is the pitch-board, taken from 114; which gives the rake or declivity of the rail.

"In *Figure* 118 is shown how to square a rail, without bending a templet round the twisted part thereof; and which is by being guided by the back; first, describe the bigness of the stuff to be used, as *a b h i*, which shows how much wood will be wanted at bottom, supposing s to be the side of the rail. And because the grain of the wood should be agreeable to the falling of the twist, therefore consider how many thicknesses of stuff will make the wood required to cut the twist out of; as here three. Therefore, as in s, continue the line *a b*; place one foot of your compasses in *a*, make the section, or part of a circle, *c d;* divide it into four parts, as 1, 2, 3, 4, because the rail s must be always reckoned as one; this, by inspection, shows how the grain of the wood is to be managed, as appears by the shape of the several pieces, 119, 120, 121, which are better, if cut so by the pitch-board, before glued together.

"In 122 is shown how to square the twisted part, making the bottom your guide; the section shows how much wood is wanted on the back.

"In 123 is shown how to square the twisted part, making a middle line on the back your guide; the section shows the wood wanting on the back and at the bottom.

"That of 124 may be cut out of a parallel piece, of the thickness of the intended rail, which, when it is glued to the twisted part, will want little or no humouring.

"*N.B.*—There is a nicety in working the mitre thereof, as *k l m*."

The above method of forming the wreath by gluing different thicknesses together in parallel blocks, perhaps originated with Price, or might be in use among workmen in his time. The process is quite mechanical, and what might occur to any well-informed workman. And though the wreath might be got out of much less stuff than by the former principle, it is tedious, and much more uncertain. To apply these properly would require the workman to understand the method of orthographical elevations; and though Mr. Price seems to have had a notion of this, his representations of the wreaths are all drawn by guess, and are therefore not to be depended upon. Another method by which this might have been ascertained, is by a plan and development of the twist, where the risings of the blocks might have been ascertained according to their several thicknesses; we shall show this improvement at the end of this article, accompanied with a diagram.

"You are to observe, the foregoing Figures must be well understood; and then, in these Figures the lengths of the newel and balusters that stand under the twist or scroll are truly described; that is, their lengths and bevels may be known before the rail be put up in its place; and, that it may prove easy, observe the plan, *Figure* 125, of the twist or scroll is the same as before, and so are the two steps P and Q, and the pitch-board, 126.

"First, resolve on the bigness of your balusters, as *a*, *b*, *c*, *d*, *e*, *f*, and also the newel. Divide the said balusters truly on a line drawn in the middle of the rail; for then what is wide on one side is narrow on the other. It is for that reason I choose to divide them on a middle line. Describe the plan of the balusters, as *p q*, *r s*, *t u*, *u w*, *x y*, and *z*, for there your twisted part ends; from thence to the eye is level.

"Observe where your scroll begins, as at *l*, and on some line, as above in 127, first make a point at *l;* then from your plan take the distances *p q*, *r s*, *t v*, *u w*, *x y*, and *z*, which transfer as above, observing to have regard to place truly each distance from *l* both ways, as *p q*, *r s*, *t v*, *u w*, *x y*, and *z*. Observe also to take from the plan the distance from *l* to *m*, which apply to the pitch-board R, as from *h* to *n*, which gives the length *h o;* take this pitch board and apply it on the line above, which, by inspection, the letters will show; this gives the slope of the rail, as *h o &c*. From *o* to *h*, and from *h* to *y*, form the curve by equal divisions, and drawing straight lines, as was before shown.

"Lastly, having the lengths of your fixed balusters, as *a b*, *Figure* 127, describe the steps S and T with the pitch-board: so that by continuing perpendicular lines, from the points on the line first terminated to the said curve and to the steps, you have the accurate lengths of the balusters, as *a*, *b*, *c*, *d*, *e*, *f;* the newel *g* being the same length as *f*, because at *f* or *z* the twisted part ends.

"The curve of the first, or curtail-step, *Figure* 125, is formed by the same rule as delivered for the plan of the rail.

"It may not be amiss to observe particularly the point of the sweep or curve's beginning, and being particular also in its application, by which this and the foregoing, though represented with but two steps, is the same, in fact, as though I had described a whole flight to show its use."

To ascertain the height of the balusters is not of very great importance to workmen of the present day. The method is, however, correct; and though it might be laid down and expressed more clearly, it is as eligible as any that can be applied to the purpose. Price's remark for taking the middle line for the division of the balusters is judicious.

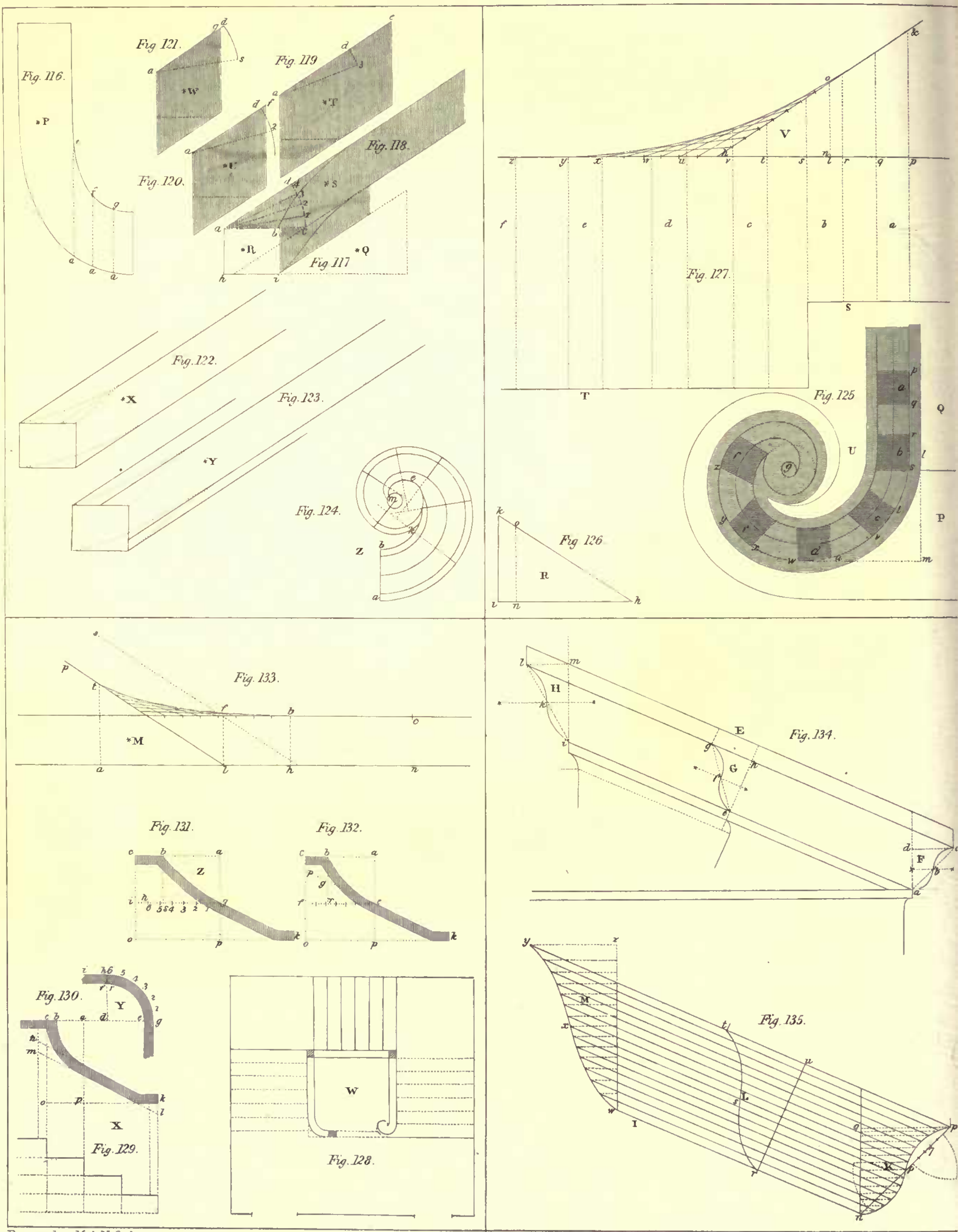
"Zealous to promote," says he, "what may be useful, I have made easy the difficulty of squaring a rail that ramps on a circular base.

"Observe, *Figure* 128 is the plan of a staircase; and at the landing is a quarter-circle: to make this easy, in 129, is three steps, described by a larger scale, and the same method as shown in 103, 104. Likewise, 109 is the plan of the rail. It was shown in 110, &c., how to trace out a mould on the rake, agreeable to this plan, or indeed any other. A considerable thickness of wood more than usual is required on the back of this rail, which will appear more plainly by inspecting 117, &c., as also the method to trace your moulds that shall bend round the said rail. Let the sides be squared, as was shown in 109, 110, 111, 112, 113, 114, 115. Observe here, in *Figure* 129, the line *k p o;* take the distance *k p*, and place it on some line at pleasure, as in 130: then divide the outer circle in 130 into a number of equal parts, as into six, as from *g* to *h*, which transfer to 131, as *g*, 1, 2, 3, 4 5, 6, *h*. The point of the ramp may be observed to fall within the fifth division, as at *s;* so that by the intersection of straight lines and equal divisions, you describe the sweep for the ramp *g b*, which makes 131, the mould, to bend round the outside of the said rail.

"Observe also in 130, from *e* to *f*, divide it into six equal parts, which transfer to 132, as from *e* to *f;* and (observe again) the ramp falls within the fifth division, as at *r*. So divide the distance from *e* to *g*, and from *g* to *b*, into equal parts, and by drawing straight lines, you have the sweep *b e*. From the point *b*, to *p*, is the thickness you want to be added extraordinary on the back of the rail 132, and which is the inner mould; so that by bending both these moulds round the rail, and by drawing them with a pencil, and cutting away the superfluous wood, you have an exact square back.

"There seems no difficulty now left unmentioned, to square twisted rails in any form whatever.

"Because I have all along strove to give variety, observe 133, in which is shown a method to have your newel under the twist, the same length as the rest; by which means also the rail twists no farther than the first quarter, and consequently the remaining part may be cut out of a plank, of the thickness of your rail, without twisting at all. There seems no explanation wanting to clear this point, but inspection. and a good conception of *Figures* 109, 110, 111, 112, 113,



Drawn by. M.A. Nicholson.

Eng.[d] by R. Th

114, 115: in this of 133, *l f* is the thickness of wood extraordinary wanting on the back of the rail."

The method which Mr. Price employs at 132, for ascertaining the thickness of stuff by a falling-mould, or development of the side of the rail, is incorrect; nor can it be found in a determinate manner without an orthographical elevation of the part of the wreath to be formed. This concludes the whole substance advanced by Price in the article Joinery, and shows improvement only in its infancy.

Mr. Price has also shown the method of forming raking-mouldings for pediments, as follows:

"And in consideration that no pediment can be performed without two kinds of cornice, (except it be knee'd at its bottom or springing, which is reckoned a kind of defect,) therefore to give each of the cymas such a shape, or curve, as shall strictly agree in their mitre, do thus: Describe the curve of the level cornice F, *Figure* 134, as *a b c*, by two such portions of circles, as that the centres for forming each may be on a horizontal or level line, drawn through the middle of the said cyma; as * *, *c d;* being the projecture thereof. Draw lines from the points of the said cyma, agreeable to the slope of the pediment, which gives or terminates the bigness of the raking cornice or cyma G; so that by drawing a line through the middle of the said member, on it are the centres * *, by which the curves *e f g* are described; the projecture, *h g*, being as before. In case a break or return be made in the pediment, then another kind of cyma must be formed, which shall agree with the two former, as H; the centres for forming each curve being on an horizontal line drawn through the middle of the cyma, as before; *i k l* is the curve, whose projecture, as before, is *l m*. These three kinds of cornice being thus formed, will agree with each other, without the trouble of tracing. But if the given curve be not described as before, then observe the method proposed in 135; by which the curve of any raking-mould whatever may be truly described. Admit the cornice given were K; *n o p* being its curve, and *p q* its projecture; by making points on the said curve, draw lines from them, agreeable to the slope of the pediment, on which place each respective projecture from K to L, so is *r s t* its curve, the projecture being *t u*, as before. And if a break or return be made, as M, then transfer the several projectures from K, observing that the points be on the lines drawn agreeable to the rake of the pediment, so will *w x y* be the curve, and *y z* the projecture, as before: which no doubt but inspection explains."

The scheme for raking-mouldings, shown at 134, is not to be depended upon. It is evident that since the figure is a prism, and since the given curve is composed of circles, the curves required must be composed of elliptic segments, unless the sections are parallel to each other, which is not the case.

The second method, shown at 135, is perfect, and is the first thing of the kind that is to be found in any English publication.

We come now to the *London Art of Building*, by William Salmon; and as it is our province to repeat only the inventions and improvements in joinery, we shall therefore omit what Mr. Salmon has said on the formation of the scroll; being, in method and substance, the same as that which we have detailed from Mr. Price, who certainly gave the first rational method of squaring the twist for the scroll part of the rail, either from his own invention, or from a practice known among workmen. And as Mr. Price has only shown the formation of the twist of a scroll, and of a rail upon a quadrantal plan in a level landing, we shall here detail the application made of the same principle by Salmon to a winding stair, where the treads of the steps are all equally divided around the circumference; but first it would be necessary to notice the candid acknowledgement which Mr. Salmon has made in respect to the principle.

"I must confess, for this method of forming twist rails, I have had my eye upon, and am obliged to, my ingenious friend, Mr. Francis Price, in his *Treatise on Carpentry*, lately published; though, on comparing them, you will not find them alike. This method of forming the raking-mould will serve for all twist rails whatsoever, with due application, as shall be shown in another example of a staircase, having a circular well-hole.

"*Figure* 136, is the plan of a circular rail having sixteen steps in the whole circumference; but here it is proposed to find the raking-mould to a fourth part thereof, or four steps, it being to a small scale. The plan being laid down, as *a c d e*, *Figure* 136, divide the outer circle into a number of equal parts, so as to transfer them on some line, as *a c*, *Figure* 137; and setting up the rise of four steps, as *a b*, gives the pitch-board, due to them all. Then taking *b c*, in *Figure* 136, applied to the pitch-board, *Figure* 137, from *c* to *d*, it gives *c e*, which transfer to *Figure* 138, from *b* to *c*. Also, from *Figure* 136, take *a d*, placed in *Figure* 137, from *c* to *g*, gives *c f*, which transfer to *Figure* 138, from *a* to *d;* and there tracing, as before taught, you will form the raking-mould required."

In such a staircase as the above, the waste of stuff is great; but when does it ever come into practice, that the steps are equally divided? In every stair there must be a landing and this would require much thicker stuff: Again, if the stair is mixed with flyers and winders, the waste stuff would in many cases be enormous, and still more so, if the joint were brought over the flyers, in order to secure the wreath and straight parts more firmly by a screw, as is the case in modern practice. The greater number of stairs now in use, are constructed upon this plan.

"Some able workmen have another method of forming this rail.

"First, they make a cylinder, equal to the whole well-hole, *f*, *e*, in *Figure* 136, or part thereof, either solid (if the well-hole be small) or (if large) by fastening boards together upright, in the exact form of the plan.

"Then they proceed to set on the said cylinder, as *Figure* 139, the height and breadth of each step, as *a*, *b*, *c*, *d*, *e*, *f*, &c., and to the extreme points, *b*, *d*, *f*, they bend round several thin pieces of the breadth of *c*, *f*, in *Figure* 137, and being glued, or otherwise fastened together, till they make the thickness of the rail, I say these when taken off from the cylinder, will be the rail, and exactly squared to the right twist.

"This is a very safe and sure method, though not very frequently made use of.

"Either of these ways will serve, should the well-hole be an ellipsis, or any other figure for its plan."

The first idea of gluing a rail in thicknesses is here shown, but the description, and the figures accompanying it, are very imperfect; nor will the rail come off squared, as Mr. Salmon asserts, without the veneers are all different in proportion to the radius of their plan, except, indeed, upon the plan which he has shown, where the rail is supposed to be continued, and therefore requires much amendment to be brought into general use.

Langley's improvements are as follow

"*To describe a twisted rail.*—Let the lines B D E, *Figure* 140, represent the edges of the two lower stairs of a staircase.

"Divide *b* 9, the tread of the second stair, into nine equal parts, continue the line D towards the left at pleasure. Draw N F, parallel to 9 *b*, at the distance of seven parts, also draw the line 14 *d* at the distance of three parts, then *d b* is the breadth of the hand-rail. Draw A *n* parallel to 9 *b*, at the distance of *b* 9, then the point *n* is the centre of the eye of the scroll. On the point *a* describe the quadrants *b c* and *d e*, which is the length of the twisted part of the rail, the remaining part, to *n*, the eye, being level. On *n* describe the circle *z x p*, whose diameter, *w p*, must be equal to *d b*, the breadth of the hand-rail. Divide the radius, *n p*, into four equal parts, and through the first part, at *o*, draw the line *r l*, cutting the line N F in *x* : on *x* describe the quadrants *c f* and *e g*, make *o t* equal unto two parts of *n p*, and draw the line *t s* parallel to A *n*. On the point *t* describe the quadrants *f h* and *g z*, make *n w* equal to three parts of *n p*, and through the point *w* draw the line *z k*, parallel to *r x* ; on *z* describe the quadrant *h v*, and on *w* the quadrant *v p*, and then is the plan completed."

This is a very anomalous attempt at the description of the scroll of a hand-rail with compasses, the first centre being at *a*, the second at *x* ; the third centre is said to be at *z*, but it proves to be at *o* ; neither *t* nor *w* answer to the remaining centres.

"*To describe the mould for the twist.*—Continue *b* 9 towards M, and F N towards *b* in *Figure* 141 ; also draw L I parallel to *b* N ; at the distance of N K, in any part of N *b*, as at *c*, draw the line *a f* at right angles to *b* N ; and on *c* describe the semicircle *a b f* : make *a d* and *f t* each equal to the rise of one stair, and draw the line *d c t*. Make *c* N equal to *c t* ; divide *b c* into any number of equal parts and draw the ordinates 15, 1 ; 16, 2 ; *k* 3, &c. ; divide *c* N into the same number of equal parts as in *b c*, and make the ordinates thereon equal to the ordinates on *b c*, and through their extremes trace the curve N *f*, which is the curve of the outside of the mould. Make *b k* equal to the breadth of the hand-rail ; and on *c*, with the radius *c k*, describe the inner semicircle. Make *c h* equal to *r t*. On *k t*, the semi diameter of the inner semicircle, make ordinates, which transfer on *c h*, as before ; and through their extremes trace the curve of the mould, which will complete the whole as required ; for as the outlines of the plan of the twisted part of the rail, *b c* and *d e*, are quadrants, therefore the outer and inner curves of the mould will be both a quarter part of two ellipses ; because the twisted rail, strictly considered, is no other than the section of a cylinder, as L M I K, whose diameter, *a f*, is equal to twice *a b*, in *Figure* 140, and its transverse diameter equal to *d t*, and conjugate diameter to *a f*.

"The twist of a rail over a circular base at a half pace, as *a b*, figure 142, is the very same thing as the preceding, as being the fourth part of an ellipsis, made by the section of a cylinder, whose diameter is equal to twice *a c*."

This method of forming the section is the same in effect as that already shown by Price. The only difference between Price and Langley is, that Price forms the face-mould of the rail from the intersection of straight lines drawn from two lines of sines placed at right angles to each other, and tracing a curve through the diagonals of the rectangles, beginning at the extremity of one of the perpendiculars, and ending at the extremity of the other. Whereas Langley divides the breadth of the plan and the length of the face-mould of each into the same number of parts, and draws lines at right angles through the points of division, and makes the respective perpendicular of the face-mould equal to those of the plan, and then traces curves through the extremities for the concave and convex sides ; and thus completes the face-mould of the twist.

Figures 143, 144.—"*To find the mould of a twisted rail to a circular or elliptical staircase.—Figure* 143. Let A B C D be the plan of a cylindrical staircase, whose base is a circle, and whose stairs wind about the cylinder *a b d*, &c. The plan of the stairs being divided, continue out the diameter *d a*, towards the right hand, as to *f*, of length at pleasure. Make *a f* equal to the girt of the semicircle *a b d*, which divide into the same number of equal parts as there are stairs in the plan of the semicircle *a b d*, as at the points 1, 2, 3, 4, &c from which erect perpendiculars, as 1 *a*, 2 *a*, 3 *a*, &c. of length at pleasure. Consider the rise of a stair, and make the perpendicular, *f g*, equal to the rise of all the twelve stairs that go round the semicircle *a b d*, and divide the perpendicular *f g* into twelve equal parts, as at the points 1, 2, 3, 4, &c. from which draw lines parallel to *f d*, continued out towards the right hand at pleasure, which will intersect the perpendiculars on the line *f a d*. in the points *ac*, *ac*, *ac*, &c. and which are the breadths and heights of the treads and risers of the twelve stairs at the side of the semi-cylinder *a b d* ; for were the whole of *Figure g f a* applied about the semi-cylinder, then the parts *a c*. *a c*, &c. would be in the respective place of each stair. Let *a e* represent the breadth of the hand-rail, and the semicircle *e* 10 *c* its base, over which its inside is to stand. Divide its diameter, *e c*, into any number of equal parts, as at 1, 2, 3, 4, &c. and draw the ordinates 1, 6 ; 2, 7 ; 3, 8 ; 4. 9, &c. which continue upwards, so as to meet the horizontal lines drawn from the perpendicular *g f*, in the points 28, 27, 26. 25, &c. through which trace the ogee curve 28, 14, *a*, which is the sectional line of the cylinder over which it stands. Make the distances, 15, 21 ; 19, 14 ; 18, 13 ; 17, 12 ; and 16, 11, equal to the ordinates 10, 5 ; 9, 4 ; 8, 3 ; 7, 2 ; and 6, 1 ; and through the points 20, 19, 18, 17, 16. to *a* on the line *f d*, trace the curve, 20, 16, *a*, which is the inside curve of the mould, and whose out-curve, 21 *a*, being made concentric thereto, will be the mould required, whose end, 21, 20, when set up in its place, will stand perpendicular over its base *b* 10.

"*Note.* This mould, though made but for one-fourth part of the cylinder, will serve for the whole, by repeating the same, or adding three or more others of the same kind to the ends of each other as often as there are revolutions in the cylinder."

It is not possible to conceive anything so void of truth as the method here shown. Over and above the absence of principle, the description is contradictory to the diagram. We are told to "divide its diameter, *e c* (into any number of equal parts) as at 1 2 3 4, &c. and draw the ordinates 1 6, 2 7, 3 8, 4 9, &c. which continue upwards so as to meet the horizontal lines drawn from the perpendicular *g f* ;" but instead of being drawn through the diameter, they pass through the divisions which divide the concave circumference of the plan into equal parts.

Langley has presumed to differ in method from Price in finding the curvature of raking-mouldings ; but in this he has been much mistaken, as may be observed in the following :—

"*To find the curvature or mould of the raking ovolo that shall mitre with the level ovolo.*—Let *n p*, *Figure* 145, be a part of the level cornice, and *a n* the points from which the raking-cornice takes its rise, also, let *f a* and *g n* represent a part of the raking-cornice. On *n* erect the perpendicular *n b*, and continue *l a* to *b* ; divide *b n* into any number of equal parts at the points 1, 2. 3, &c. and from them draw the ordinates, 1 2, 3 4, 5 6, &c. In any part of the raking ovolo, as at *c*, draw the perpendicular *c m*, and make *c d* equal to *b a*, the projection of the level ovolo. Divide *c m* into the same number of equal parts as are in *b n*, as at the points 1, 3, 5, 7, &c. from which draw ordinates equal to the ordinates in *b n*, and through the points 2, 4, 6, &c. trace the curve required. In the same manner the curvature or mould

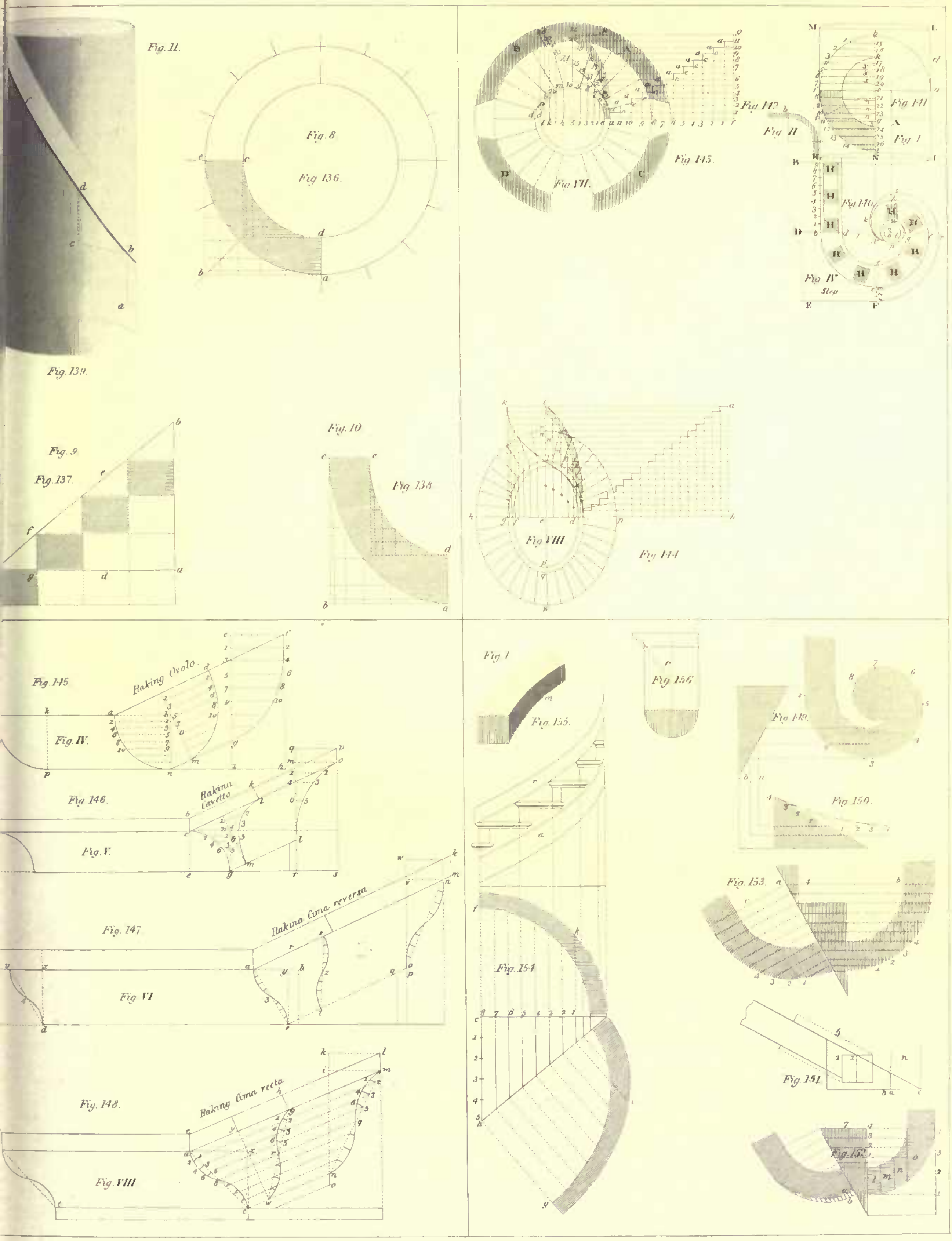


Fig. 11.
Fig. 139.
Fig. 8
Fig. 136.
Fig. VII.
Fig. 143.
Fig. 142
Fig. II
Fig. 141
Fig. I
Fig. 140
Fig. IV
Step
Fig. 9
Fig. 137.
Fig. 10
Fig. 138
Fig. VIII
Fig. 144
Fig. 145
Raking Ovolo
Fig. IV.
Fig. 146.
Raking Cavetto
Fig. V.
Fig. 147
Raking Cima reversa
Fig. VI
Fig. 148.
Raking Cima recta
Fig. VIII
Fig. I
Fig. 155.
Fig. 156
Fig. 149.
Fig. 150.
Fig. 153.
Fig. 154
Fig. 151
Fig. 152

may be found when the upper member is a cavetto, cyma-recta, or cyma-reversa, as is exhibited in *Figures* 146, 147, 148."

"*To find the curvature or mould of the returned moulding in an open or broken pediment.*—Let the point *f*, *Figure* 145, be the given point, at which the raking-moulding is to return. Continue *n p* towards *h* at pleasure, and from the point *f* let fall the perpendicular *f h;* draw *f e* parallel to *h p*, and make *f e* equal to *b a*, the projection of the level cornice. Draw *e i* parallel to *f h*, and divide *e g* into the same number of equal parts as are contained in *b n*, as at the points 1, 3, 5, 7, &c. from which draw the ordinates 2 1, 4 3, 6 5, &c. equal to the ordinates in *b n*. Through the points 2, 4, 6, 8, &c. trace the curve required. In the same manner the curvature or mould may be found when the upper member is a cavetto, cyma-recta, or cyma-reversa, as is exhibited in *Figures* 146, 147, 148."

In the treating of a subject in order to make it as perfect as possible, it ought to embrace every article hitherto known that is intimately connected with it; and no author ought to be ashamed to copy an article from another when it comes within his plan; but then he ought to acknowledge his authority, provided that it has not become common property; in this case he may either use it with or without such acknowledgment, as he pleases. There are some authors, however, who, rather than follow the principle of another, will show a different method in order to have the appearance of originality; but as this has every chance of being detected and exposed in future, it must reflect a double disgrace upon their memory. This circumstance is applicable to Langley: it would have redounded to his credit to have copied Price's second method, and to have made honourable mention of his name.

Mr. Abraham Swan has also contributed something to the practical improvement of joinery: his method of describing the scroll is that invented by Vignola; we shall therefore refer the reader to our review upon Price for the detail; but though his face-mould and its application are the same as given by Price, the manner in which he constructs his diagram in order to obtain it is more obvious to the practical joiner, as the corresponding parts of the section may be turned into the same position with regard to the plan, that the section of the solid itself has with regard to its base.

The manner of squaring twist-rails.

Figure 149, "exhibits the pitch-board, to show what part of the step the twisted part of the rail contains; the three dotted lines drawn from the rail to the pitch-board represent the width of the rail, that from the middle shows the ridge, or middle of the rail, which is to be kept level. The dotted lines *a* and *b*, show how much half the width of the rail turns up from its first beginning to 3.

Figure 150, "shows the same pitch-board, with the manner of the rails turning up. If the sides of the twisted part of the rail be shaped by the rail-mould, so that they direct down to its ground-plan; that is, the upper side of the rail being first struck by the mould, then apply the mould to the under side, as much back as the bevel of the pitch-board shows, by being struck on the side of the rail, and then *Figure* 150, being applied to the outside of the rail, from its first twisting part to 3, will show how much wood is to be taken off."

In this part Mr. Swan is so unintelligible, that his reader can only guess at his meaning; by the term *rail-mould* he may either mean the face-mould or the falling-mould; but from the application which he makes of the said *rail-mould*, a practical workman only can discover his meaning to be that of the face-mould.

Figure 151, "exhibits the square of the rail, with the raking-line of the pitch-board drawn through the middle on the upper side; then draw the depth of the side of the rail parallel to this, and the dotted lines from the diagonal of the rail; these lines show what quantity of wood will be wanting on the upper and lower sides of the rail. Set your compasses at *c*, and draw the circular stroke from the raking part of the pitch-board to *b;* take the distance *a b*, and transfer it from *a* to *b*, in *Figure* 152. The several distances thus found, may be set at any number of places, ranging with the straight part of the rail; and it then forms the width of the mould, for the twisting part of the rail.

Figure 152, "shows the sweep of the rail. The rail cannot be fixed less than one-fourth part from the nosing, or front of the step.

"The remaining part of the pitch-board may be divided into any number of parts, as here into four; from these divisions draw lines across the pitch-board to the raking-line, then take the distances from the ground-line of the pitch-board to the plan of the rail, and set them perpendicular from the raking-line of the pitch-board; so shall these divisions, when the rail is in its proper position, lie directly over the divisions on the ground-plan.

"In this Figure, *l*, *m*, and *n*, rise as much above *o*, as the dotted line in *Figure* 151, does above the width of the rail; and they sink as much below *o*, as the other dotted line in *Figure* 151, falls below the width of the rail; the same thicknesses must be glued upon *o*, though the greatest part will come off in squaring. The reason of placing the letters *l*, *m*, *n*, where you see them, is, that they might not obstruct the small divisions of the rail-mould."

This is hardly intelligible to any but Mr. Abraham Swan himself.

Figure 153, "shows how to find the rail, when it takes more than one step. The remaining part of the pitch-board is divided into four parts, as before in *Figure* 152, and it takes in two such parts of the next step. Draw lines from these divisions to the diagonal of the pitch-board, as in *Figure* 152, then take the distance, *a b*, and set it from *c* to *d*, and so proceed with the other divisions.

"Here is also shown another way to find the outside of the rail-mould. Draw all the divisions across the plan of the rail; then take the distance from the ground-line of the pitch-board to 4, transfer it from the diagonal of the pitch-board to 4 on the rail; and so proceed with the other distances. Then, when the rail is put in its proper position, *c* will be perpendicular to *b*, and all the divisions, as 1, 2, 3, 4, &c. in the rail, will be perpendicularly over 1, 2, 3, 4, &c., in the ground-plan."

This method of laying down the face mould is simple, and easily comprehended by every one who understands anything of the nature of a prismatic section.

Figure 154, "shows the plan of a rail of five steps.

"*To find the rail.*—Set five divisions, as from *e* to *h*, which is the height of the five steps; draw the diagonal from *h*, to the plan of the rail; then take the distance *e f*, and transfer it from *g* to *h*, and proceed in the same manner with the other seven distances."

"*To find the width of the rail-mould.*—Draw the lines across the plan of the rail, as at *k*, set that distance from the diagonal to *i;* and so proceed with the rest, as was shown in *Figure* 153.

"Having formed the sides of the rail, perpendicular to its ground-plan, and having squared the lower end of the rail, then take a thin lath, and bend it within the rail, as is represented by *m*, in *Figure* 155."

The general practice of forming the pitching-triangle is by the number of treads, and the rise in the same number of steps. This is not, however, to be understood of a winding-stair, but of a flight of steps.

"This is the readiest method for squaring a solid rail; but if the rail be bent in the thickness, the nosing of the steps must be drawn upon a cylinder, or some other solid body of a sufficient width to contain the width of the rail, or string-board.

"*r* represents the depth of the rail, touching the nose of each step. You are to take a sufficient number of thicknesses of this width, to make the thickness of your rail; glue them altogether upon your cylinder, or templet, confine them till they are dry, then the rail taken off is ready squared. Proceed in the same manner with the architrave marked *a*."

His method for gluing a rail in thicknesses is the same as Salmon's, but his diagram is better constructed.

Mr. Abraham Swan has also applied the development of a conic frustum to the formation of mouldings upon the spring, round a cylinder, as follows:

Figure 156, "shows the method of bending a cornice round any circular body. When you have found the spring of your cornice, which is shown at the right hand, let the dotted lines be drawn parallel to the spring, and where they intersect the centre, or middle of this body, as in *c*, you will have the radius to strike the curve of your cornice. This principle is as correct as the nature of wood will admit of, and the thinner the wood is, the more exactly will it apply. Besides this, there is another method of forming an annular moulding on a cylinder by thicknesses.

Mr. William Pain has also contributed to the practice of joinery; and though he has not invented any new methods, the plates of his books exhibit the various elevations of stairs, or sections, as they are called, in greater perfection than is to be found in any prior publication: by this means he ascertains the lengths of the rough strings, and the framing of the carriages. He has also shown the stretch-out or development of the rail, and its connection with the string-board, in a more obvious manner to the student, than any of his predecessors. In his *Builder's Pocket Treasury and Practical Builder*, he describes the scroll in the same manner as is to be found in the *British Carpenter*, by Price; his text is, however, very unintelligible. In *Plate* 93, of his *Golden Rule*, third edition, is the following description, engraved on the plate, for finding the face-mould of a hand-rail upon a circular or elliptic plan:—"The method for tracing the raking-moulds for stairs, or any kind of moulding on a cylinder, (see *Figure* 157).—The mould *a* on an ellipsis, and the mould *b* on a circle. Stretch the rise and tread of one quarter, as *a b*, or *c d*, and trace the moulds *a* and *b*, from the plan, as 1, 2, 3, 4, 5, 6, 7, 8, &c. which is plain to inspection." It is not so very plain, nor is there any connection by which its evidence appears. He does not even show how the outer edge of the face-mould is to be obtained: in the diagram it is quite erroneous, its breadth being equal throughout the length of the curve. He tells us to stretch out the rise and tread of one quarter, as *a b*, or *c d*; but on inspecting the diagram, we find that "*a b*, or *c d*," is the hypothenuse of a right-angled triangle, whose base is the tread, and its height the rise of the steps in one quarter: this method is not regulated by principle, but by whim or trial, and is therefore erroneous. In *Plate* 67, of his *Practical House Carpenter*, sixth edition, is a semicircular stair, with winders in the semicircle, and flyers adjoining to the winders, where they begin and end, (see *Figure* 158.) As is usual with Mr. Pain, there is no description of letter-press, and the explanation is contained on the plate, as follows:

"A staircase on a circular plan, drawn half an inch to a foot, with falling moulds and face-mould stretched out, with all the parts figured for practice, the ramps may be traced by the intersection of lines.

"A. Depth of the block for the circular part.

"B. The thickness of ditto."

Figure 159, shows the rail stretched out for the outside falling-moulds, showing the thickness of stuff.

Figure 160, the rail stretched out for the inside falling-mould; and *Figure* 161, the method of getting out the face-mould. In the construction of the face-mould, instead of the rise and tread of the steps, as he writes, on the lines of the figure, we find, by the said diagram, that the diameter and rise of the steps in the semi-circumference are used. Such contradictions entirely confound his readers; and though the latter is nearer to the truth than the rise and treads of the steps, as he writes, the face-mould is far from the pitch, except the wreath were formed for a whole semicircle, as we shall hereafter show; nor can the thickness of stuff be obtained from the stretch-out of the outside falling-mould, as exhibited in *Figure* 159. In the said figure, the reader may also notice the inconsistency of showing the scroll in perspective, while the rail itself is stretched out.

In *Plate* 68, of the said *Practical House Carpenter*, is shown the plan of the rail of a semicircular stair, upon a level landing. *See Figure* 162. He writes thus upon the Plate: "Face-mould for a continued rail on a landing, without winders." In this diagram he uses the diameter and height of one step, which is quite analogous to the method used in the preceding example.

In *Plate* 70, of the said "*Practical House Carpenter*," he shows another stair, upon the same plan as in the first example, (*see Figure* 163;) above is shown an elevation of the rail at *e*, in order to get the thickness of stuff. This diagram certainly shows some idea of the principle, but he has failed in not giving the true delineation with regard to the thickness and depth, and in drawing the two lines which ought to contain the thickness of stuff, to touch the sections at each end, without cutting into them; but to be correct, they should touch the extreme parts. The method of tracing the face-mould is shown in *Figure* 164. It is quite analogous to the two preceding examples. He shows the face-mould in all these examples for the wreath of a whole semi-circumference, which is twice the extent that it ought to be: for though it is not impossible to execute the whole wreath for a semicircle, yet such execution is attended with a prodigious waste of stuff and time; besides the impossibility of matching the grain of the wood. He writes thus upon the plate:

"B. The string-board stretched out for the circular part, (*Figure* 165.)

"*d f*. The hand-rail stretched out.

"*e*. The section of the circular rail, showing the thickness of stuff.

"*c*. The face-mould traced from the plan A, for a solid rail.

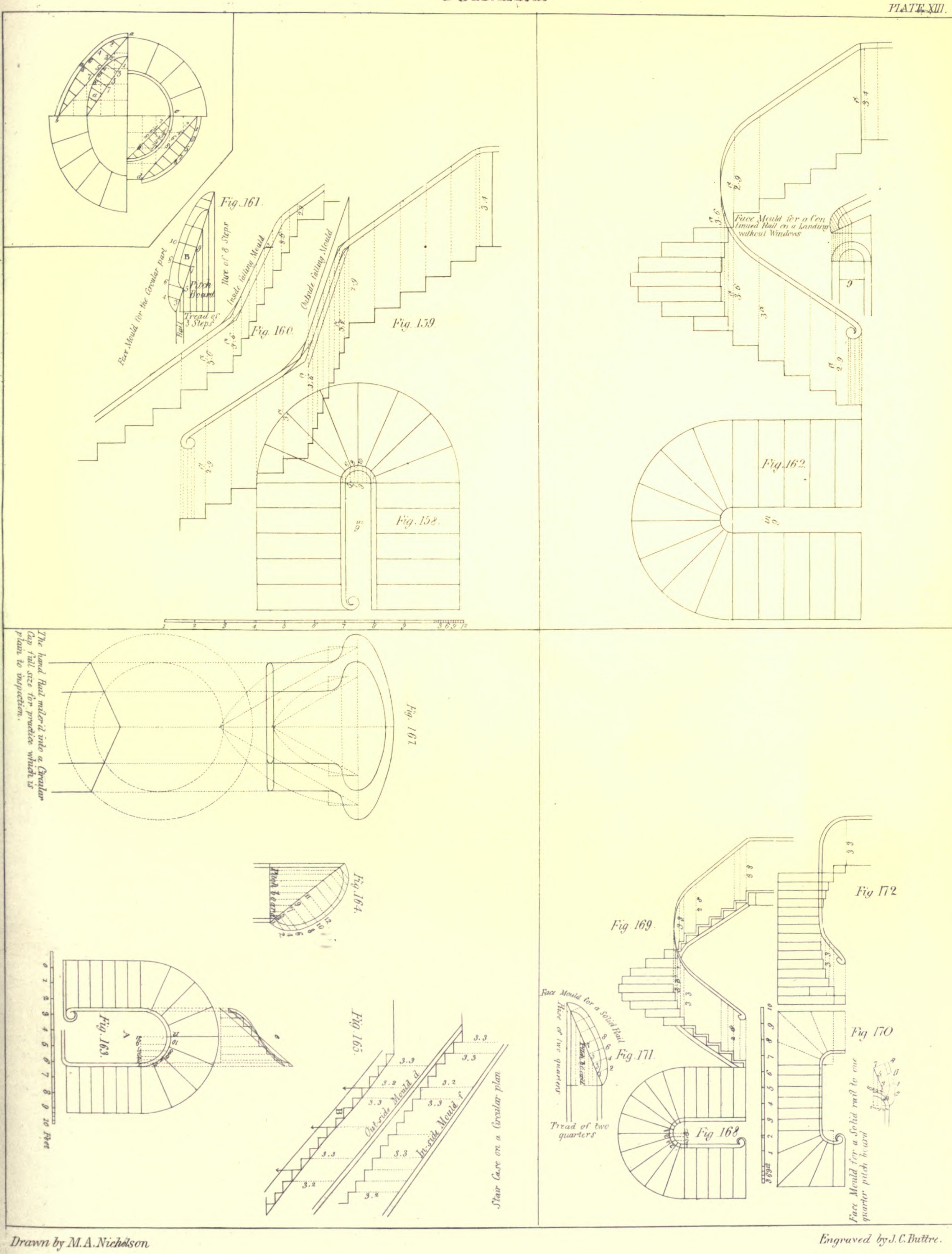
"If the rail is bent in thicknesses, *d* and *f*, *Figures* 165, 166, represent the mould drawn a quarter of an inch to a foot."

In *Figure* 167, is his erroneous method of drawing the circular cap with compasses, which has no relation to any principle.

In *Plate* 76, of the said *Practical House Carpenter*, see *Figure* 168, is also shown a stair upon the same plan as in the first example: the method of finding the face-mould is analogous to the first, viz., the diameter of the plan of the rail, and the rise of the steps round the semi-circumference, he forms a mould for the whole semi-circumfer-

JOINERY.

PLATE XIII.



Drawn by M.A. Nicholson

Engraved by J.C. Buttre.

ence as before. The elevation of the rail is shown above. See *Figure* 169.

In *Figure* 170, also in the said *Plate* 76, is shown a stair with winders in the quadrantal turnings, and flyers joining the winders. In finding the face-mould, *Figure* 171, the radius of the rail, and the height of the steps in the quadrantal are used, and the face-mould is traced, as in the former examples, and is exactly one-half. Besides the waste of stuff attending this method, it is impossible to match the grain; for if the fibres match the straight rail at one end, they will stand at right angles to those of the straight rail at the other end, in such a stair as the present; and in semicircular turnings the fibres of the wreathed piece would be at right angles to both of the straight parts of the rail. These are not the only disadvantages which accompany this method: as it is evident, that a rail thus got out must be much weaker than one where the fibres run parallel with the chord of the face-mould, neither can it be well secured by bolts at the joints. In Mr. Pain's works, he does not show the application of the face to the plank. However, upon the whole, though he has little or no invention in respect of hand-railing, he has as much originality to claim as any of his predecessors, Price excepted. His orthographical elevations of stairs, though very useful, are very ill projected. In his display of dog-legged staircases, his elevations are tolerably well drawn, see *Figure* 172. He has also been useful in showing the constructions of carriages for geometrical stairs, as they were produced in his time. Though his plates abound in contradictions and false schemes, they show his intention more clearly than some of the preceding authors.

Although the principles of cylindric soffits in an oblique straight wall, where the axis of the cylinder is parallel to the horizon, may be gathered from Price; Pain has exhibited the first example: but the constructions which he gives in his *British Palladio*, and in his *Practical House Carpenter*, are wrong, as we shall show under the article SOFFIT; and yet, in the *British Palladio*, in a similar case, in the covering of polygonal domes, *Plate* 39, *Figures* A, B, C, D, he is right. It is something singular, that the construction which he gives for a circular wall is correct, as shown in his *Golden Rule*, in his *Practical Builder*, in his *British Palladio*, and in his *Practical House Carpenter*.

The method of constructing and gluing up columns is shown in *Plate* 18, of the *Practical House Carpenter*. He shows the methods for gluing on the blocks for carving the leaves in the Ionic and Corinthian capitals, *Plates* 34 and 35, *Practical House Carpenter*.

In *Plate* 63, of the same work, he attempts the construction of raking-mouldings, but fails, as Langley had done before. He also shows, in the same work, how the proportions of the heights of the members of cornices upon a diminished scale are obtained, but neglects to show the projections in the same ratio.

In summing up the whole, we shall omit the several schemes which have failed; and the various authors, with their inventions and improvements, will stand as follow: Price first showed a method for constructing hand-rails, and applied the same to the wreath part of a scroll and to the quadrantal rail on a landing: he also spoke of its application to continued winding stairs, but gave no example. We shall afterwards notice the disadvantages attending his method. This author also gave the first construction of raking-mouldings, in the *Art of Hand-railing*, and Salmon, following Price's principle, gave an example of a continued winding-stair. Langley, in his first example, varied this construction, by applying ordinates dividing the plan and the section into a like number of equal parts, and making the ordinates of the section equal to the corresponding ordinates of the plan; and in this Langley gave the first introduction to ordinates in hand-railing, though ordinates were used by Price in other prismatic constructions.

Swan connected the face-mould with the plan, by placing the pitch-board between them, and so drew ordinates perpendicular to the base of the pitch-board, which he carried up to the hypothenusal line, used as a base to the prismatic section, and then drawing ordinates to such base, made the corresponding ordinates of the section equal to those of the plan, and thus completed the face-mould. This was certainly an improvement upon Langley's first method, as by this means it became more evident to the reader. The methods, however, shown by Langley and Swan, were in effect the same as Price's; that is, they would give the same moulds, under the same data or circumstances, and consequently would partake of the same advantages or disadvantages, as we shall exemplify at the end of this article.

The application of the surface of the frustum of a cone was first applied by Swan, to mouldings bent to the spring round a cylindric body. Pain followed the scheme of ordinates laid down by Swan, and constructed his falling-moulds in a more eligible manner than any of the preceding authors; but he is very inconsistent in a disagreement between his text and his diagrams, as well as in showing his moulds for the formation of rails, answering to a complete semicircular plan.

There are several particulars with respect to hand-railing to be observed on the whole; in all the wreaths hitherto constructed, the joints are always made at the spring, viz., at the dividing surface, between the straight and circular parts, and the fibres of the wood will always run perpendicular to those of the straight rail, at one end at least; by this means the fibres, or grain, as they are called, are ill-matched, and the wreath becomes extremely weak at the joint. In none of these methods shown by Langley and Swan, which in effect are Price's, will the section coincide in any more than any one point on the top of the lower extremity of the wreath, and this circumstance, therefore, occasions a vast waste of stuff, as we shall presently prove. Pain also showed the method of constructing columns; forming and gluing up capitals, in order to be carved; with the formation of a cylindro-cylindric soffit, when the axis of the cylindric opening was in a plane perpendicular to the axis of the cylindric wall. The construction of a pediment in a circular wall was also tried by this author, and so far as he proceeded he was correct, but was deficient in not giving the whole of the requisite moulds and instructions, which rendered what he had done of no value.

We have now noticed all the methods that may be considered either as inventions or improvements in the art of joinery, and we trust that the account is impartial, and what every one inclined to do justice will find to be the case; and if anything has been mistaken, it is occasioned by the disagreement between their text and diagrams, and not from any intention to lessen their merit, or the value of their works.

Mr. Nicholson has invented the method for the development of a conic soffit in a circular wall, or of a conic surface terminated by a plane, or by a cylindric surface. And though the cuneoidal surface is not capable of development, he has shown how it may be unfolded, so as to terminate upon a plane or cylindric surface, by a method which comes very near to the truth.

He has discovered an entire new principle of squaring the wreath of a hand-rail, by which the face-mould may touch the tops of two vertical sections at each end, either in one of its angular points or in its whole breadth, supposing both the wreath and the mould to be set up in the true pitch.

He has invented a method of tracing the mitre-cap for the hand-rail, as used in dog-legged staircases, from a given section of the rail.

He has invented a method of gradating the steps, so as to form a regular surface upon the soffit at the junction of the flyers and winders; this not only gives an easy turn to the skirting, but permits the rail to be kept at a uniform distance from the nosings of the steps.

He was the first that showed a development of the plank, in order to apply the face-mould, and to range the two sides in the cylindric or prismatic surfaces according to the plan of the rail.

In the article Hand-Railing, he has shown a more regular method of lescribing the spiral lines of the scroll, by finding the centres in a fret or right-angled guilloche; so that the difference of any two adjoining sides of the fret will be always the same. In order to describe the scroll with compasses, he also invented the method of regulating the difference of radii of a scroll by a line of sines; as had formerly been done by a line of tangents, in order to trace the scroll by hand.

He was the inventor, and the first that showed the method of getting the scroll out of the solid, without gluing any part.

The method of apping an iron rail was never practised with certainty until his invention appeared in the *Carpenter's Guide.*

He was the inventor of the method of springing the plank, by making its plane of inclination to rest upon three vertical sections of the wreath, viz., one at each end and one in the middle, being obtained by three heights taken from the falling-mould. By this means the thickness of the rail is ascertained with certainty, and will never exceed 2½ inches where the rail is intended to be 2 inches deep, and 2¼ inches broad; whereas, by former methods, the plank would require to be 6 or 8, or even 10 inches thick.

No author before him ever regulated the pitch of the plank by the falling-mould, but by the height of the steps only; by this he obtained an immense saving of stuff.

He also invented the method of cutting the veneers in thickness, so that the rail may come off squared from the cylinder.

He was the first author that showed the method of scribing down the skirting upon stairs, however irregular the steps might be in respect of each other.

He also invented a method for squaring the bars for the head of a sash in a circular wall; no method had been ever shown before by which such work might be executed.

He invented, and was the first to show, a method for the formation of a circular architrave in a circular wall.

Besides Price's method of raking mouldings, he added that for the angle-bars of a polygonal window, such as are used in shop fronts.

He improved the method of proportioning mouldings, by showing how the projections were to be found in the same ratio with the heights, which had been neglected by other writers.

He was the first that treated upon hinging, and the hanging of doors and shutters, and the various kinds of folding joints.

In *Figure* 176, No. 1, A B C D E F G H I is half the ground-plan of a continued rail, viz., where the risers are equal to each other, as are likewise the heads.

Figure 177 shows the falling-mould, and the development below it, to the quadrant E F G H I; and because the risers and treads are all equal, the edges of the falling-mould will be straight lines parallel to each other: *e f g h i*, No. 2, is an orthographic projection of the quarter of the rail, corresponding to E F G H I, No. 1; in No. 2, draw L V parallel to A I, No. 1; make the angle V L M, No. 2, equal to the angle which the edge of the falling-mould makes with the base of the development in *Figure* 177; through *i* draw K N parallel to L M; through N draw N M perpendicular to L M; through L draw L K parallel to M N; then M N or L K will be the thickness of stuff necessary, according to the method given by Price and Swan.

a b c d e f g h i, No. 3, is a projection of the rail to the whole semi-circumference. We shall now show the thickness of stuff according to Pain. It will be recollected that he finds the pitch of the rail by the diameter or semi-diameter, and the rise of the steps in the semi-circumference or quarter accordingly: suppose, then, there are eight steps in the semi-circle, now *w y* is the diameter, and *y x* the rise of eight steps; therefore join *w x* and you have the line of section of the cutting-plane: through *a* draw R S parallel to *w x*, and through *i* draw Q T, also parallel to *w x:* draw T S and Q R perpendicular to *w x;* then the breadth Q R or T S, and the length Q T or R S of the rectangle Q R S T, will be respectively the thickness and length of the stuff.

The projection of the upper half of No. 3 is equal and similar, and similarly situated to No. 2; the lower half of No. 3 is equal and similar to the upper part when reversed, the lower part at *a b c d* showing the soffit, and the upper, *f g h i*, the back or top of the rail.

Figure 178 shows the projection for a quarter of the rail, upon a plane parallel to one of the radii: this shows an equal thickness to that shown at No. 3, *Figure* 176, the pitch being obtained from the radius, and the height of the steps in a quarter of the circumference.

Figure 179 shows the method of finding the face-mould, according to the first invention of Nicholson, shown in the *Carpenter's New Guide*, where the cutting plane of the cylinder is perpendicular to the plane of the chord of the rail, and passes through the upper corners of the sections at each end. *Figure* 180 shows the projection upon a plane parallel to the chord of the plan, agreeable to the face-mould, *Figure* 179. All these projections are made agreeable to one pitch-board, *Figure* 177.

We shall now show the quantity of stuff according to each method. *Figure* 181 is a development of the plank, showing the application of the face-mould according to Price, together with the thickness, the length, and breadth of the plank. The particular measures are to be taken from the subjoined scale.

	Ft.	In.	
The length measures	1	5	which reduced to inches, gives 17.
The breadth	0	8½	
The thickness	0	6	

By these measures we obtain 867 solid inches in the quantity of stuff required by Price's method.

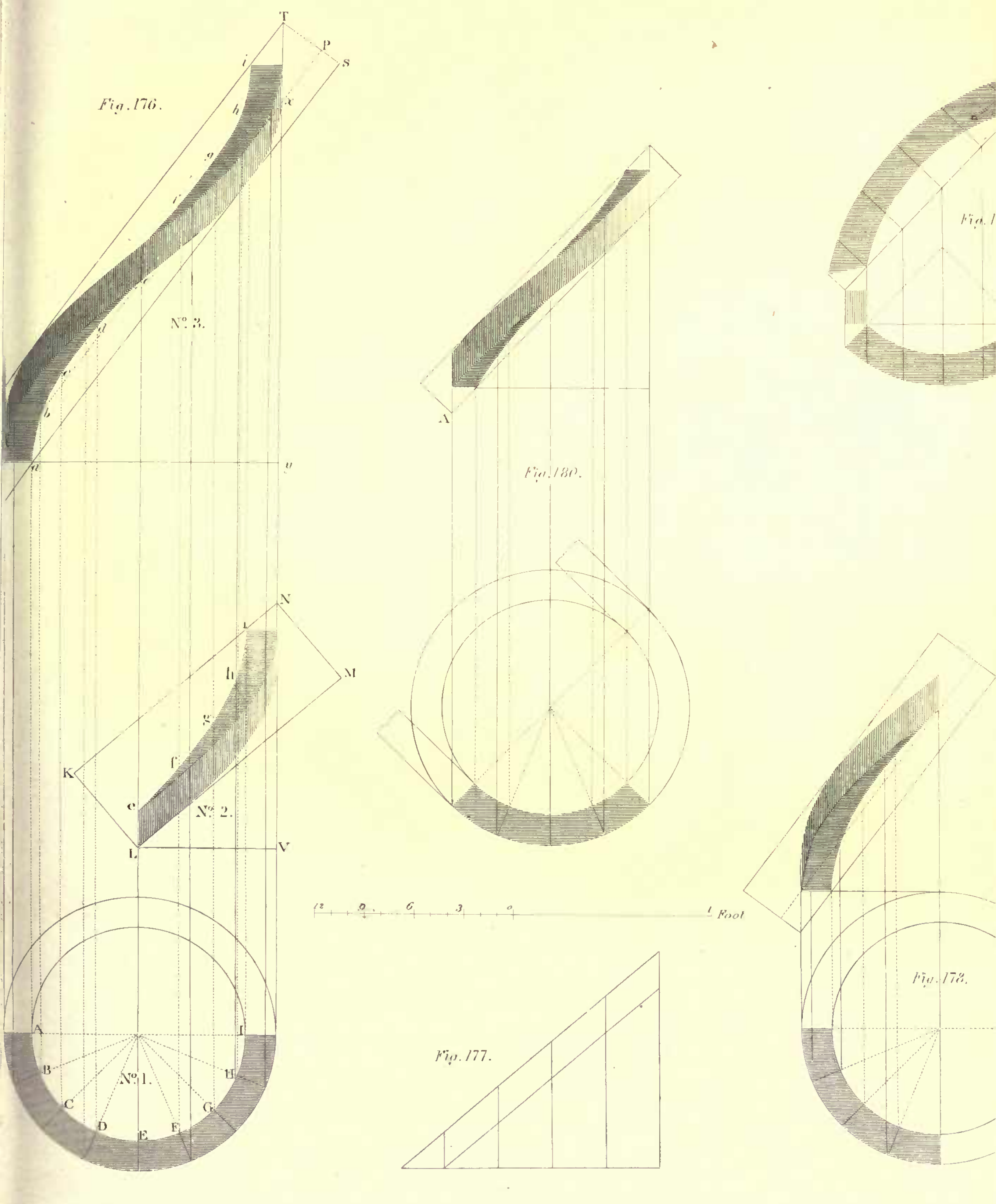
Figure 182 is a development of the plank according to the pitch and face-mould required by Pain's method, for a whole semi-circumference.

	Ft.	In.	
The length measures	2	10	which reduced to inches, gives 34.
The breadth	0	8½	as in Price's.
The thickness	0	4½	

By these measures we obtain 1,300½ solid inches in the quantity of stuff for a whole semi-circumference, as required by Pain's method.

JOINERY.

PLATE XV



...wn by M. A. Nicholson.

Engraved by J.C.B...

JOINERY.

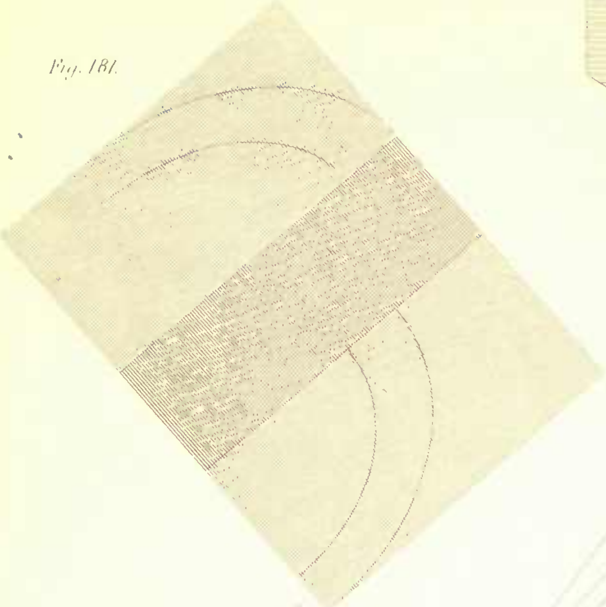


Fig. 181.

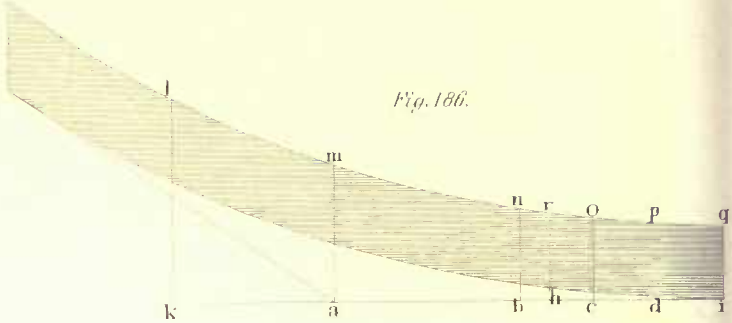


Fig. 186.

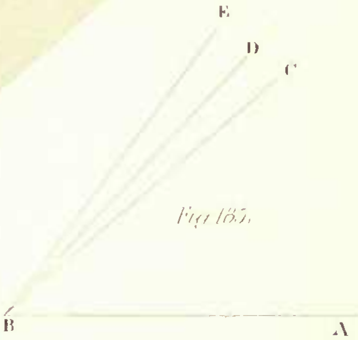


Fig. 185.

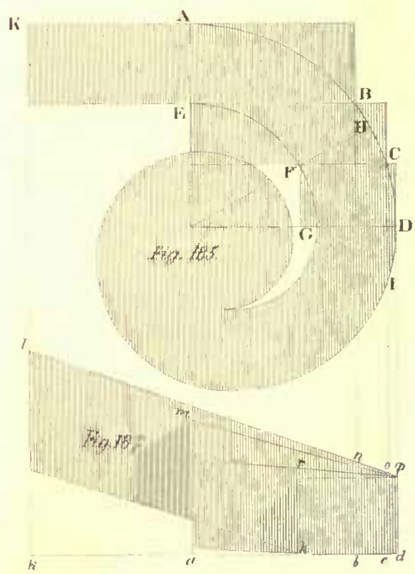


Fig. 185.

Fig. 187.

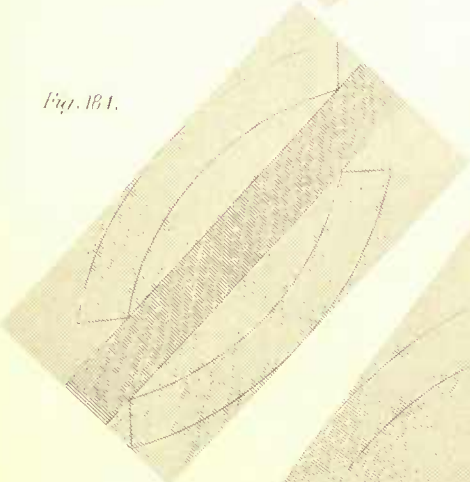


Fig. 184.

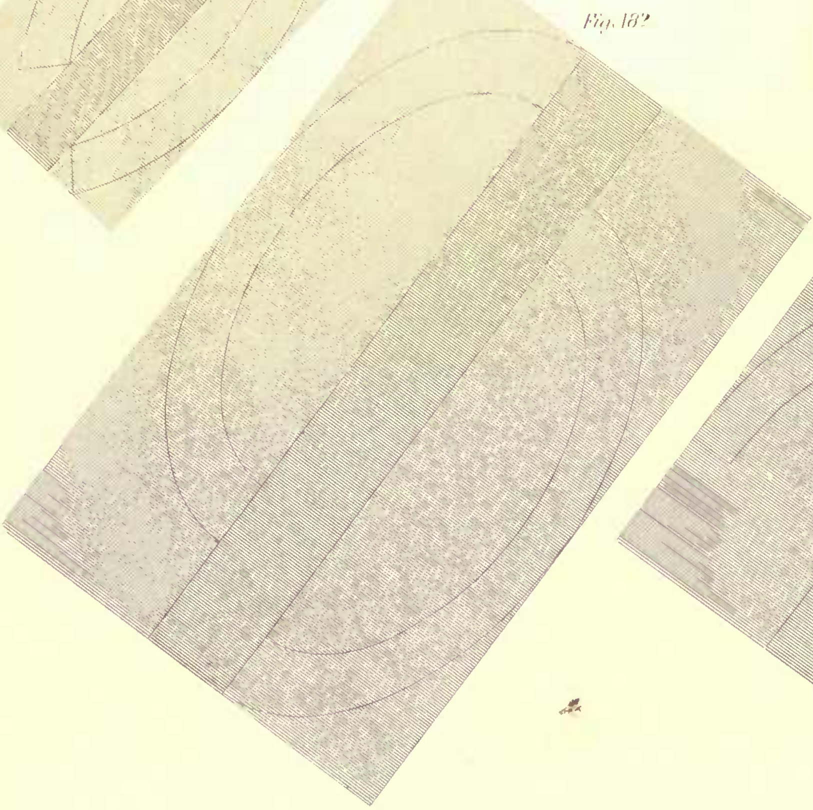


Fig. 182.

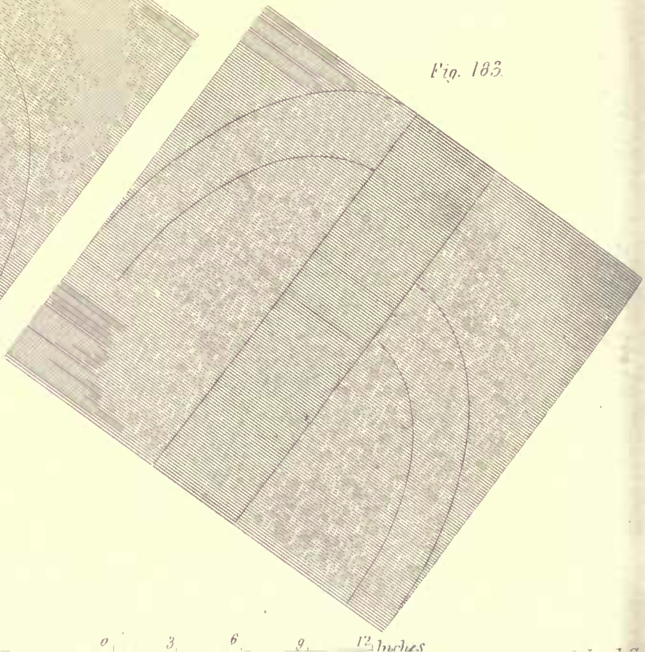


Fig. 183.

Feet 2 1 0 3 6 9 12 Inches

Fig. 1.

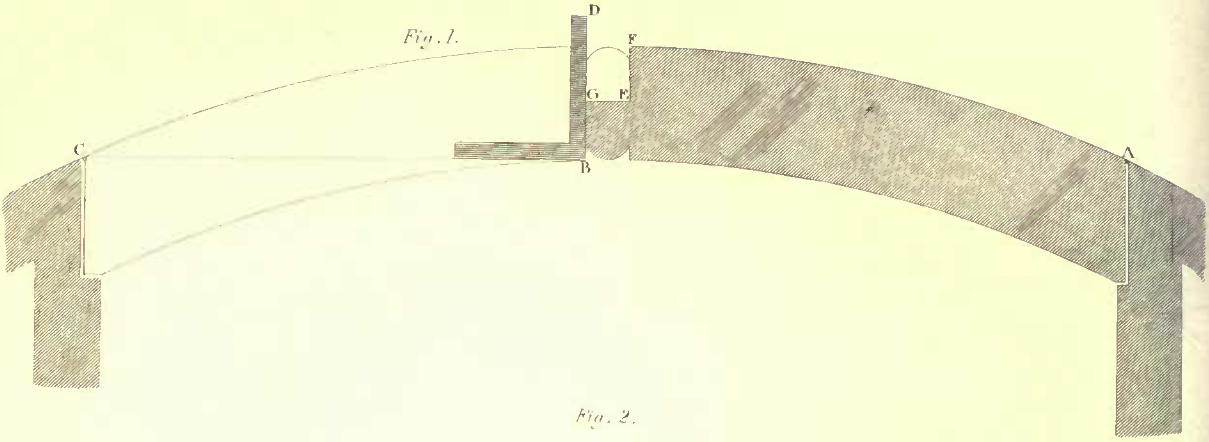


Fig. 2.

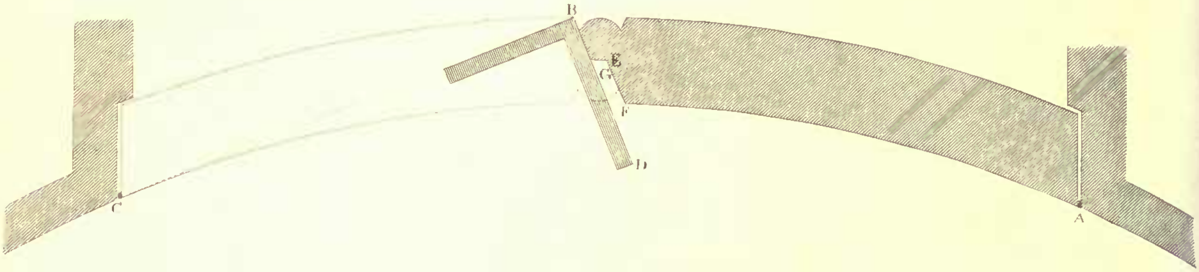


Fig. 3.

Fig. 4.

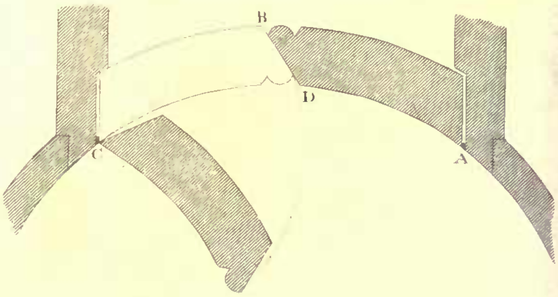


Fig. 5.

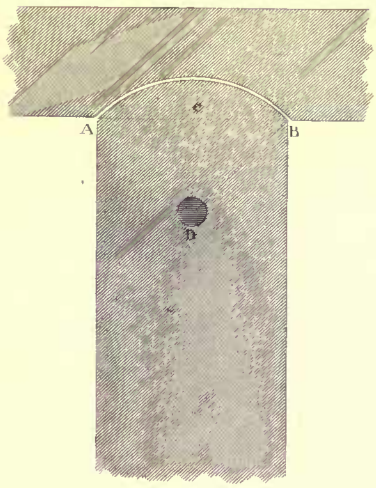


Fig. 6.

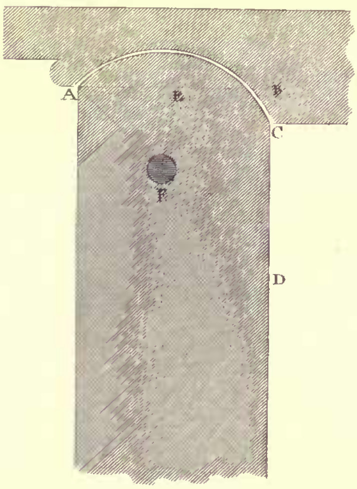
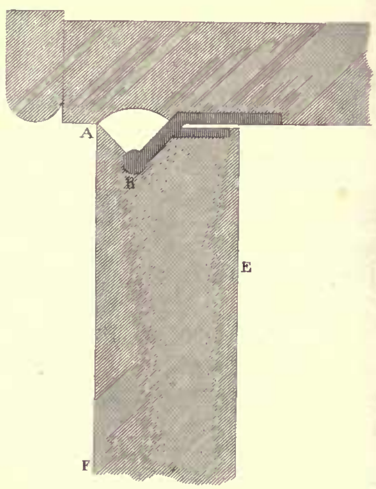


Fig. 7.



Drawn by P. Nicholson. Engraved by J.C.L

Figure 183 is a development of the plank for a quarter of the circumference, as required by Pain's method.

	Ft.	In.	
The length measures	1	8	which reduced to inches, gives 20.
The breadth	0	8½	as before.
The thickness	0	4½	

By these measures we obtain 765 solid inches required by Pain for one quarter of the circumference.

Figure 184 is a development of the plank, showing the quantity of stuff according to the method used by Nicholson.

	Ft.	In.	
The length measures	1	8½	which reduced to inches, gives 20½.
The breadth	0	4	
The thickness	0	3	

By these measures we obtain 246 solid inches for the quantity of stuff, by the method invented by Nicholson.

From these calculations, it appears that if the quantity of stuff which Nicholson's method requires, be called *unity*, or *one*, Pain's method will require three times as much, and that invented, or first presented by Price, three and a half times as much. In these we have only compared the numbers answering to the solidity of one quarter of the circumference, as the formation of a rail for the whole semi-circumference would be ridiculous, not only on account of the quantity of stuff, but the impossibility of being able to match the fibres at the joint, as has been before observed.

It may, however, be observed, in Pain's method, that though the quantity of stuff required for one quarter of the circumference be much greater than the necessary quantity, yet the thickness and breadth for a whole semi-circumference does not appear extra for such a large portion of the rail.

It may also be observed, that none of the preceding authors ever followed a falling-mould, nor has only one of them brought the solid of the wreath into the straight of the rail. If these had been done, the thickness of stuff required would have been much greater than that required for the quadrantal part of the circumference only.

It is remarkable that they should have made the sections of the prism for the face-mould upon a plane perpendicular to one of the radii, and consequently parallel to the other radius of the quadrantal plan, as the rail requires much thicker stuff in this position than any other they could have chosen.

Figure 185 shows the several inclinations according to the plane of section: A B C is the inclination according to Price and his followers; A B E is that according to Pain; and A B D that practised by Nicholson; which indeed is the only inclination founded upon principle, and is nearly an arithmetical mean between the other two; that used by Pain being too high, and that by Price too low.

It has already been observed that the method of preparing the scroll, by gluing blocks side by side, was very incorrect, being founded only in whim: and though gluing up scrolls in parallel blocks is not an approved method, nor ought to be so, yet it may not be amiss to show the true principle. Let *Figure* 185 be the plan of the scroll, the shank being formed by the parallel blocks K B, E C, F D, glued to the block or central part, which forms the eye. *Figure* 186, the falling-mould, the heights k l, a m, b n, c o, d p, i q, are those upon the points A, B, C, D, on the plan, and the height h r that upon F or H. *Figure* 187 is an elevation or projection of the blocks, showing the method of gluing them together; the heights *k l*, *a m*, *b n*, *c o*, *d p*, are respectively equal to the corresponding heights in *Figure* 186. This *Figure*, viz., 187, shows how the blocks are to be formed before they are put together.

In addition to the copious treatise given on this article, the following general description will be found very useful.

Plate XVI.—*Figures* 1, 2, 3, 4. *The method of hinging folding-doors.*—Suppose the bead to be drawn on both sides of the door; so that a plane parallel to, and equidistant from, either jamb, may bisect each of the beads, and the joint to be formed alike on both sides of this plane: Let C be the centre of the hinge, and B the arris on the plane side of the quirk next to the bead; join C B; draw B D at right angles, cutting the concentric circle, G E, which bisects the thickness of the door in G; also let F be the arris on the plane side of the quirk of the opposite bead on the alternate side: draw F E parallel to B D; then B G E F will be the joint required.

Figure 5.—*To make a door swing either way, supposing the jamb formed alike on both sides.* Let A and B be the points where the faces of the door intersect the jambs; join A B, and bisect it in C; draw C D perpendicular to A B, and make C D equal to A C or C B; on D, as a centre, with the radius D A or D B, describe the arc A B; and A B will be the joint required.

Figure 6.—*To make the joints correspond to a rebate on the opposite jamb or lintel.*—Let A and C be the points where the faces of the door intersect the jamb; produce D C, the face of the door, to B, and draw A B perpendicular to B D; make B D equal to A B; join A D and A C; bisect A C in E; draw E F perpendicular to A C, cutting A D at F; from F, as a centre, with the distance F A, or F C, describe the arc A C, which will be the joint required.

Figure 7.—*The method of concealing the revolving joint of doors or shutters.*—Make the angle F A E half a right angle; place the centre of the hinge at B, in the line A E, and let the hinge be so constructed that the two sides of the cavity, or hollow, may form a right angle.

JOINT, the surface of separation of two bodies brought into contact, and held firmly together either by a glutinous liquid, or by opposite pressures, or by the weight of one body lying upon the other. A joint is, however, not the mere contact of surfaces, but the nearer they approach the more perfect is the joint. Perhaps two pieces of wood adhering together by means of glue, or other such tenacious liquid, between two plane surfaces, is the most perfect. In masonry, the distances of the planes intended to form a joint are very considerable, owing to the coarseness of the particles which enter the composition of the cement.

JOINTER, in joinery, the largest plane used by the joiner to straighten the face or edge of the stuff which he is preparing.

JOINTER, in bricklaying, a crooked piece of iron, forming two curves of contrary flexure by its edges on each side, used for drawing the coursing and vertical joints by the edge of the jointing-rule.

JOINTING RULE, a straight edge used by bricklayers for regulating the direction or course of the jointer, in the horizontal and vertical joints of the brickwork.

JOISTS, one or more horizontal rows of parallel equidistant timbers in a floor, on which the flooring is laid. There are three kinds of joists, viz., binding-joists, bridging-joists, and ceiling-joists.

JONES, INIGO, a celebrated architect, born in London about 1572. He was bred a joiner, but his skill in drawing recommended him to the notice of the earl of Pembroke; who sent him to Italy, where he acquired a complete knowledge of architecture. James I. made him surveyor-general of his works, which office he discharged with great fidelity. He continued in the same post under Charles I., and had the superintendence of the building of St. Paul's, Covent-garden; with the management of the masques and interludes for the entertainment of the court. This brought him into a squabble with Ben Jonson, his coadjutor, who ridiculed him in his comedy of *Bartholomew-fair*, under the name of *Lantern Leatherhead.* He suffered considerably during the time of Cromwell, so that grief, misfortunes, and age, brought him to his grave in July, 1651. In 1655, appeared his *Discourse on Stonehenge*, in which he attempts to prove it to have been a Roman temple. As an architect, Inigo generally, but not always, shines to great advantage. He designed the palace of Whitehall and the Banqueting-house, the church and piazza of Covent-garden, Coleshill in Berkshire, Cobham-hall in Kent, and various other buildings, public and private. The principal of his designs were published in folio, in 1727, and some in 1744.

JUFFERS, stuff about four or five inches square, of any length. This term is not now in use, though frequently found in old books.

JUMP, in masonry, one among the very numerous appellations given to the dislocations of the strata, by practical miners of different districts.

JUMPER, a long iron tool, with a steel chisel-like point, used in quarries and mines for drilling or boring shot-holes in rocks which require to be blasted with gunpowder. *Drill*, *neger*, and *gad*, are other terms by which this tool is called.

K.

KAABA. *See* Caaba.

KALEIDOSCOPE, an optical instrument, the invention of Sir David Brewster. It creates and exhibits, by reflections, a variety of beautiful colours and symmetrical forms; so that such as may be deemed appropriate, may be made use of for patterns, as in carpets, and for other purposes of ornamental design.

KAOLIN, a species of clay, one of the two ingredients in Chinese porcelain.

KEEP TOWER, the middle, or principal tower in a castle. *See* Castle.

KEEPING, to be in keeping with, or harmonize with,—a technical term used in painting, and signifying the peculiar management of those parts of the art, colouring and chiaroscuro, which produces the proper degree of relievo in objects admitted into a composition; according to their relative positions in the imagined scene, and the degree of importance the artist attaches to them.

KENILWORTH CASTLE, is famed in the annals of Warwickshire for its antiquity. "This ancient castle," says Dugdale, "was the glory of all these parts, and for many respects may be ranked, in a third place at the least, with the most stately castles of England." This fortress was built by Geoffry de Clinton, in the time of Henry I. He was chamberlain and treasurer to that monarch. By subsequent kings and occupiers it was greatly enlarged and strengthened at different times: and in the various civil and domestic wars of England, it was frequently the object of contention with different monarchs and nobles. Edward II. was confined for a time in Kenilworth Castle, shortly before his murder in Berkley Castle, (A.D. 1327). In the following reign, John of Gaunt became owner of the castle, which he much augmented by new and magnificent buildings. Henry IV., son of John of Gaunt, united the castle, which he inherited, to the domains of the crown, of which it formed part till the time of Elizabeth, who granted it to Robert Dudley, Earl of Leicester. The magnificent entertainment given here by Leicester to Elizabeth, has been made familiar to the general reader by Sir Walter Scott's historical romance of "Kenilworth." After the civil war of Charles I., the castle was dismantled, but extensive and picturesque ruins remain. What remains of the buildings shows that the whole was an immense and spacious pile; consisting of an outer wall with bastion towers, a tilt-yard, with towers at each end; and several buildings within the ballium, or base-court. The area within the walls consists of seven acres. There were four gatehouses, and the walls were from ten to fifteen feet in thickness. At a short distance from the castle was a priory for Black Canons; of which buildings, parts of the gateway and chapel remain. Near these is the parish church, the western door-way of which is a curious specimen of ancient architecture.

KERF, the way made by a saw through a piece of timber, by displacing the wood with the teeth of the saw.

KEY, in a general sense, a fastener; that which fastens, as a piece of wood in the frame of a building, &c.

KEY or COTTAR, in engineering, a wedge-shaped or tapering piece of iron or wood; which is driven firmly into a mortise prepared to receive the same, to tighten and secure the several parts of any framing or contrivance together, as a rail to a chair, &c., forming a fastening. When a key is passed through a timber-beam, or two or more thicknesses of metal or other material, placed side by side, it is customary to clasp them together by *gibbs*, previous to inserting the key.

Key, now more commonly spelt Quay, a long wharf by the side of a harbour, river, or canal, furnished with posts, and rings, whereby ships and boats may be secured; also with cranes, capstans, and other convenient mechanism for loading and unloading.

Key, an instrument for locking and unlocking doors, *See* Lock.

Key, of a floor, the last board that is laid.

KEYED DADO, that which is secured from warping by bars grooved into the back; see the following article.

KEY-HOLE, a hole or aperture in a door or lock, for receiving a key.

KEY-PILE, the centre pile plank of one of the divisions of sheeting-piles contained between two gauge piles of a coffer-dam or similar work. It is made of a wedge-form, narrowest at the bottom, and, when driven, keys or wedges the whole together.

KEYS, in naked flooring, pieces of timber framed in between every two joists, by mortise and tenon; and when driven fast between each pair, with their ends butting against the grain of the joists, are called *strutting pieces*.

Keys, in joinery, pieces of timber let into the back of a board, transverse to the fibres, and made of one or several breadths of timber, either by a dovetailing, or by first making a groove equal to the width of the keys, and then cutting narrow grooves in the sides of the first-made groove close to the bottom, preserving a sufficient substance at the top of each.

Keys are used for the purpose of preventing boards from warping.

Dado, when made of broad boards, glued together, should always be keyed. *See* Dado.

KEY-STONE, of an arch or vault, the last stone placed on the top thereof; which, being wider and fuller at the top than at the bottom, wedges, as it were, and binds in all the rest.

M. Belidor makes the thickness of the arch-stones of a bridge, one twenty-fourth part of the width of the arch; but Mr. Gautier, another experienced engineer, makes their length, in an arch 24 feet wide, 2 feet; in arches, 45, 60, 75, 90 wide, 3, 4, 5, 6 feet respectively; and it is observed by Mr. Muller, that the thickness allowed by Belidor is not sufficient to prevent the weight of the arches from crushing the key-stones to pieces by their pressure against one another.

The name *key-stones*, or *arch-stones*, is sometimes also given to all the stones which form the sweep of an arch, or vault, answering to what the French more distinctly call *voussoirs.*

KILDERKIN, a liquid measure, which contains two firkins, or eighteen gallons. Two kilderkins make a barrel, and four a hogshead.

KILN, a kind of oven, or stove, for admitting heat, in order to dry substances of various kinds, as corn, malt, hops, &c. It also signifies a fabric or building constructed for the purpose of burning limestone, chalk, and other calcareous stones, into lime. Kilns are of different kinds, and formed in different ways, according to the purposes for which they are designed.

Kiln, *Brick*. *See* Brick.

Kiln, *Hop*, a stove or kiln for the purpose of drying or stoving hops.

Kiln, *Lime*, a sort of kiln constructed for the purpose of burning lime. The operation called burning lime, consists in exposing marble, limestone, chalk, oyster-shells, or any other carbonate of lime, for some time to a white heat, by which means the carbonic acid and water contained in these substances are expelled; and the earth, which has the peculiar characters assigned to lime, is left behind in a mass which has little coherence, and is therefore easily reduced to powder. It is usually called quick-lime after calcination. Newly prepared, it absorbs water with great avidity; it will absorb one-fourth of its weight of that fluid, and still remain perfectly dry. If a sufficient quantity of water be poured upon it, the lime falls into powder; some of the water is converted into vapour by the disengaged caloric of that part which unites with the lime; this is called the slacking of lime; if the quantity slacked be considerable, and performed in a dark place, light will be observed as well as heat. Kilns are built of different forms or shapes, according to the manner in which they are to be wrought, and the kinds of fuel to be employed. It may be remarked, that, in places where materials are dear, from their being fetched from a distance, and where the fuel is coals, and also expensive, the form of a kiln is mostly that of an inverted cone, a form which has its inconveniences; but in districts where the art of burning lime is practised with superior attention and correctness, the form has of late years been gradually changing from conical to elliptical. Some writers are of opinion, that the best form of a lime-furnace, in the established practice of the present day, is that of an egg placed upon its narrower end, having part of its broader end struck off, and its sides somewhat compressed, especially towards the lower extremity; the ground-plot or bottom of the kiln being nearly an oval, with an eye, or draft-hole, toward each end of it. It is supposed that two advantages are gained by this form, over that of the cone. By the upper part of the kiln being contracted, the heat does not fly off so freely as it does out of a spreading cone. On the contrary, it thereby receives a degree of reverberation, which adds to its intensity. But the other, and still more valuable effect, is this: when the cooled lime is drawn out at the bottom of the furnace, the ignited mass, in the upper parts of it, settles down, freely and evenly, into the central parts of the kiln; whereas, in a conical surface, the regular contraction of its width, in the upper as well as the lower parts of it, prevents the burning materials from settling uniformly and levelling downward. They *hang* upon the sides of the kiln, and either form a dome at the bottom of the burning mass, with a void space beneath it, thereby endangering the structure, if not the workmen, employed; or, breaking down in the centre, form a funnel, down which the underburnt stones find their way to the draft-holes. And the contraction of the lower part of the kiln has not the same effect; for, after the fuel is exhausted, the adhesion ceases, the mass loosens, and, as the lime cools, the less room it requires. It therefore runs down freely to the draft-holes, notwithstanding the quick contraction of the bottom of the kiln or surface.

Lastly, with respect to the lime-furnace, the fire requires to be furnished with a regular supply of air. When a kiln is first lighted, the draft-holes afford the required supply. But after the fire becomes stationary in the middle, or towards the upper part of the kiln, (especially of a tall kiln,) while the space below is occupied by burnt lime, the supply from ordinary draft-holes becomes insufficient. If the walls of the kiln have been carried up dry or without mortar, the air finds its way through them to the fire. In large deep kilns that are built with air-tight walls, it is common to form air-holes in their sides, especially in front, over the draft-holes. But these convey the air, in partial currents, to one side of the kiln only, whereas that which is admitted at the draft-holes passes regularly upward to the centre, as well as to every side of the burning mass; and, moreover, tends to cool the burnt lime in its passage downward, thereby contributing to the ease and health of the workmen. Hence, it is to be observed, the size of the draft-holes ought to be proportionate to that of the kiln and the size of the stones taken jointly, (air passing more freely among large than among small stones,) and the required supply of air should be wholly admitted at the draft-holes. By a sliding or a shifting valve, the supply may be regulated, and the degree of heat be increased or diminished, according to circumstances.

The most ancient kind of lime-kiln is probably that which is made by excavating the earth in the form of a cone, of such a size as may be necessary; and afterwards building up the sides, or not, according to the circumstances of the case; the materials being then laid in, in alternate layers of fuel and stone, properly broken, until the whole is filled up. The top is then covered with sods, in order that the heat may be prevented from escaping: and the fire lighted at the bottom, and the whole of the contents burnt, in a greater or less space of time, in proportion to the nature of the stone, and the quantity that is contained in the kiln. From the circumstance, of the top parts of these kilns, in some districts, being covered over and the sides sometimes built up with sods, they are termed *sod-kilns*, in order to distinguish them from the other sorts. When the whole of the contents of such kilns are grown cold, they are drawn or taken out from the bottom; and the kiln again filled, if necessary. These kilns are obviously intended for burning only one kiln-full at a time. But as the burning of lime in this way is tedious and uneconomical, other methods and forms of kilns have been had recourse to. Where lime is much wanted, either for building or other purposes, they use perpetual kilns, or what are more generally known by the name of *draw-kilns*. These, as all lime-kilns ought to be, are situated by the side of a rising bank, or sheltered by an artificial mound of earth. They are generally built either of stone or brick; but the latter, as being better adapted to stand excessive degrees of heat, is considered as preferable. The outside form of such kilns is sometimes cylindrical, but more generally square. The inside should be formed in the shape of a hogshead, or an egg, opened a little at both ends, and set on the smallest; being small in circumference at the bottom, gradually wider towards the middle, and then contracting again towards the top. In kilns constructed in this way, it is observed, fewer coals are necessary, in consequence of the great degree of reverberation which is created, above that which takes place in kilns formed in the shape of a sugar-loaf reversed. Near the bottom, in large kilns, two or more apertures are made: these are small at the inside of the kiln, but are sloped wider, both at the sides and the top, as they extend towards the outside of the building. The uses of these apertures are for admitting the air necessary for supplying the fire, and also for permitting the labourers to approach with a drag and shovel, to draw out the calcined lime. From the bottom of the kiln within, in some cases, a small building, called *a horse*, is raised in the form of a wedge, and so constructed as to accelerate the operation of drawing out the burned limestone, by forcing it to fall into the apertures which have been mentioned above. In other kilns of this kind, in place of this building, there is an iron grate near the bottom, which comes close to the inside wall, except at the apertures, where the lime is drawn out. When the kiln is to be filled, a parcel of furze or faggots is laid at the bottom; over this a layer of coals; then a layer of limestone, which is previously broken into pieces, about the size of a man's fist; and so on alternately; ending with a layer of coals, which is sometimes, though seldom, covered with sods or turf, in order to keep the heat as intense as possible. The fire is then lighted in the apertures; and when the limestone towards the bottom is completely calcined, the fuel being considerably exhausted, the limestone at the top subsides. The labourers then put in an addition of limestone and coal at top, and draw out at bottom as much as they find thoroughly burned; and thus go on, till any quantity required be calcined. When limestone is burned with coals, from two-and-a-half to three-and-a-half bushels, on a medium, three bushels of calcined limestone are produced for every bushel of coals used in the process.

A lime-kiln of this sort is described in Count Rumford's *Essays*, in the possession of the Dublin Society, as well as the principal objects that ought to be had in view in constructing the kiln pointed out: the first of which is, to cause the fuel to burn in such a manner as to consume the smoke, which has here been done by obliging the smoke to descend and pass through the fire, in order that as much heat as possible might be generated. Secondly, to cause the flame and hot vapour which rise from the fire to come in contact with the lime-stone by a very large surface, in order to economize the heat, and prevent its going off into the atmosphere; which was done by making the body of the kiln in the form of a hollow truncated cone, and very high in proportion to its diameter; and by filling it quite up to the top with lime-stone, the fire being made to enter near the bottom of the cone.

"Thirdly, to make the process of burning lime perpetual, in order to prevent the waste of heat which unavoidably attends the cooling of the kiln, in emptying and filling it, when, to perform that operation, it is necessary to put out the fire.

"And fourthly, to contrive matters so that the lime in which the process of burning is just finished, and which, of course, is still intensely hot, may, in cooling, be made to give off its heat in such a manner as to assist in heating the fresh quantity of cold limestone with which the kiln is replenished, as often as a portion of lime is taken out of it.

"To effectuate these purposes, the fuel is not mixed with the limestone, but is burned in a close fire-place, which opens into one side of the kiln, some distance above the bottom of it. For large lime-kilns on these principles, there may be several fire-places all opening into the same cone, and situated on different sides of it: which fire-places may be constructed and regulated like the fire-places of the furnaces used for burning porcelain.

"At the bottom of the kiln there is a door, which is occasionally opened to take out the lime.

"When, in consequence of a portion of lime being drawn out of the kiln, its contents settle down or subside, the empty space in the upper part of the kiln, which is occasioned by this subtraction of the burned lime, is immediately filled up with fresh limestone.

"As soon as a portion of the lime is taken away, the door by which it is removed must be immediately shut, and the joinings well closed with moist clay, to prevent a draught of cold air through the kiln. A small opening, however, must be left, for reasons which are explained below.

"As the fire enters the kiln at some distance from the bottom of it, and as the flame rises as soon as it comes into this cavity, the lower part of the kiln (that below the level of the bottom of the fire-place) is occupied by lime already burned; and as this lime is intensely hot, when, on a portion of lime from below being removed, it descends into this part of the kiln; and as the air in the kiln, to which it communicates its heat, must arise upwards in consequence of its being heated, and pass off through the top of the kiln, this lime, in cooling, is by this contrivance made to assist in heating the fresh portion of cold limestone with which the kiln is charged. To facilitate this communication of heat from the red-hot lime just burned, to the limestone above in the upper part of the kiln, a gentle draft of air through the kiln, from the bottom to the top of it, must be established, by leaving an opening in the door below, by which the cold air from without may be suffered to enter the kiln. This opening (which should be furnished with some kind of a register) must be very small, otherwise it will occasion too strong a draft of cold air into the kiln, and do more harm than good; and it will probably be found best to close it entirely, after the lime in the lower part of the kiln has parted with a certain proportion of its heat."

It is a common practice in some places to burn limestone with furze. The kilns which are made use of in these cases are commonly known by the denomination of *flame-kilns*, and are built of brick; the walls from 4 to 5 feet thick, when they are not supported by a bank or mound of earth. The inside is nearly square, being 12 feet by 13, and 11 or 15 feet high. In the front wall there are three arches, each about 1 foot 10 inches wide, by 3 feet 9 inches in height. When the kiln is to be filled, three arches are formed of the largest pieces of limestone, the whole breadth of the kiln, and opposite to the arches in the front wall. When these arches are formed, the limestone is thrown promiscuously into the kiln to the height of 7 or 8 feet, over which are frequently laid fifteen or twenty thousand bricks, which are burned at the same time with the limestone. When the filling of the kiln is completed, the three arches in the front wall are filled up with bricks almost to the top, room being left in each sufficient only for putting in the furze, which is done in small quantities, the object being to keep up a constant and regular flame. In the space of thirty-six or forty hours, the whole limestone, about 120 or 130 quarters, together with 15,000 or 20,000 bricks, are thoroughly calcined. Kilns constructed in this way may be seen near Wellingborough, in Northamptonshire, and other places in the northern parts of the kingdom. In many of the northern counties of Scotland, which are situated at a great distance from coal, it is also a common practice to burn limestone with peat; and, considering the rude ill-constructed kilns which are used for the purpose, it is astonishing with what success the operations are performed. In some of these districts, it is stated that limestone is sufficiently calcined with peats, laid *stratum super stratum*, in kilns formed of turf; but owing to the quantity of ashes which fall from the peat, the quality of the lime is considerably injured; and, from the open and exposed situation of many of these kilns, the waste of fuel is immense. But the most common method of burning limestone with peat, is in kilns constructed somewhat similar to those in the districts where furze is used as the only fuel. In kilns of this description there are, in general, only two arches, or fire-places, and the peats are thrown into the bottom of these arches, the fronts of which are seldom closed up, by which means the wind has often great influence in retarding the operation, and frequently prevents the complete calcination of the limestone. An improvement might, it is supposed, be made on these kilns at a very trifling expense: if an iron grate were laid across the bottom of the arch, with a place below for the ashes to fall down, and the front of the arch closed up by a door made of cast-metal, one-third of the fuel might be saved, and the operation performed in a shorter time, and with a much greater certainty, than by the method now practised in such kilns.

In a communication to the Board of Agriculture, Mr. Rawson described a method of constructing a lime-kiln, by which a considerable saving of fuel was effected.

This kiln was made 20 feet in height; at the bottom was placed a metal plate, one foot in height, intended to give air to the fire; the sloped sides were 6 feet in height, the breadth at the top of the slope 8 feet; the sides carried up perpendicular 14 feet; so that every part of the inside, from 14 feet to the mouth, was exactly of the same dimensions. On the mouth of the kiln was placed a cap, built of long stones, and rather sharply contracted, about 7 or 8 feet high. In the building of this cap, on one side of the slope, the mason being over the centre of the kiln, anything dropping down would fall perpendicularly to the eye beneath. Here was placed an iron door 18 inches square, and then the remainder of the building of the cap was carried up until the whole of the top was contracted to 14 inches. The kiln was fed through the iron door, and, when filled, the door was close shut. The outside wall was 3 feet at the bottom battering up to 2 feet at top, and built at such a distance from the inside wall of the kiln, that 2 feet of yellow clay might be well packed in between the walls; without this precaution kilns are almost certain to split. At 8 feet high from the eye of the kiln, two flues were carried through the front wall, through the packed clay to the opposite side of the kiln, to give power to the fire. It is asserted, that, with this kiln, one-third more lime has been produced from a given quantity of fuel, and also that stones of bad quality might be put into the kiln without the necessity of being broken so small as usual. As many situations will not admit of building a kiln 20 feet high, while other situations may allow of its being built 30, or even 40 feet, (for it cannot be made too high,) the diameter of the kiln should be proportioned to the height to which it is carried up.

In the same communication, Mr. Rawson also described another and rather curious application of this sort of contrivance. He states that, "for several years, he has made use of a small kiln in an outside kitchen, the height 9 feet, the diameter 3½ feet. In the side of the kiln next the fire, he had 3 square boilers placed, one of them large, containing half a barrel, with a cock, which supplied the family with constant boiling water; for the two others, he had tin vessels made to fit the inside with close covers, in which meat and vegetables with water were placed, and put into the two smaller boilers, which never had any water, but had close covers. The tin boilers were heated sooner than on the strongest fire, and when the meat, &c., were sufficiently dressed, the whole was taken out of the metal boilers. At one side he had an oven placed for roasting and boiling meat; the bottom was metal of 26 inches diameter, and 1½ inch thick, a flue from the fire went underneath. Even with the bottom of the oven, a grating 9 inches square was placed, which opened a communication between the oven and the hot fire of the kiln. The height of the oven was 14 inches, shut close by a metal door of 18 inches square, and the top, level with the mouth of the kiln, was covered by another metal plate of half an inch thick, on which was placed a second oven; the heat which escaped through the half-inch plate, though not near the fire, was sufficient to do all small puddings, pies, breakfast-cakes, &c. &c. The meat in the large oven was placed on an iron frame, which turned on a pivot, and stood on a dripping-pan, and was turned by the cook every half hour. And over the kiln he had a tiled stage for drying corn, and a chimney at one side, with a caul on the top, which carried off all steam and sulphur: a large granary was attached to the building." It is added, that the lime, if sold, would more than pay for fuel and attendance; and he has frequently had dinner dressed for fifty men, without interfering with his family business in any great degree.

An admirable combination of a lime-kiln, with a coke-oven, was the subject of a patent granted to Mr. Charles Heathorn some years ago, since which time it has been in successful operation at Maidstone and other places. The object of this invention, as expressed in the specification of the patent, is the preparation of quick-lime and coke in the same kiln at one operation. The economy of this process must be evident from the circumstance, that the inflammable part of the coal, which is separated to form it into coke, is the only fuel employed to burn the lime; and as the coke is in many places as valuable as the coal from which it is prepared, the cost, if any, of making lime, must be reduced to the most trifling amount.

In burning lime, some burners prefer peat to coal for the fuel; but that preference has probably arisen from an injudicious management of coal. Mr. Dobson asserts peat to be more economical than coal; that coal, by its excessive heat, causes the limestone to run into solid lumps, which it never does with peat, as it keeps them in an open state, and admits the air freely; that the process of burning goes on more slowly with coal, and does not produce half the quantity of lime.

This inconsistency requires no comment; nevertheless, peat is a very useful fuel for the purpose, and an excellent substitute for coal, where the latter is scarcer or dearer. All kinds of lime exposed to the air recover nearly their original weight, except chalk-lime, which, although long exposed, never recovers more than seven-eighths of its original weight. Some limestones, as Portland-stone, yield a very white lime; others, as chalk and roe-stone, a lime with a yellowish cast; the latter is best adapted for mixing with tarras, puzzolana, or Parker's cement, for buildings under water. It has long been said by lime-burners, that if limestone be imperfectly burned in the first instance, no further exposure of it to the fire will produce quick-lime. This assertion, which it was supposed was the offspring of ignorance, has been confirmed by M. Vicat, in a valuable treatise lately published by him on mortar and cements. Such lime, which is technically termed dead lime, does not slake with water, but upon being ground and made into a paste with water, differs from common mortar by setting under water.

KILOMETRE, a thousand metres. In the French system of measures, the metre is the unit, and is equivalent to 3.2808992 English feet. The kilometre is about five-eighths of our statute mile.

KING-POST, or Crown-Post. *See* Crown-Post.

KIOSK, a word applied in Turkey to a kind of open pavilion, or summer-house, supported by pillars.

KIRB-PLATE. *See* Curb-Plate.

KIRB-ROOF. *See* Curb-Roof.

KITCHEN (Welsh, *kegin*) the cooking-room, an apartment used for the preparation of food, and furnished with suitable accommodations and utensils for that purpose, of which the following are some of the principal.

A range of grating; a smoke-jack in the chimney, to turn the spits for roasting; a large screen to stand before the fire, to keep off the cold air from the articles roasting, by which means the operation is considerably accelerated. An oven, and also a copper boiler, should be constructed on one side of the fire-place, and on the other side, a large cast-iron plate, fixed horizontally, on which to keep sauce and stew-pans continually boiling with a uniform degree of heat. Several preserving stoves should be fitted up, according to the number of the family; and a table as large as the kitchen will admit of. It would be impossible to enumerate the whole of the articles for culinary purposes; but, besides the above, the kitchen should also be furnished with dressers, having drawers or cupboards under them, put up in every vacant part; it should also have shelves fitted up round the sides, in order to set stew-pans, sauce-pans, &c. out of the way. Adjoining to the kitchen, ought to be a large coal-cellar, for the convenient supply of the fire. The water ought to be conducted to the kitchen by means of pipes, to be drawn off by one or more cocks, as may be wanted. The screen should be made of wood, and lined with tin, and fitted up with shelves, so as to hold the dishes and plates to be made hot for dinner. The copper-boiler is sometimes made double, or divided, and both parts heated by the same fire; each part should be furnished with a water-cock. The kitchen table should not be less than three inches thick. If the windows do not afford a very good light, a sky-light should be placed over the table, with a moveable cap, so as to admit any quantity of air at pleasure.

Modern science has introduced so many improvements in this part of a large establishment, that it would be impossible to describe them. For the perfection of the department comprehended under the simple word *kitchen*, we would recommend our readers to inspect that of the Reform Club, or any similar *cuisine*. It is to be regretted that similar improvements, as far as may be deemed advisable, are not more generally introduced into establishments of a humbler description.

KNEE, a piece of timber cut at an angle, or having grooves to an angle.

Knee, in hand-railing, a part of the back with a convex curvature; it is the reverse of a *ramp*, which is hollow on the back.

KNIFE, *Drawing*. *See* Drawing Knife.

KNOTTING, a process in painting, for preventing the knots from appearing in the finish.

Knotting is a composition of strong size, mixed with red lead, for the first knotting, which prevents the gum from coming through. The second knotting is a composition of white-lead, red-lead, and oil; but in principal rooms, where the knots happen to be very bad, they are often silvered: which is done by laying on a coat of gold size, and, when properly dry, a silver leaf is placed on them, which is sure to prevent the knots appearing.

The operation of knotting is the first process in painting.

KNUCKLE, of a hinge, the cylindrical part, where the one strap is indented into the other, and revolves upon a pin fixed as an axis, in that of the cylinder. *See* Hinging.

KYANIZING, the term applied to the process of preserving timber and other substances from dry rot, invented by Mr. Kyan. Processes of a similar description, and for similar purposes, but differing in the chemical agents employed, have also been patented by Sir William Burnett and others, and called from the respective inventors, Burnettizing, Payanizing, Bethellizing, &c.

Kyan's preparation consists in immersing the substance to be preserved in a solution of corrosive sublimate, which is said to neutralize the primary element of fermentation, and render the fibre of the wood indestructible. The principal advantage, however, claimed for the process, is, that it seasons the timber in so short a time; what, in ordinary circumstances, occupies two or three years, being, by means of Kyanizing, effected in as many months. It is also said to protect the wood from the ravages of insects. We desire to offer no opinion on the comparative merits of these several methods of effecting the same objects. All have been in turn lauded and decried, as all have been in turn used and condemned. They are used extensively in railway sleepers and other engineering works, which, from their exposure, are very liable to premature decay.

It is generally understood, however, among practical men, that timber, though prepared by any of these processes, cannot be depended upon for a certainty to resist the combined effects of moisture and great heat.

L.

LABEL, an ornament placed over an aperture, in the castellated style of building, consisting of a horizontal part over the head, with two parts returning downwards at a right angle, one on each side of the aperture: sometimes these are terminated at the bottom with a bead, but most frequently return again at a right angle outwards, and, consequently, parallel to the part over the head.

LABOUR, in measuring, the value put on a piece of work, in consideration only of the time required to perform it.

LABRUM, a vase or basin placed in the caldarium of the ancient baths, to contain hot water for persons who had used the vapour bath.

LABURNUM, a well-known tree; the wood of the tree-laburnum is much prized by cabinet-makers and turners.

LABYRINTH, (Greek, λαβυρινθος) among the ancients, a large and intricate edifice cut into various isles and meanders running into each other, so as to render it difficult to get out.

Four celebrated labyrinths were noted by the ancients, and by Pliny ranked amongst the wonders of the world: viz., the Cretan, the Egyptian, the Lemnian, and the Italian. That of Crete is the most famed; it was built, as Diodorus Siculus conjectures, and Pliny positively asserts, by Dædalus, by command of king Minos, who kept the Minotaur shut up in it, on the model of that of Egypt, but on a less scale; but both affirm, that in their time it no longer existed, having been either destroyed by time, or purposely demolished. It was from this labyrinth that Theseus is said to have made his escape by means of Ariadne's clue.

Diodorus Siculus and Pliny represent this labyrinth as having been a large edifice; while others have considered it as merely a cavern hollowed in the rock, and full of winding passages. "If the labyrinth of Crete," says the Abbé Barthelemi, "had been constructed by Dædalus under the order of Minos, whence is it that we find no mention of it either by Homer, who more than once speaks of that prince, and of Crete, or by Herodotus, who describes that of Egypt, after having said that the monuments of the Egyptians are much superior to those of the Greeks; or by the more ancient geographers; or by any of the writers of the ages in which Greece flourished? This work was attributed to Dædalus, whose name," says our author, "is sufficient to discredit a tradition. His name, like that of Hercules, had become the resource of ignorance, whenever it turned its eyes on the early ages. All great labours, all works which required more strength than ingenuity, were attributed to Hercules; and all those which had relation to the arts, and required a certain degree of intelligence in the execution, were ascribed to Dædalus." According to Diodorus and Pliny, no traces of the labyrinth of Crete existed in their time, and the date of its destruction had been forgotten. Yet it is said to have been visited by the disciples of Apollonius of Tyana, who was contemporary with those two authors. The Cretans, therefore, believed that they possessed the labyrinth. "At Nauplia, near the ancient Argos," says Strabo, "are still to be seen vast caverns, in which are constructed labyrinths, that are believed to be the work of the Cyclops;" the meaning of which, as Barthelemi understands him, is, that the labours of men had opened in the rock passages which crossed and returned upon themselves, as in quarries. Such, he says, is the idea we ought to form of the labyrinth of Crete. He then suggests an inquiry, whether there were several labyrinths in that island? Ancient authors speak only of one, which most of them place at Cnossus, and some few at Gortyna. Belon and Tournefort describe a cavern situated at the foot of mount Ida, on the south side of the mountain, at a small distance from Gortyna: which, according to the former, was a quarry, and, according to the latter, the ancient labyrinth. Besides this, another is supposed to have been situated at Cnossus, and, in proof of the fact, it is alleged, that the coins of that city represent the plan of it. The place where the labyrinth of Crete was situated, according to Tournefort, was, as Barthelemi supposes, one league distant from Gortyna; and, according to Strabo, it was distant from Cnossus six or seven leagues; with respect to which our author concludes, that the territory of the latter city extended to the vicinity of the former. In reply to the inquiry, what was the use of the caverns, denominated labyrinths, Barthelemi imagines, that they were first excavated in part by nature; that in some places stones were extracted from them for building cities, and that, in more ancient times, they served for an habitation or asylum to the inhabitants of a district exposed to frequent incursions. According to Diodorus Siculus, the most ancient Cretans dwelt in the caves of mount Ida. The people, when inquiries were made on the spot, said, that their labyrinth was originally a prison. It might indeed have been applied to this use; but it is scarcely credible that, for preventing the escape of a few unhappy wretches, such immense labours would have been undertaken.

In Walpole's collection of *Travels in various Countries of the East*, there is an account by Mr. Cockerell of an excursion from the town of Candia to a curious excavation in a mountain about three miles from Agio Deka, a village near the site of Gortys, and 20 miles inland from Candia, which the inhabitants call by the name of the labyrinth. It is a very intricate maze, cut through a freestone rock; many of the passages are very low and narrow, but the principal way is about 8 feet wide, and as many in height. There are several square chambers at the ends of some of the passages, and piers have been left in the middle to support the superincumbent rock. Mr. Cockerell has explored all the excavation that was accessible, of which he gives a plan; it is in its whole length, including the windings, about three-quarters of a mile, but this is evidently only part of the whole, as many of the passages are stopped up in consequence of the falling in of the rock. Some have supposed this to have been the labyrinth of Minos.

The labyrinth of Egypt, according to Pliny, was the oldest of all; and was subsisting in his time, after having stood, according to tradition, as he says, 4,600 years. He says it was built by king Petesucus, or Tithoës; but Herodotus makes it the work of several kings: it stood on the southern bank of the lake Mœris, near the town of Crocodiles, or Arsinoe, and consisted of twelve large contiguous palaces, in which the twelve kings of Egypt assembled to transact affairs of state and religion, containing 3,000 apartments, 1,500 of which were under ground.

This structure seems to have been designed as a pantheon, or universal temple of all the Egyptian deities, which were separately worshipped in the provinces. It was also the place of the general assembly of the magistracy of the whole nation; for those of all the provinces or nomes met here to feast and sacrifice, and to judge causes of great consequence. For this reason, every nome had a hall or palace appropriated to it; the whole edifice containing, according to Herodotus, 12; Egypt being then divided into so many kingdoms. Pliny makes the number of these palaces 16, and Strabo makes them 27. All the halls were vaulted, and had an equal number of doors opposite to one another, six opening to the north, and six to the south, all encompassed by the same wall. The exits, by various passages and innumerable returns, afforded to Herodotus a thousand occasions of wonder. The roofs and walls within were encrusted with marble, and adorned with sculptured figures. The halls were surrounded with pillars of white stone finely polished; and at the angle, where the labyrinth ended, stood the pyramid, which Strabo asserts to be the sepulchre of the prince who built the labyrinth. According to the description of Pliny and Strabo, this edifice stood in the midst of an immense square, surrounded with buildings at a great distance. The porch was of Parian marble, and all the other pillars of marble of Syene; within were the temples of their several deities, and galleries, to which was an ascent of 90 steps, adorned with many columns of porphyry, images of their gods, and statues of their kings, of a colossal size: the whole edifice was constructed of stone, the floors being laid with vast flags, and the roof appearing like a canopy of stone: the passages met, and crossed each other with such intricacy, that it was impossible for a stranger to find his way, either in or out, without a guide; and several of the apartments were so contrived, that on opening of the doors, there was heard within a terrible noise of thunder. Although the Arabs, since the days of Pliny, helped to ruin this structure, yet a considerable part of it is still standing. The people of the country call it the palace of Charon.

Strabo, Diodorus Siculus, Pliny, and Mela, speak of this monument with the same admiration as Herodotus; but not one of them says it was constructed to bewilder those who attempted to pass through it; though it is manifest, that, without a guide, they would have been in danger of losing their way. The Abbé Barthelemi suggests, that this danger introduced a new term into the Greek language. The word *labyrinth*, taken in the literal sense, signifies a circumscribed space, intersected by a number of passages, some of which cross each other in every direction, like those in quarries and mines, and others make larger or smaller circuits round the place from which they depart, like the spiral lines that are visible on certain shells. Hence it has been applied, in a figurative sense, to obscure and captious questions, to indirect and ambiguous answers, and to those discussions, which, after long digressions, bring us back to the point from which we set out.

The labyrinth of Lemnos is mentioned by Pliny as having existed on the island, like those of Egypt and Crete. It was said to have been supported by 150 columns of wonderful beauty, and to have gates so well poised, that a child could throw them open. Pliny adds, that it was constructed by three native architects, and that some remains of it were still in existence.

The labyrinth of Italy was built, it is said, by Porsenna, king of Etruria, for his tomb, but the accounts of it partake so much of the fabulous, that it has been doubted by many authors whether it ever existed at all.

Labyrinth Fret, a fret with many turnings, in the form of a labyrinth; one of the most ancient ornaments in the world.

LACHRYMATORY, the name of a small glass or bottle, like a phial, sometimes found in the sepulchres of the ancients, in which it was supposed the tears of the deceased person's friends were collected and preserved.

LACONICUM, a recess in the caldarium, in which the labrum for the ablutions of those using the vapour-bath was placed. Some writers apply the term merely to the cupola in the floor of the hot-bath, in which the flame from the hypocaust played, to heat the apartment.

LACUNARIS, Lacunaria or Lacunars, in architecture, the panels of coffers formed on the ceilings of apartments, and sometimes on the soffits of the corona of the Ionic, Corinthian, and Composite orders.

In the temple of Minerva at Athens, the lacunars are placed immediately above the frieze within the portico, and formed with a single recess, having an ovolo at the top, which moulding terminates the vertical plane sides, and the horizontal heads of the lacunars. The lacunars are not square, but longer in the longitudinal than in the transverse direction of the building.

In this they are formed in one recess, with an ovolo at the top of the recess, or the farthest extremity of the sides. The lacunars are longer from front to rear of the portico, than in the transverse direction of the building.

In the temple of Theseus at Athens, the lacunars are formed above the frieze, in two rows, between large beams which reach from the rear to the front of the pronaos: their figures are of a square horizontal section, and have only a single recess upwards, with an ovolo above it. The side of the square of each coffer is about one-fifth part of the diameter of the column, and their recess upwards of half the side of their square. The distance between the beams is equal to the breadth of the antæ at the bottom, or nearly equal to the diameter of the columns. The beams are not regulated by the columns, but placed at equidistant intervals, to receive the two rows of lacunars, or coffers. Within the temple or cella, the beams reach transversely, from side to side; but without, and under the soffit of the pronaos, they extend longitudinally from the front to the rear of the pronaos, and the lacunars in the same direction.

In the soffit of the temple of Pandrosus at Athens, the lacunars are formed immediately above the architrave, each into three recesses, with an ovolo at the bottom of each, nearly as broad as the perpendicular surface. The whole depth of the recess is nearly half the side of the square of its lower part. Each part diminishes gradually in breadth in a sloping straight line, till the side of the square of the upper part is so contracted as to be only half that of the lower. Each succeeding third part diminishes regularly in altitude, so that, accounting the bottom the first, the altitude of the second, or the one next above, is something less, and the third about the same quantity less than the second. Each ovolo is something less in height than the vertical surface below it, and has the same ratio to its respective surface.

The cella of the temple of Vesta at Rome is surrounded with a circular colonnade. The ceiling of the portico has a double row of lacunars, being two in the breadth of the portico. The lacunars approach as nearly to a square as is consistent with their diminution, formed by radiations towards the centre of the building, and are constructed in two recesses. The greatest breadth of the outside lacunar is about nine-thirteenths of the diameter of the columns. The whole depth of the recess upwards is about one-seventh of a diameter. The radiating sides are in vertical planes, and the other two sides of each arc vertical cylindric concentric surfaces. The greatest breadth of the upper recess is about two-thirds of the lower. The hollow of this recess is occupied by a rose of a circular form. The recess or cradle vaults of the temple of Peace at Rome are arched, and enriched with octagonal lacunars, each formed in three recesses, which diminish in their margins as they recede upwards. Between the octagonal lacunars are others of a square form in a diagonal position. The ceiling of the middle of the chapel of the said temple, is comparted with hexagonal and rhomboidal lacunars.

The lacunars of the arch of Titus at Rome are square, the side of each being about three-quarters of the diameter of the column.

LADDER, a well-known contrivance used in building operations &c., it is formed of two long side pieces of wood, connected by rounds or treads, forming the steps by which the workmen ascend.

LADY-CHAPEL, a name invented by modern architects and virtuosi, to signify the chapel which is generally found in our ancient cathedrals behind the screen of the high altar. It is denominated from its being generally dedicated to the Virgin Mary, called *Our Lady*.

LANCET ARCH, the same as pointed arch.

Lancet Window, that of which the head is a lancet arch; but the term is more generally applied to those windows which are long and narrow, with lancet arches.

LANDING, the first part of a floor at the head of a stair, also a resting place in a series of flights of steps.

LANTERN, in architecture, a turret raised above the roof with windows round the sides, in order to light the apartment below. Lanterns are much more convenient than skylights; for as the surface of the glass stands vertical, they are not so liable to be broken, nor so subject to the rattling noise of heavy rains and hail. The word lantern is also applied to light erections at the top of towers or domes, as at Boston church, Lincolnshire, and St. Paul's, London.

LANTERN, is also used for a square cage of timber, with glass in it, placed over the ridge of a corridor, or a gallery between two rows of shops, to illuminate them.

LAP, the junction of two bodies where they mutually cover each other.

LARDER, or SAFE, a place in which undressed meat is kept for the use of a family.

It ought to be so large, as to hold a quantity proportioned to the number of the family, and should be well ventilated through the roof, so as to keep a continued circulation of air; the light must be from windows in the wall, which ought to have a northern aspect. The roof ought to be double, so as to contain a cavity for air, in order to preclude the heat of the sun, and the whole building constructed of wood. The windows should be wired, or of perforated zinc, rather than glazed, and the interstices so small as not to admit of any flies. In order to prevent the sun from getting in, the exterior roof should over-hang the safe, so as to keep off the sun's rays, which will only be in the morning and afternoon of the day. If a northern aspect cannot be obtained for light, other means must be employed to preclude the sun's rays. The floor should be elevated above the ground, to prevent dampness, say two or three feet, as may be found convenient; and the safe here spoken of should not adjoin any other building, since its use is to keep the meat cool. The safe should be fitted up with a row of shelves and several rows of hooks, in the manner that butchers hang up joints of meat, &c. The shelves are necessary to lay the meat on when wanted. The hooks must be fastened to beams, and not to the sides of the safe; and the beams should be placed so high as to keep the meat above the head of any person.

LARMIER (from the French) signifying tears; the word is of the same import as CORONA, which see.

LATCH, the catch for holding a door fast.

LATH, a slip of wood used in plastering, tiling, and slating. These are what Festus calls *ambrices;* in other Latin writers they are denominated *templa;* and by Gregory of Tours, *ligaturæ.*

In plastering, the narrower the laths are, the better they are for the purpose, so that they be of sufficient breadth to hold the nails, as the more the number of interstices is increased, the more readily will the lime or stuff hang; and the thicker they are, the better will they be adapted to resist violence; but then they would be much more expensive. The laths are generally made of fir, in three, four, and five feet lengths, but may be reduced to the standard of five feet. Laths are single or double; the latter are generally about three-eighths of an inch thick, and the former barely one quarter, and about an inch broad. Laths are sold in bundles; the three-feet are eight score to the bundle, four-feet, six score, and the five-feet, five score.

The lath for plain tiling is the same as that used in plastering. Laths are also distinguished into *heart* and *sap laths;* the former should always be used in plain tiling, and the latter, of an inferior quality, are most frequently used by the plasterer. Heart-of-oak laths, by the statute Edw. III. should be one inch in breadth, and half an inch in thickness; but now, though their breadth be an inch, their thickness is seldom more than one quarter of an inch; so that two, as they are now made, are but equal to one. According to the same statute, pantile laths are nine or ten feet long, three-quarters of an inch thick, and one and a half inch broad, and should be made of the best yellow deal: the bundle consists of twelve such laths. A square of plain tiling will require a bundle of laths, more or less, according to the pitch. The distance of laying laths one from another is various, differing more in some places than in others; but three and a half, or four inches, are usual distances, with a counter-lath between rafter and rafter; but if the rafters stand at wide intervals, two counter-laths will be necessary. Laths are employed for various other purposes besides plastering and tiling, as in filleting for sustaining the ends of boards; in naked flooring and roofing, for furring up the surfaces; and in every kind of small work, where the dimensions of the parts do not exceed the scantling of laths.

In lathing for plastering, it is too frequent a custom to lap the ends of the laths upon each other, where they terminate upon a quarter or batten, to save the trouble of cutting them; but though this practice saves a row of nails, it leaves only a quarter of an inch for plaster, and if the laths are very crooked, as they frequently are, there will be no space whatever left to straighten the plaster; the finished surface must, therefore, be rounded, contrary to the intention and to the good effect of the work; but if the ends are to be laid upon each other, they should be thinned at the lapping out to nothing at the extremity, or otherwise they should be cut to exact lengths.

Laths should be as evenly split as possible; those that are very crooked should not be used, or the crooked part should be cut out; and such as have a short concavity on the one side, and a convexity on the other, not very prominent, should be placed with the concave side outwards. The following is the method of splitting laths: the lath-cleavers having cut their timber into lengths, they cleave each piece with wedges into eight, twelve or sixteen pieces, according to the scantling of the timber: the pieces thus cloven are called *bolts;* then in the direction of the felt-grain, with their dowl-axe, into sizes for the breadth of the laths: this operation they call *felting;* and, lastly with their chit, they cleave them into thicknesses by the quarter-grain.

In the United States of America, machinery has been employed for rending as well as for sawing out laths: there is nothing original in the latter operation, but there is apparently something worthy of notice by our countrymen in the annexed report of American patents, which we extract from the *Franklin Journal* of Philadelphia.

In Rice's machine, "a stock is fixed in a frame, in which it slides freely backward and forward; it is moved by a cog-wheel, which works in cogs on one side of the stock, in the manner of a rack and pinion. A knife, is fixed upon the stock, and the timber to be cut into laths, &c., is fixed in a frame, and is made to bear against the stock and the lath is cut by the traversing motion of the stock. The knife, it is said, many have a double edge, so as to cut a lath by the forward and backward motion."

Lynch's machine "consists of a long plank, which operates as a plane stock; this plank is made to slide upon its edge between upright standards upon a firm platform; a wide iron like a plane-iron, is fixed so as to cut on one face of this plank much in the manner of the cutters of some single machines; the throat of the plane, if we may so call it, has other cutters standing at right angles with the first cutter, and at such distances apart as to reduce the laths to a proper width. The cutter plank is made to traverse by means of a pitman at one end, operated upon by any suitable power.

Lath-Bricks are bricks made much longer than the ordinary sort, and used instead of laths for drying malt upon, for which purpose they are extremely convenient, as not being liable to catch fire, and retaining the heat much longer than those made of wood, so that a very small fire is sufficient after they are once heated.

LATHE, a very useful engine for the turning of wood, ivory, metals, and other materials. The invention of the lathe is very ancient. Diodorus Siculus says, the first who used it was a grandson of Dædalus, named Talus. Pliny ascribes it to Theodore of Samos, and mentions one Thericles who rendered himself very famous by his dexterity in managing the lathe. With this instrument the ancients turned all kinds of vases, many whereof they enriched with figures and ornaments in basso relievo. The lathe is composed of two wooden cheeks or sides, parallel to the horizon, having a groove or opening between; perpendicular to these are two other pieces called puppets, made to slide between the cheeks, and to be fixed down to any point at pleasure. These have two points, between which the piece to be turned is sustained; the piece is turned round, backwards and forwards, by means of a string put round it, and fastened close to the end of a pliable pole, and underneath to a treadle or board, moved with the foot. There is also a rest which bears up the tool, and keeps it steady.

LATTICE, from lath; wood or iron work made by crossing bars, rods, or laths, in such a manner as to form open chequered or reticulated work.

LATTICE-WINDOWS are those made of bars or strips of iron which cross one another like net-work: windows of lattice or lath were once general in England.

LAUNDRY, a large room, wherein linen after washing is mangled and ironed (and sometimes dried, if there is not a drying-room for the purpose.) The chief and most important utensil in a laundry, is a good stove to heat the irons, likewise dry the linen, besides which there should also be a large range of grating, to air the linen after being ironed or mangled. The stove ought to stand nearly in the middle of the room, and have a long iron pipe for the smoke to ascend, which should be carried several times backward and forward, and at length terminate in the flue of the chimney near the ceiling, by which means it will throw a considerable heat into the room. As it is a known property of heat to ascend, large racks or horses are made so as to be drawn up by pulleys horizontally to the ceiling, where the linen will dry very soon. There should be a mangle, a mangling table, and a large board or dresser fixed to the window side of the room, which ought to be fitted up underneath with large drawers and cupboards for holding linen in, after finished. There should be an adjoining room for the laundry-maids to sleep in. There ought to be a place to hold a sufficient quantity of coals to serve for a day or two, which is filled from the coal-house, near the wash-house; there ought also to be a place fitted up for the maids to wash their hands.

LAVATORY, a cistern or conduit attached to the cloisters in monastic establishments, and used by the monks and other members of the communities for their ablutions; several of these lavatories are still in existence, as in the cloisters of Norwich, Wells, Gloucester and other cathedrals. The name lavatory, or *lavadero*, is also given to certain places in Peru and Chili, where gold is obtained from the earth by washing.

LAVER. The basin or vessel, placed in the court of the Jewish tabernacle, where the officiating priests washed their hands, and feet, and cleansed the entrails of victims.

LAWN, an open space of short-grass ground, in the front of a residence, or in a garden, park, or other pleasure-ground. These, when extended in the principal fronts of habitations, add considerably to the neatness and grandeur of their appearance, by laying them open, and admitting more extensive prospects. Where there is a sufficient scope of ground, they should be as large as the nature of the situation will admit, always being planned in the most conspicuous parts immediately joining the houses, and extended outward as far as convenient, allowing width in proportion; having each side or verge bounded by elegant shrubbery compartments in a varied order, separated in some parts by intervening spaces of grass-ground, of varied dimensions, and serpentine gravel-walks, gently winding between and through the plantations, for occasional shady, sheltered, and private walking: or similar walks carried along the fronts of the boundary plantations, and immediately joining the lawns, for more open and airy walking in; and in some concave sweeps of the plantations there may be recesses and open spaces both of grass and gravel, of different forms and dimensions, made as places of retirement, shade, &c.

Though the usual situations of lawns are those just mentioned; yet if the nature of the ground admit, or in cases where there is a good scope of ground, they may be continued more or less each way; but always the most considerably on the principal fronts, which, if they be to the south, or any of the southerly points, are the most desirable for the purpose.

With respect to the dimensions, they may be from a quarter of an acre, or less, to six or eight acres, or more, according to the extent and situation of the ground. Sometimes lawns are entended over *ha-has*, to ten, twenty, or even to fifty or sixty acres, or more. But in these cases they are not kept mown, but eaten down by live stock.

The form must be directed by the nature of the situation; but it is commonly oblong, square, oval, or circular. But in whatever figure they are designed, they should widen gradually from the house outward to the farthest extremity, to have the greater advantage of prospect; and by having that part of them within the limits of the pleasure-ground, bounded on each side by plantations of ornamental trees and shrubs, they may be continued gradually near towards each wing of the habitation, in order that the inhabitants may be sooner in the walks of the plantations, under shade, shelter, and retirement. The terminations at the farther ends may be either by *ha-has* to extend the prospect, or by a shrubbery or plantation of stately trees, arranged in sweeps and concave curves. But where they extend towards any great road, or distant agreeable prospect, it is more in character to have the utmost verge open, so as to admit of a grand view from and to the main residence.

The side-boundary verges should have the plantations rurally formed, airy and elegant, by being planted with different sorts of the most ornamental trees and shrubs, not in one continued close plantation, but in distinct separated compartments and clumps, varied larger or smaller, and differently formed, in a somewhat natural imitation, being sometimes separated and detached, less or more, by intervening breaks, and open spaces of short grass, communicating both with the lawns and interior districts; and generally varied in moderate sweeps and curves, especially towards the lawns, to avoid stiff, formal appearances, both in the figure of the lawns and plantations. In planting the trees and shrubs, which should be both of the deciduous and evergreen kinds, where intended to plant in distinct clumps, either introduce the deciduous and evergreens alternately in separate parts, or have some of both interspersed in assemblage; in either method, placing the lower growth of shrubs towards the front, and the taller backwards, in proportion to their several statures, so as to exhibit a regular gradation of height, that the different sorts may appear conspicuous from the main lawns. They may be continued backwards to a considerable depth, being backed with trees and shrubs of more lofty growth. The internal parts of the plantations may have gravel or sand walks, some shady, others open ; with here and there some spacious short-grass openings, of different dimensions and forms.

It is seldom that extensive lawns in parks or paddocks, &c. have any boundary plantations close to what may be considered as a continuation of them beyond the pleasure-ground, but they are sometimes dotted with noble trees, dispersed in various parts, at great distances, so as not to obstruct the view; some placed singly, others in groups, by twos, threes, fives, &c. and some placed irregularly, in triangles, sweeps, straight lines, and other different figures, to cause the greater variety and effect, each group being diversified with different sorts of trees, all suffered to take their natural growth. Where small, these kinds of openings should always be kept perfectly neat, by being often poled, rolled, and mown ; but where they are of larger extent, this is scarcely ever the case.

LAYER. *See* Course.

LAZARETTO, or, Lazar-House, a public building, in manner of an hospital, for the reception of poor sick : or in some countries, an edifice, or sometimes a ship, appointed for persons coming from places suspected of the plague, to perform quarantine.

The name " Lazaretto," is derived from St. Lazarus, who, in the Romish calendar, is patron of lepers. Leprosy during the middle ages was a common disease in Italy and other parts of Europe, and the lepers, or persons afflicted with it, were called lazzari. Hence the term lazaretto applied to the hospitals where such persons were confined. In England similar receptacles were often called lazar-houses, or houses of lepers.

John Howard, the distinguished philanthropist, whose services in the cause of humanity can never be forgotten, was the first who drew public attention to the state of the lazarettos on the continent. In the year 1785, he personally inspected most of these institutions, and in his work entitled " An account of the principal Lazarettos in Europe," has given a complete exposition of the plans of the buildings, and their chief regulations. The result of this inspection was the adoption of many of the valuable suggestions made by Howard : and many a weary traveller, suffering under the annoyances of the quarantine system, has had reason to bless the name of the man who did so much to alleviate them. Although some improvements have been made since Howard's time, the main features of these buildings remain nearly the same. His description of those he visited, therefore, may, even at the present day, be considered a faithful one, and interesting to those who, " living at home at ease," have little idea of what it is to be in quarantine. The first lazaretto he inspected was that at Marseilles, which is situated on an elevated rock near the city, at the end of the bay, fronting the south-west, and commanding the entrance of the harbour. It is a spacious building, and its situation renders it very commodious for the purposes of trade. Within the lazaretto is the governor's house, a chapel, in which divine service is generally performed, and a tavern, from which persons under quarantine may be supplied with necessaries. In order to prevent any communication not allowed by the regulations of the establishment, there is a double wall round the lazaretto ; and at the gate there is a bell for calling any person within this enclosure ; and by the number and other modifications of the strokes, every individual knows when he is called. At Genoa the lazaretto is situated on the sea-shore, near the city, detached from other buildings, and encompassed by a double wall. Another lazaretto, belonging to the Genoese, stands on a rising ground at Varignano, near the gulf of Spezia. At Leghorn there are three lazarettos. At Naples, the lazaretto is very small, and is situated on a peninsula near the city. Vessels having *clean* bills of health, lie at the entrance of the port, near the health-office, but those with foul bills, are required to perform their quarantine at the lazaretto. At Messina, the lazaretto stands on an island near the city. The health-office at Zante, is in the city, at the water-side. The old lazaretto is distant about half a mile from the city, and situated on a rising ground near the sea. There is another, called the new lazaretto, which is appropriated to a numerous body of peasants, who pass over to the Morea, to work in harvest time ; on their return, they perform here a seven days' quarantine : and other persons perform fourteen days quarantine in the old lazaretto. The lazaretto at Corfu is finely situated on a rock surrounded with water, about a league from the city. The lazaretto of Castel-Nuova, in Dalmatia, is on the shore about two miles from the city ; at the back of it there is a delightful hill, which belongs to a convent of friars. Persons in quarantine, after a few days, are allowed to walk there, and divert themselves with shooting, &c.

In order to obtain the most complete and satisfactory information, by performing the strictest quarantine, Howard determined to go to Smyrna, and there to take his passage to Venice in a ship with a foul bill. He was thus enabled to give a particular account of his reception and accommodation in the new lazaretto of this city, which is chiefly assigned to Turks and soldiers, and the crews of those ships which have the plague on board ; and this he thought the more necessary, as the rules and tariffs of the other lazarettos in Europe have been evidently formed from those established at Venice. The city of Venice has two lazarettos, appropriated to the expurgation of merchandise susceptible of infection, coming from suspected parts and for the accommodation of passengers in performing quarantine, as also for the reception of persons and effects infected in the unhappy times of pestilence. The old lazaretto is two miles, and the new about five miles, distant from the city, both on little islands, separated from all communication, not only by broad canals surrounding them, but also by high walls ; they are of large extent, being about 400 geometrical paces in circumference. Of these Mr. Howard has given a particular description ; with an account of the regulations and mode of government to which they are subject, and a plan of the old lazaretto. At Trieste there are two lazarettos ; one new, but both clean, and a contrast to those which he had seen at Venice. Of the new one he has given a plan. It is surrounded, at the distance of about twenty yards, by a double wall, within which are separate burying places for Roman Catholics, Greeks, and Protestants. Howard closes his account of the principal lazarettos in Europe, with the outlines of a proper lazaretto, and an engraved sketch of a plan for its construction. He has likewise subjoined, in minute detail, various pertinent remarks respecting quarantine and lazarettos in general.

Within the last few years, however, more enlightened views on the whole subject of the quarantine system have begun to prevail, and are gradually obtaining support. Eminent medical authorities, both in this country and on the Continent, have expressed the strongest opinions, as to its total inefficacy in preventing the introduction of disease ; while on the other hand the injury done by it to the interests of commerce, injury which cannot be adequately estimated, is earnestly and justly insisted upon by the merchants of all nations. It may be hoped, then, that these considerations may have their proper effect with those in authority, and that laws so oppressive and so injurious may shortly be abolished. A greater attention to sanitary regulations will go far to prevent the generation of disease at home; and then, even without quarantine laws, we need have little apprehension of contagion from abroad.

LEAD, (from the Saxon *læd.*) The colour of lead is of a bluish white; when tarnished, it becomes yellowish-white, then bluish, and at last bluish-black. Lustre when untarnished, 3; hardness, 5; and specific gravity, somewhere between 11 and 12. According to Brisson, it was 11·352: and a specimen tried by Gellert, which was found at Freyburg, was estimated at 11·445. Next to gold, platina, and mercury, it is the heaviest metal, being upwards of eleven times heavier than an equal bulk of water. The heaviest is reckoned the best. It stains paper and the fingers. Next to tin, it is the most fusible of all the metals. It is soluble in most of the acids, though more readily so in the nitrous diluted than the others. By exposure to the moist atmosphere, it rusts or oxides. It is malleable and unelastic, and its oxide is easily fusible into a transparent yellow glass

Lead is most used in building, particularly for coverings, gutters, pipes, and in glass windows. For which uses, it is either cast into sheets in a mould or milled; which last, some have pretended, is the least serviceable, not only on account of its thinness, but also because it is so exceedingly stretched in milling and rendered so porous and spongy, that when it comes to lie in the hot sun, it is apt to shrink and crack, and consequently will not keep out the water. Others have preferred the milled lead, or flatted metal, to the cast, because it is more equal, smooth, and solid.

The lead used by glaziers is first cast into slender rods, twelve or fourteen inches long, called *canes;* and these, being afterwards drawn through their vice, come to have a groove on either side for the panes of glass; and this they call *turned* lead.

The method of paling or soldering lead for fitting on of embossed figures, &c., is by laying the part whereon the figure is to be paled, horizontally, and strewing on it some pulverized rosin: under this they place a chafing-dish of coals till such time as the rosin becomes reddish, and rises in pimples; then the figure is applied, and some soft solder rubbed into the joinings; when this is done, the figure will be paled on, and as firm as if it had been cast on. For other uses in building, see the article SHEET LEAD.

LEAN-TO, a small building with a shed-roof attached to a larger one.

LEAVER. *See* LEVER.

LEAVER BOARDS. *See* LEVER BOARDS.

LEAVES, a representation in marble, stone, brass, wood, or other material of natural leaves. *See* ORNAMENT.

LEDGE, a surface on which to support a body in motion or to support a body at rest.

The ledges of a door are the narrow surfaces wrought upon the jams and soffit parallel to the wall, in order to stop the door, so that when the door is shut, the ledges coincide with the surface of the door.

The ledges of a door are therefore one of the sides of the rebate, each rebate having only two sides. In temporary works the ledges of doors are formed by fillets.

LEDGEMENT, the development of a surface, or the surface of a body stretched out on a plane, so that the dimensions of the different sides may easily be ascertained.

LEDGERS, in scaffolding for brick buildings, the horizontal pieces of timber parallel to the wall, fastened to the standards by chords, in order to support the put-logs, on which are laid the boards for working upon.

LEGAL COLUMN. *See* COLUMN.

LEGS, of a right-angled triangle, the two perpendicular sides.

LEGS of an hyperbola, the two parts on each side of the vertex.

LENGTH (from the Saxon *leng.*) the greatest extension of a body. In a right prism, the length is the distance between the ends: in a right pyramid, or cone, the length is the distance between the vertex and the base.

LENGTHENING, of timber, is the method of joining several beams, so as to form a long beam of any given length. *See* SCARF.

LESBIUM MARMOR, a name given by the ancients to a species of marble of a bluish white, sometimes used for vases, and other ornamental works, but principally in the walls of public buildings.

LEVEL, a mathematical instrument, used for drawing a line parallel to the horizon and continuing it out at pleasure, and by this means, for finding the true level, or the difference of ascent or descent between any two places, for conveying water, levelling the surface of floors, and for various other purposes in architecture, hydraulics, surveying, &c.

LEVEL, *Carpenter's*, consists of a long rule, straight on its lower edge, about ten or twelve feet in length, with an upright piece fixed to its upper edge, perpendicular to, and in the middle of the length, having its sides in the same plane with those of the rule, and a straight line drawn on one of its sides perpendicular to the straight edge of the rule. This standing piece is generally mortised into the other, and firmly braced on one side, in order to secure it from accidents, and has its upper end kerfed in three places, viz., through the perpendicular line, and on each side. The straight edge of the transverse piece has a hole or notch cut out on the under side, equal on each side of the perpendicular line. A plummet is suspended by a string from the middle kerf at the top of the standing piece, so that, when hanging at full length, it may vibrate freely in the hole or notch. When the straight edge of the level is applied to two distant points, with its two sides placed vertically, if the plummet hangs freely, and coincides with the straight line on the standing piece, the two points are level; but if not, suppose one of the points to be at the given height, the other point must be lowered or heightened, as the case may require, until the third is brought to a coincidence with the perpendicular line. By two points is meant two surfaces of contact, as two blocks of wood, or chips, or the upper edges of two distant beams.

The use of the level in carpentry, is to lay the upper edges of joints in naked flooring horizontal, by first levelling two beams as remote from each other as the length of the level will allow; the plummet may then be taken off, and the level be used as a straight edge. In the levelling of joints, it is best to make two remote joints first level in themselves, that is, each throughout its own length, then the two level with each other; after this, bring one end of the intermediate joists straight with the two which have been levelled; then the other end in the same manner; then try the straight edge longitudinally on each intermediate joist, and such as are found to be hollow must be furred up straight.

To adjust the level.—Place it in its vertical situation upon two pins or blocks of wood; then, if the plummet, hanging freely, settle upon the line on the standing piece, (or, if not, one end being raised, or the other end lowered, to make it do so,) turn the level end for end, and if the plummet fall upon the line, the level is just; but if not, the bottom edge must be shot straight, and as much taken off the one end as you may think necessary; then trying the level first one way and then the other, as before, if a coincidence takes place between the thread and the line, the level is adjusted; but if not, the operation must be repeated till it come true.

The most convenient class of levels is the *spirit level*, called also the *air level*, which is more accurate than any other kind, and is most extensively used. The invention of this instrument has been ascribed to M. Thevenot. Others have attributed this application of a bubble of air to Dr. Hooke. The instrument consists of a cylindrical glass tube filled with spirits of wine, except leaving in it a small bubble of air; its ends being hermetically sealed to keep in the fluid. This bubble, being the lightest of the contents of the tube, will, by the laws of hydrostatics, always run towards that end of the tube which is most elevated; but when the tube is perfectly horizontal, the bubble will have no tendency towards either end. The tube is not strictly cylindrical withinside, though it bears that appearance, but is slightly curved, the convex side being upwards, and by this means the bubble will rest in the middle of the tube when it is horizontal, but approaches either end if elevated above the other. The simplest form of a spirit level for fixing any plane truly horizontal, consists of a glass tube of the above description, called a *bubble tube*, fixed into a block of wood, as at A B, *Figure* 1. The lower surface, D E, of the block is made flat; and when the bubble, C, stands between two scratches marked on the glass at *a b*, the line D E is horizontal. The method of making it correct is this: the tube is first fitted into the block, the lower edge, D E, of which is placed on a bench or table as nearly horizontal as can be determined, so that the bubble stands between the scratches *a b*. The level is now reversed, that is, the end D is put where E was at first. In this position, if the bubble stands in the middle, it proves the level to be correct, and the table horizontal; but if it runs to either end of the tube, it shows that end to be too much elevated: suppose it D, for instance; this end of the tube must therefore be let deeper into the wood, or the surface D E rectified to produce the same effect: one-half the error must be compensated by this means, and the other half by rectifying the table or support; for D E, the level, must now be reversed again to verify these corrections; and when they are so made that the bubble stands at *a b*, either way, the level is correct. To illustrate this more plainly, see *Figure* 2, which represents a section of the bubble tube; but, for elucidation, is shown as if curved much more than they are ever made. Suppose the convex or upper surface of the tube to be a segment of a large circle, B C D; from the laws of hydrostatics, it is plain that the bubble of air, being the lightest body in the tube, will certainly occupy the highest point of the circle at C; and the two points, B, D, being equally distant therefrom, will be in the same horizontal line B E D. The larger the radius of the circle D B, so will the level be the more sensible of any deviation from the horizontal, because the bubble will have to traverse a greater distance along the tube, in proportion to any partial elevation of either end.

LEVELLING, the art or act of finding a line parallel to the horizon, at one or more stations, in order to determine the height of one place with respect to another; for the laying grounds even, regulating descents, draining morasses, conducting waters for the irrigation of land, &c.

LEVER, or LEAVER (from the French *levier*, formed of the verb *lever*, derived from the Latin, *levare*, "to raise") in mechanics, an inflexible straight bar, supported, in a single point, on a fulcrum, or prop, and used for the raising of weights.

The lever is the first of those called *mechanical powers*, or simple machines, as being, of all others, the most simple; and is chiefly applied to the raising of weights to small heights.

In a lever three things are to be considered: the weight to be raised, or upheld; the power by which it is to be raised, or sustained; and the fulcrum, or prop, by which the lever is supported, or rather on which it moves round, the fulcrum remaining fixed.

Levers are of three kinds: sometimes the fulcrum, or centre of motion, is placed between the weight and the power. This is called a *lever of the first kind*, or *vectis heterodromus;* to which may be reduced scissors, pincers, snuffers, &c.: sometimes the weight is between the fulcrum and the power, which is called a *lever of the second kind;* such are the oars and rudder of a boat, the masts of ships, cutting knives fixed at one end, and doors whose hinges are as the fixed point: and sometimes the power acts between the weight and the fulcrum, which is the *lever of the third kind;* such is a ladder lifted by the middle to rear it up against a wall: these two are called *vectes homodromi.*

In this last, the power must exceed the weight in proportion as its distance from the centre of motion is less than the distance of the centre from the weight. And as the first two kinds of lever serve for producing a slow motion by a swift one, so the last serves for producing a swift motion of the weight by a slow motion of the power. It is by this kind of lever that the muscular motions of animals are performed, the muscles being inserted much nearer to the centre of motion than the point where the centre of gravity of the weight to be raised is applied; so that the power of the muscle is many times greater than the weight which it is able to sustain. Though this may appear at first a disadvantage to animals, because it makes their strength less; it is, however, the effect of excellent contrivance; for if the power were, in this case, applied at a greater distance than the weight, the figure of animals would be not only awkward and ugly, but altogether unfit for motion; as Borelli has shown in his treatise *De Motu Animalium.*

The knowledge of the properties of the lever is of the utmost use in ascertaining the laws of the resistance of timber; we shall therefore begin with the first principles of motion, from which the properties of the lever are obtained; and also the principles of the centre of gravity of one, or of a system of bodies.

1. Force is the power exerted on a body to move it.

2. Direction of motion or tendency is the effort which one body makes to move another towards a given point.

3. Line of direction is the straight line in which a body moves, or has a tendency to move, without having any regard to the point to which it tends.

4. Angle of direction is the angle contained between two lines of direction.

5. When two or more bodies act against each other without any of them being overcome by the rest, this state of quiescence is called *equilibrium.*

6. Opposite directions, or opposite tendencies, are when each of two bodies move, or have a tendency to move, to a different point in the same line of direction.

7. Opposite forces are those that act upon each other in the same line of direction, but have a tendency to contrary points in the line, by which tendency an equilibrium is produced, or otherwise a change of motion.

8. Contrary directions are when two bodies move, or have a tendency to move, in lines parallel to two opposite planes.

Axiom 1.—Every body endeavours to preserve its present state, whether of rest or of moving uniformly in a right line, till it is compelled to change that state by some external force.

Axiom 2.—The alteration of motion either generated or destroyed in a body, is proportional to the force applied, and is made in the direction of that right line in which the force acts.

Axiom 3.—Action and reaction are equal between two bodies in opposite directions.

Axiom 4.—Two equal forces acting against each other, or against a body, in opposite directions, destroy each other's effect.

Axiom 5.—If a body is acted upon by two forces in opposite directions, it is the same thing as if it were only acted upon by one force equal to their difference, in the direction of the greater force.

Axiom 6.—If a body is kept in equilibrio by three or more forces, the sums of the contrary forces, when reduced to parallel directions, are equal.

Axiom 7.—When a right line is drawn in a direction of its length by two forces acting at its extremities, the line may either be flexible or inflexible.

Axiom 8.—When a right line is pressed or pushed by two forces in the direction of its length, and retains its straightness, the right line is inflexible.

Axiom 9.—When a right line is stretched by two forces, the right line draws each of the forces with the same intensity that the forces stretch the line; because action and reaction are equal and contrary.

Axiom 10.—When a right line is pressed by any two forces at its extremities in the direction of the line, it repels the force with the same intensity with which it is pressed by the forces.

Axiom 11.—If two forces act upon a body and keep it in equilibrio, their lines of direction are in the same right line, and the two forces are equal, and have opposite tendencies.

Axiom 12.—A force pulling by a string or flexible line upon one side of a body, has the same effect in moving or in keeping it in equilibrio, as an equal force pushing or pressing on the same line of direction on the other side.

Axiom 13.—A force acting upon a body has the same power in whatever point of the line of direction it is applied.

Axiom 14.—If a line be pressed or drawn by two opposite forces in the direction of the line, all its parts will be equally stretched or compressed.

Postulate.—Grant that the intensities of forces may be represented by right lines, as well as their directions.

Proposition I.—Plate I. *Figure* 1.—If any body, A, be moved by any impulse which would cause it to describe the right line A B, uniformly in a given time; and if the same body, A, be moved by another impulse, which would cause it to describe the right line A D, uniformly in an equal time: these two impulses, acting at the same instant, would carry the body through the diagonal, A C, of a parallelogram A B C D.

For the impulse which is given in the direction A B, will not prevent the body from coming to D C, by the action of the impulse in the direction A D, in an equal time to that in which A D would have been described by the separate impulse: for the same reason the impulse which is given in the direction A D, will not prevent the body from coming to B C, by the action of the impulse in the direction A B, in an equal time to that in which A B would have been described by the separate impulse: therefore, as the body will meet the lines D C and B C at the same time, it will meet in the intersection C; but because the lines A B and A D, are uniformly described in the same time, any two parts, A E and A F, taken from these lines in the ratio of the lines themselves, will also be described in equal times; and because B C is equal to A D, and E G equal to A F; A B : B C : : A E : E G; therefore the body moves in a straight line which is the diagonal of the parallelogram.

Corollary 1.—Hence, if the direction, intensity, and tendency, of any two forces acting upon a solid are given, a single force may be found, which shall be equivalent to the two.

Corollary 2.—Any single force, whose quantity and line of direction are given, may be resolved into two forces, which shall act at a given point in that line, in two given directions.

Proposition II.—Given, the tracts, intensities, and tendencies of two forces making any angle with each other, to find a single force equivalent to them.

Case I. *Figure* 2.—When each of the two given forces have a tendency, from the points A and C towards B, or from B towards A and C. Complete the parallelogram A B C D, and draw the diagonal B D, and it will represent the quantity and direction of the third force, that will be equivalent to A B and C B; and its tendency will be from B towards D, when the extreme forces tend towards B; but towards B when the extreme forces have a tendency from B.

Case II. *Figure* 3.—When the two given forces tend to two different points. Let A B and B C be the two given forces, let the tendency of A B be from B towards A, and that of B C from C towards B; produce either, as A B, to E: make B E equal to A B, and complete the parallelogram B C D E; draw the diagonal B D, and it will be equivalent to B C and B E, or because B E is equal to B A, and both in the same straight line: and since both forces tend to the same point, A, the force B D is equivalent to B A and B C.

It is evident, that though the angles and directions given were the same in both cases, yet the tendency and quantity would be different in each.

Proposition III.—To resolve any force into two others, in any given directions, which shall act against any point of the line of direction of the given force. *Figure* 4.

Let B E be the line of direction of the given force, B the given point, from which the required intensities are to act, and B F, B G their directions. Make B D equal to the intensity of the given force; complete the parallelogram A B C D; then B A is the force acting in the line B F; B C that in the line B G; and their tendencies are contrary to the middle force.

Proposition IV.—If any two forces keep a third in equilibrio, the direction of the third has the same point of concourse, and is in the same plane with the other two, and all the three forces are to each other as the sides and diagonal of a parallelogram formed on their lines of direction, *Figure* 5.

Let A B, B C, be the two forces; complete the parallelogram A B C D; then the force D B is equivalent to A B and B C; but if any force be in equilibrio with D B, it must be equal and opposite; therefore, make B E equal and opposite, and the two forces B D and B E are in equilibrio: take away the force D B, and let its equivalent forces A B and B C counteract B E, then the three forces A B, C D, and B E, are also in equilibrio: because B D and B E are in a straight line, the direction of E B passes through the point B, and is in the same plane with A B and B C; for D B is in that plane: and because B E is equal to B D, the three forces A B, C B, E B, are expressed by the two sides A B and B C, and the diagonal D B of the parallelogram A B C D, formed on their lines of direction.

Corollary 1.—Hence, if any three forces be in equilibrio with each other, they are as the sides of a triangle drawn parallel to their directions.

Corollary 2.—If the directions of any three forces, acting against the same point, keeping it in equilibrio, be given, and one of the intensities; the intensities of the other two may be found.

Proposition V.—The lines of direction of three forces keeping each other in equilibrio, or a solid, and the intensity and tendency of one of them being given; to find the intensity and tendency of the other two.

Case I. *Figure* 4.—When two of the angles formed by the three lines of direction are less than two right angles. Let the three directions be B F, B E, B G, and let the given intensity be in the line B E, and let its tendency be from E towards B. Make B D equal to the given intensity, and complete the parallelogram A B C D. A B is the intensity in its own line of direction B F, its tendency being from B towards F; and B C is the intensity of the force in its line of direction B G, its tendency being from B towards G: for produce E B to H, since the force acting in the line E B presses the point B, then, by *Axiom* 12, it is the same thing, whether the force in the line E B press the point B, or an equal force on the other side of B: in E H draw the point B, and instead of the force pressing the point B by a force at E, let the point B be drawn by a force at H; thus the point B will be drawn by three forces, which are in equilibrio by the last Proposition. Or if the point B had been drawn by a force acting at E, the two forces acting in the lines B F and B G would have pressed these lines, and consequently three forces acting at F, G, H, would be all pressing the point B; it therefore appears, when three forces keep each other in equilibrio, and their lines of direction make two angles less than two right angles, that the force acting in the intermediate line will be contrary to those in the two extreme lines.

Though this example only shows how to find the two extreme forces when the intermediate force is given; yet the intermediate force and one of the extreme forces may as readily be found by having the other extreme force given: because when one of the angles of a parallelogram is given, and the position of a diagonal passing through that angle, it may be described as readily by having either of the sides as the diagonal.

Case II. *Figure* 5.—When any two angles of direction are greater than two right angles.

Let A B, E B, C B, be the three directions, whereof any two angles made by these lines are greater than two right angles, and consequently the remaining one less than two right angles. Let the given force act in E B; produce E B through the opposite angle to D, so as to divide it into two angles; make B D to represent the intensity in E B, then by completing the parallelogram A B C D, as before, B A will represent the intensity in B A, and B C in B C; and as the forces are supposed to act at the points A, E, C, they are either all drawing the point B or all pressing it.

Proposition VI.—Given, the directions of four forces in the same plane, keeping a solid in equilibrio, and one of the intensities, to find the intensities of the other three.

Produce any two directions till they meet each other; also, produce the other two directions till they meet each other; join the two angular points; then by means of the given force, find the other two at the same point: then, because two forces acting at each point of concourse in the same right line must be equal, and have opposite tendencies, the force in this line acting at the other point of concourse will now be given: therefore, find the two remaining intensities in the same manner as at the first point of concourse.

Example I. *Figure* 6.—Let E A, F B, G C, H D, be the direction of the forces that support the body A B C D, and let the given force be in E A. Produce E A, F B, till they meet in I; also produce G C, H D, till they meet in Q. Join I Q, and produce it to P; then let I K represent the given force, and complete the parallelogram I K L M. Make Q P equal to I L, and complete the parallelogram O P Q R; then will I M represent the intensity in F B, O Q in G C, and R Q in H D.

Example II. *Figure* 7.—Let A B D be a lever with three arms, A C, B C, D C, revolvable about C, as a fulcrum, supported in the direction C O; and let forces act at the extremities A, B, D, in given directions, A K, D E, E B, and keep it in equilibrio: it is required to find the proportion of the forces. Produce two of the directions till they meet; also produce the other direction, and that of the prop, till they meet; join the two angular points, and proceed as in Example I., and find the parallelograms H E F G, and K L M N: then L K is the force acting at A, and M K that in the direction of the prop, H E, the force acting at B, and F E that at D. The tendencies of these forces are thus distinguished: let the point B be drawn towards E, then the line E B is in a state of tension; and because the angles H E G and G E F are less than two right angles, the force in the direction E D will also be in a state of tension, and the middle one, E K, in a state of compression. Again, because the angles L K M and M K N are less than two right angles, and because E K is in a state of compression, K A is likewise in a state of compression, and the middle one C K, is in a state of tension; or the post, C O, on the opposite side, is in a state of compression, acting on the other side of G.

It must be observed, when any force acts upon any point of a solid body, that to draw on one side of the point is the same as to press upon the other side, or to press upon one side is the same as to draw upon the opposite; therefore, as the point C is drawn by the force M K, the prop, C O, is compressed by the fulcrum at C. The arms C A, C B, C D, are supposed to be void of weight. If the forces acting at A, B, D, be weights, P, Q, R, going over the pulleys S, T, U, all the lines, A S, B T, D U, will be in a state of tension.

Proposition VII.—Given, the direction of five forces in one plane, keeping a solid in equilibrio, and the intensities and tendencies of two of them, to find the intensities and tendencies of the rest.

Find a force equivalent to the two given forces; then unite this given force with the three remaining ones, and the directions of four forces, with the intensity of one of them, will be given to find the rest, which may be found by the last problem.

Let A B C D F, *Figure* 8, be a lever, with four arms, F A, F B, F C, F D, revolvable about E, and let it be acted upon by five forces, four of which act upon the arms at the points A, B, C, D, in lines of direction A Q, B S, C K, D I, and the other upon the centre at F, in the line of direction F P; then the intensities and tendencies of the two forces acting in the directions C K, and D I, are given; the one from C to K, and the other from I to D. Produce the two directions C K and D I to meet each other at G, and complete the parallelogram G K I H, as in *Case* 2, Problem II., and G H will be the direction and quantity of the force equivalent to G I and G K: then proceed, as in Problem VI., with the given force G H now found, and the three remaining directions, A Q, B S, P F, and complete the parallelograms M N O P and Q R S T; then N P is the quantity that supports the point or axis F in the direction N F, and S R that which supports B in the direction B R.

From this example it appears, that when the direction of any number of forces is given, and all the intensities and tendencies but three, the intensities and directions of these three may be found by compounding any two of the given forces, then uniting the force found with another of the given forces, and again compounding these, and so on until all the given forces are compounded: then proceeding with the last compounded force and the three remaining directions, as in Problem.

Proposition VIII.—If there be two straight lines, A B, B C, *Figure* 9, making any angle, A B C, with each other, and if two forces, equal and opposite in the directions A X, C Y, in the same straight line be applied, and three others in the directions A W, B Z, C J, then if the whole be in equilibrio, the directions Z B, A W, C J, will have the same point of concourse, or otherwise they will be parallel. Join A C, cutting Z B produced in T; take any distance, A D, and complete the parallelogram A O D F; make B H equal to A F, and complete the parallelogram B H I K: make C L equal to B K, and C E equal to A D, and complete the parallelogram C M E L; then all the points A, B, C, are in equilibrio by forces proportional to, and in the directions of the sides and diagonals of the respective parallelograms at these points; now there can be no equilibrium unless C J coincide with C M, for no other force but C M, both in direction and quantity, will balance the two given forces C L and C E; suppose therefore that C J coincides with C M, produce the directions A W and C J to meet Z B produced; then if A W and C J do not meet it in the same point, they will meet it in two different points, U and V; for draw O F, R L, N G, S M, parallel to B V, cutting A C at O, R, N, S; also draw H P, K Q, parallel to A C, cutting B V at P and Q; then will A O=H P=K Q=C R, and therefore A N=S C;

now the triangles A B T and A F O are similar,
therefore . . . . T A : T B : : Q A : O F
likewise in the triangles C T B and C R L. . . . . T B : T C : : R L : a C
therefore . . . . T A : T C : : R L : O F
but because L R is equal to S M, and O F to N G . . . . . T A : T C : : S M : N G
then again, by similar triangles, A U T, and A G N . . . . T U : T A : : N G : N A
and it has been proved that . . . . T A : T C : : S M : N G
also by the similar triangles T C V and S C M . . . . . . T C : T V : : S C : S M
therefore . . . . T U : T V : : S C : N A

but because S C and N A are equal; T U is equal to T V, therefore the points U and V coincide; consequently the three directions meet in the same point.

Corollary 1.—F O + L R is equal to B I; for the triangle A F O is equal and similar to the triangle H B P equal and similar to the triangle K Q I; and the triangle C L R is equal and similar to the triangle K B Q.

Corollary 2.—If V *a* be made equal to A G, and V *c* to C M, and the parallelogram V *a b c*, be completed, the forces in the directions A W, Z B, and C J, are as V *a*, V *b*, and V *c*, viz., the three parts of a parallelogram in these directions; for draw *a e* and *c d* parallel to A C, meeting V B in *e* and *d*, then will V *e*=G N=O F=B P, and *e b*=V *d*=M S=R L=B Q=P I, therefore B P+P I=V *e*+*e b*; but B P+I P is the force in the direction Z B, consequently the three forces V *a*, V *b*, V *c*, are equal to those that act in A W, Z B, and C J.

Corollary 3.—If the points A and C are joined by an inflexible line, A C, it is evident that the equilibrium will still be maintained, for this line (by the last proposition) acts the same as the two opposite forces in A X and C Y.

Corollary 4.—When A W, B Z, and C J, are parallel, F D will coincide with F O, G A with G N, L E with L R, and C M with S M: now L R : O F : : T A : : T C; it will therefore be C M : A G : : T A : T C; consequently, the force A G=force C M=force B I.

Corollary 5.—Hence, if the directions of three forces acting in the plane of a triangle, at the angles, be in equilibrio, the three intensities are as the parts of a parallelogram formed on their lines of direction.

Proposition IX.—If three forces acting against the same point be in equilibrio with each other, and if any point F, *Figures* 10 *and* 11, taken in the line of direction of any one of the forces, the other two forces are to each other reciprocally as the distances of their lines of direction from that point.

Let the lines of direction of the three forces be A D, B D, and C D.

CASE I. *Figure* 10.—When the point, F, is taken in the line of direction of the middle force. Complete the parallelogram D E F G; draw F H perpendicular to A D, and F I to C D. Then because the opposite angles D E F and D G F of the parallelogram are equal, the angles H E F and I G F are equal; and because E H F and G I F are right angles, the triangles E H F and G I F are similar; therefore F G : F E : : F I : F H; but E D is equal to F G, and G D is equal to F E, therefore E D : G D : : F I : F H; that is, the force acting at A is to the force acting at C, as F I to F H.

CASE II. *Figure* 11.—When the point F, is taken in one of the extreme lines of the direction, A D. On D F, as a diagonal, complete the parallelogram D E F G; draw F H perpendicular to D B, and F I to D C; then because G F H and E F I are right angles, and the angle I F H is common, the remaining angles I F G and H F E are equal; and because the angles F I G and F H E are right angles, the triangles G I F and E H F are similar; therefore F G : F E : : F I : F H; that is, the forces at B and C are reciprocally as the distances of their lines of direction taken from any point in the lines of direction of the other force. Therefore, universally, if any three forces be in equilibrio, any two of them are reciprocally as the distances of their lines of direction, taken from any point in the line of direction of the other force.

Proposition X. *Figures* 12 and 13.—If a solid, A B C, be supported by three forces in the lines of direction Z B, A W, C J, these three lines will have the same point of concourse, or be parallel to each other.

Join A B, B C, C A; now the triangle A B C cannot be in equilibrio, unless the directions have the same point of concourse, or be parallel, and also in the plane of the triangle: otherwise the forces at the two points in each of the sides of the triangle would not be equal in opposite directions; therefore the equilibrium of the triangle would be destroyed, as has been shown by Proposition VIII., and consequently that of the solid would also be destroyed.

Corollary 1.—The intensities of any three forces keeping a solid in epuilibrio, will be as the parts of a parallelogram formed on their lines of direction.

Corollary 2.—Likewise the intensities of any two forces are reciprocally as the distances of their lines of direction from any point in the line of the other force, whether their directions meet or are parallel to each other.

Corollary 3.—Hence, in three forces acting upon a prismatic solid, or lever, in parallel directions, any two forces will be to each other in the reciprocal ratio of the distances of their lines of direction, on the opposite side of the solid, to the direction of the other force.

Proposition XI.—If a solid be in equilibrio by three forces, and if any point be taken in the line of direction of any one of them: the products of each of the other two, by the distance of their respective lines of direction from that point, will be equal. *Figure* 14.

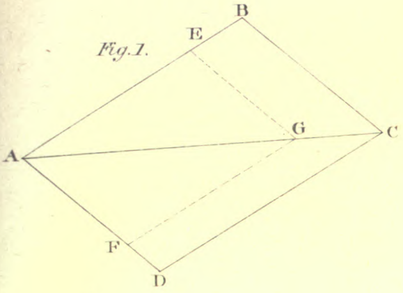


Fig. 1.

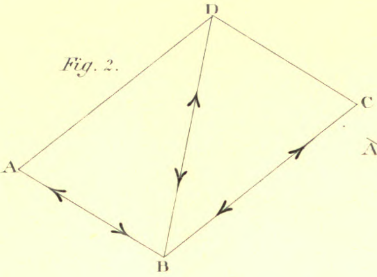


Fig. 2.

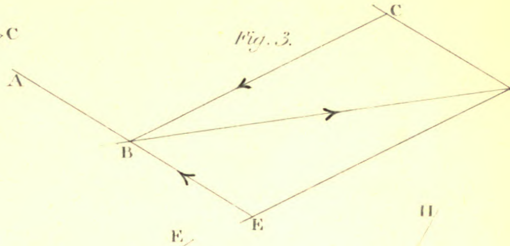
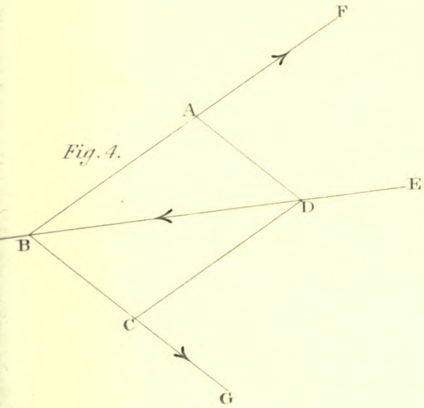


Fig. 3.



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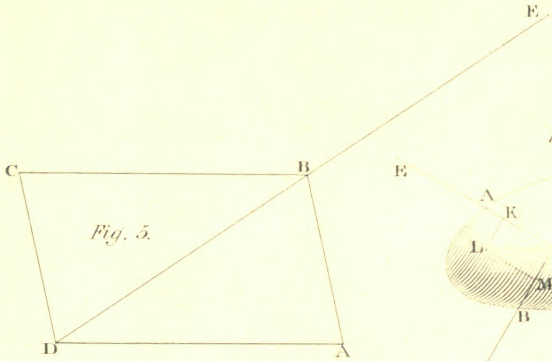

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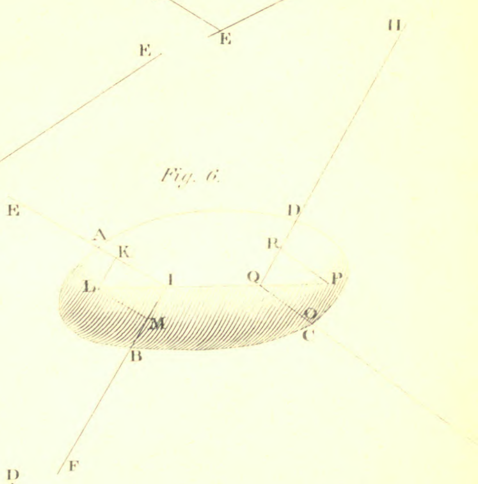

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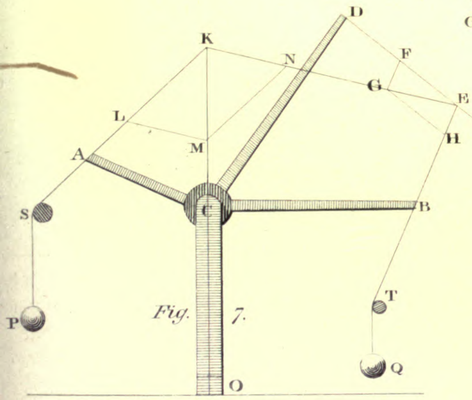


Fig. 7.

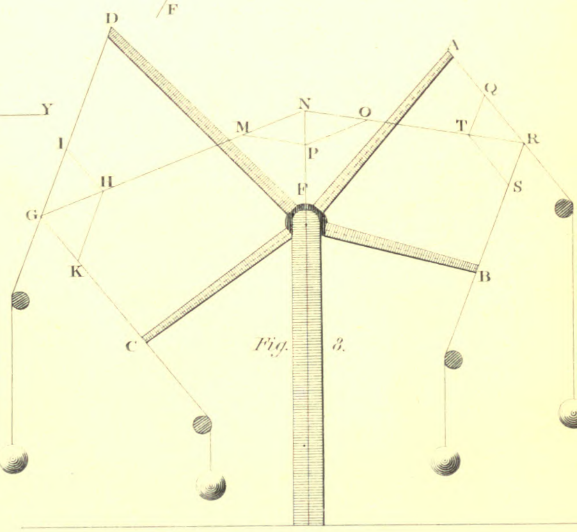
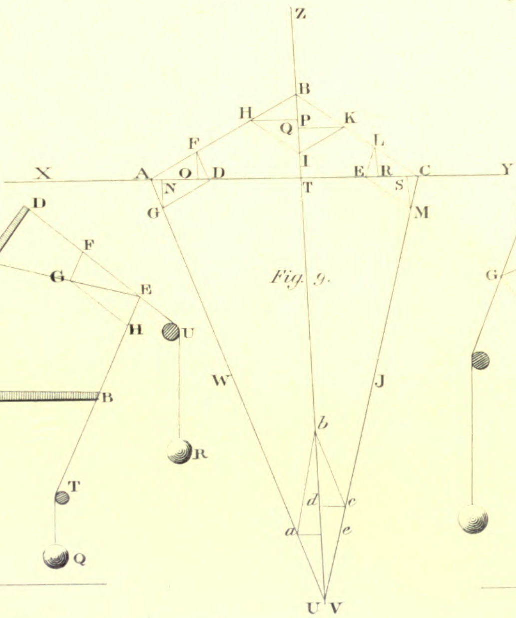


Fig. 8.



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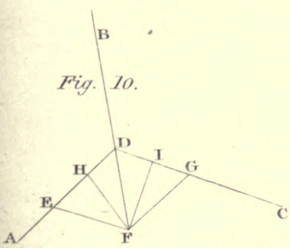


Fig. 10.

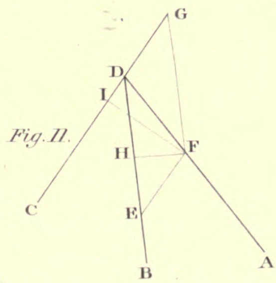


Fig. 11.

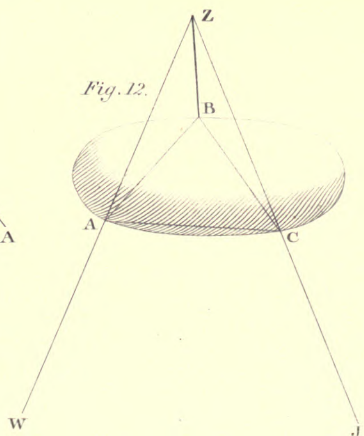


Fig. 12.

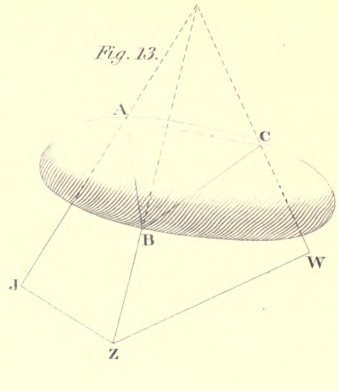


Fig. 13.

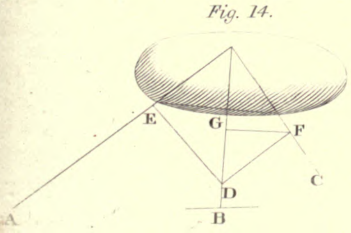


Fig. 14.

Let A, B, C, represent the intensities at A, B, C, in the directions E A, G B, F C. Take any point, D, in the middle line of direction, and draw D E, D F perpendicular to the other two lines of direction; then (*Corollary* 2, last Problem) A : C : : D F : D E; therefore A D E = C × D F. Again, from any point, F, in one of the extreme lines of direction, draw F G and F H perpendicular to the other two, then A : B : : F G : I H; therefore A × F H = B × F G.

Corollary 4.—Hence, if three forces act perpendicular to a prismatic rod, or beam, the products of any two, each by its distance on the beam from the third, are equal.

Corollary 5.—Hence, if three forces act perpendicular to a prismatic rod, or beam, the products of any two of their distances from the third, in the direction of the beam, are equal; for in this case all the lines, F D, D E, F G, F H, coincide in one straight line, and become parallel to the beam, and the segments intercepted by the directions are equal to those on the beam.

LEVER BOARDS, a set of boards so fastened together that they may be turned at any angle to admit of more or less air or light, or to lap upon each other, so as to exclude all air or light through apertures.

LIBRARY, an edifice or apartment destined for holding a considerable number of books placed regularly on shelves; or the books themselves lodged in it. Some authors refer the origin of libraries to the Hebrews; and observe, that the care those people took for the preservation of their sacred books, and the memory of what concerned the action of their ancestors, became an example to other nations, particularly to the Egyptians. Osimandyas, king of Egypt, is said to have taken the hint first; and, according to Diodorus, had a library built in his palace, with this inscription over the door, ΨΥΧΗΣ ΙΑΤΡΕΙΟΝ. Nor were the Ptolemys, who reigned in the same country, less curious and magnificent in their books.

The scripture also speaks of a library of the kings of Persia, Ezra v. 17. vi. 1., which some imagine to have consisted of the historians of that nation, and of memoirs of the affairs of state; but, in effect, it appears rather to have been a repository of laws, charters, and ordinances of the kings. The Hebrew text calls it the house of treasures, and afterwards the house of the rolls, where the treasures were laid up. We may, with more justice, call that a library, mentioned in the second of Esdras to have been built by Nehemiah, and in which were preserved the books of the prophets, and of David, and the letters of their kings.

The first who erected a library at Athens was the tyrant Pisistratus: and yet Strabo refers the honour of it to Aristotle. That of Pisistratus was transported by Xerxes into Persia, and was afterwards brought back by Seleucus Nicanor to Athens. Long after, it was plundered by Sylla, and re-established by Adrian. Plutarch says, that under Eumenes there was a library at Pergamus, containing 200,000 books. Tyrannion, a celebrated grammarian, contemporary with Pompey, had a library of 30,000 volumes. That of Ptolemy Philadelphus, according to A. Gallius, contained 700,000 rolls, which were burnt by Cæsar's soldiers.

Constantine, and his successors, erected a magnificent library at Constantinople; which in the eighth century contained 300,000 volumes, all burnt by order of Leo Isaurus; and among the rest, a copy of the Iliad and Odyssey, written in letters of gold, on the entrails of a serpent.

The most celebrated libraries of ancient Rome. were the Ulpian, and the Palatine. They also boast much of the libraries of Paulus Æmilius, who conquered Perseus; of Lucilius Lucullus, of Assinius Pollio, Atticus, Julius Severus, Domitius Serenus, Pamphilius Martyr, and the emperors Gordian and Trajan.

Anciently, every large church had its library; as appears by the writings of St. Jerome, Anastasius, and others. Pope Nicholas laid the first foundation of that of the Vatican, in 1450.

The Bodleian library at Oxford, built on the foundation of that of duke Humphrey, exceeds that of any university in Europe, and even those of all the sovereigns of Europe, except the emperor's and the royal library of France, which are each of them much older. It was first opened in 1602, and has since found a great number of benefactors; particularly Sir Robert Cotton, Sir H. Savil, Archbishop Laud, Sir Kenelm Digby, Mr. Allen, Dr. Pococke, Mr. Selden, and others. The Vatican, the Medicean, that of Bessarion at Venice, and those just mentioned, exceed the Bodleian in Greek manuscripts; which yet outdoes them all in Oriental manuscripts.

As to printed books, the Ambrosian at Milan, and that of Wolfenbuttle, are two of the most remarkable, and yet both inferior to the Bodleian. The principal public libraries in London, beside that of the Museum, are those of the College of Heralds, of the College of Physicians, and of Doctors' Commons, to which latter every bishop, at the time of his consecration, gives at least £20, sometimes £50, for the purchase of books; those of Gray's Inn, Lincoln's Inn, Inner Temple, and Middle Temple; that of Lambeth, founded by archbishop Bancroft, in 1610, for the use of succeeding archbishops of Canterbury, and increased by the benefactions of archbishops Abbot, Sheldon, and Tennison, and said to consist of at least 15,000 printed books, and 617 volumes in manuscript; that of Redcross-street, founded by Dr. Daniel Williams, a presbyterian divine, and since enriched by many private benefactions; that of the Royal Society, called the Arundelian, or Norfolk library, because the principal part of the collection formerly belonged to the family of Arundel, and was given to the society by Henry Howard, afterwards duke of Norfolk, in 1666, which library has been increased by the valuable collection of Francis Aston, Esq., in 1715, and is continually increasing by the numerous benefactions of the works of its learned members, and others: those of St. Paul's, and of Sion College; the Queen's library, erected by Queen Caroline in 1737; and the Surgeons' library, kept in their hall in Lincoln's Inn Fields. In order to give some idea of the construction of a library, it will be necessary to know the different sizes of paper, and for this purpose the following table will be found useful:

	Inches.	
1. Foolscap	13½ by	16½
2. Crown	15	20
3. Demy	17½	22
4. Medium	18	23
5. Royal	19¼	24
6. Super-royal	19¼	27
7. Elephant	23	28
8. Imperial	22	30
9. Columbier	23½	34
10. Atlas	26½	34½
11. Double Elephant, or Grand Eagle	26½	40

The dimensions of the shelves, and their distances from each other, will therefore be determined by the kind of books intended to be deposited on them.

Library, *the King's*, at St. James's, was founded by Henry, eldest son of James I. and made up partly of books, and partly of manuscripts, with many other curiosities, for the advancement of learning. It has received many additions from the libraries of Isaac Casaubon, and others.

Library, *Cottonian*, originally consisted of 958 volumes of original charters, grants, instruments, letters of sovereign princes, transaction between this and other kingdoms and states, genealogies, histories, registers of monasteries, remains of Saxon laws, the book of Genesis, thought to be the most ancient Greek copy extant, said to have been written by Origen in the second century, and the curious Alexandrian copy or manuscript in Greek capitals. This library is kept in the British Museum, with the large valuable library of Sir Hans Sloane, amounting to upwards of 42,000 volumes, &c. There are many public libraries belonging to the several colleges at Oxford and Cambridge, and the universities of North Britain.

LIGHTHOUSE, a marine building, erected for the purpose of exhibiting a light, to warn seamen in the night of their approach to any sand, promontory, or insulated rock: as those on the South Foreland, Flamborough Head, the Eddystone, &c.; or a building erected at the entrance of a harbour, to direct the ingress and egress of vessels during the night, as at Ramsgate, and other places. The latter kind are generally smaller than the former, and are called *harbour-lights*.

Lighthouses are generally built in the form of circular towers, from 50 to 100 feet in height, arched over at the top with a projecting platform surrounded by an iron railing. On this platform a framing of stone is fixed higher than the railing, containing an excavation for the reception of the bottom of the lantern; the space between this frame and the railing, is called *the gallery*, into which the light-keepers ascend to clean the outside of the glass.

When lighthouses are erected on the main land, there is nothing peculiar in their construction; in some cases, however, they are required in situations difficult of access, and exposed to the accumulated fury of winds and waves; and to erect a permanent building on a spot of this description, requires uncommon resources, and necessarily brings every energy of the architect into action.

The most celebrated antique building of this description was the Pharos of Alexandria in Egypt, the work of Sostratus of Cnidus, under the patronage of Ptolemy Lagus, and his successor Philadelphus, about 283 years before the Christian æra; it is ascertained to have existed for a period of about 1,600 years, and is supposed to have been thrown down by an earthquake. This lighthouse obtained its name from the Island of Pharos, on which it stood; and from its great celebrity, other structures of a similar kind have frequently obtained the same name; as the *Faro di Messina*, and others; but among the moderns, the most remarkable are the *Tour de Corduan* off the French coast, and the *Eddystone Lighthouse*, near the coast of Cornwall. The former of these, begun in the reign of Henry II., and finished under Henry IV. in 1610, stands upon a small island near the mouth of the Garonne, in the Bay of Biscay, and was the work of Luis de Foix, a celebrated French architect. The latter, which has been very justly considered as the *chef-d'œuvre* of this species of architecture, was constructed by the celebrated Smeaton; and still stands an enduring monument of his genius. A full description of this remarkable structure has already been given under the article Eddystone Lighthouse.

Among other remarkable buildings of this kind may be noted the Bell-rock lighthouse, off Arbroath, in the mouth of the Frith of Tay.

The reef of rocks on which the Bell-rock lighthouse is founded, is about 427 feet long and 230 feet broad; at the ordinary height of spring tides it is about 12 feet under water; and from the floating sea-weed, the ridge can be traced 1,000 feet farther in a south-westerly direction, when the tides are very low. It is situated on the eastern coast of Scotland, about 16 miles south by east from the Red-head; 12 miles south-east from Arbroath; 17 miles north by east from the isle of May; and 38 miles north by west from Abbs-head. Its geographical position is in 56° 29′ of north latitude, and 2° 22′ of west longitude. The reef presents an exceedingly rugged and uneven surface. The rock is composed of red sand-stone, similar to the strata of the contiguous promontory of Red-head and of the opposite shores of Dunglas in Berwickshire. The present vegetation of the rock consists only of sea-plants; some of them not of common occurrence on our coast. It is the occasional resting-place of the seal and the cormorant; and is the chosen residence of numerous marine *vermes*. At the distance of 100 yards, when the tide is low, the water varies from two to three fathoms in depth. The greatest depth between the rock and the opposite shores of Fife is 23 fathoms. This rock, though a mere spot on the surface of the ocean, produces all the remarkable phenomena of in-shore and off-shore tides, which exist on the projecting coasts of the mainland, or among the Scottish islands.

In the erection of the Eddystone lighthouse, the dangers and difficulties which were encountered and overcome, owing to the smallness of the surface of the rock, were great and numerous; and although the surface of the Bell-rock was considerably larger, still, being more sunk, and only discovered at low water, the dangers to be encountered were equally great and overwhelming. Owing to the enlarged diameter of the rock, the engineer was enabled to make the masonry of this building more than double the cubical contents of the Eddystone. The following short table will exhibit to our readers the relative dimensions, &c. of the two lighthouses:—

	Eddystone.	Bell-rock.
Height of the rock, about	Level with high water mark.	Level with low water mark
Height of masonry above the rock ..	70 feet.	100 feet.
Diameter of the first entire course ..	26 feet.	42 feet.
Cubic contents in feet, about	13,147.	28,530
		Ascertained.
Expense understood to have been about	£21,000.	£61,331 9 2

Very early, no doubt, attempts were made to obviate the dangers of this fatal spot; and accordingly, tradition reports that the monks of the Abbey of Arbroath erected a bell on the rock, which was to be rung by machinery affected by the flowing and ebbing of the tides, whence the present name of the rock, it is said, took its rise.

After many complaints of the want of a lighthouse, and especially after the violent storm in 1799, during which many ships were driven from their moorings in Yarmouth Roads, and even the Downs, and so many of them destroyed on the Scotch coast, that, when the storm subsided all the bays were margined by broken timber, it was at last resolved to construct a lighthouse. A bill for this purpose was passed in 1806, which enabled the commissioners of the northern lighthouses to levy three-halfpence a ton upon all British vessels trading to and from the ports between Berwick and Peterhead, and twice as much upon foreign vessels. The bill also empowered the commissioners to borrow £25,000 from government; and they had £20,000 of accumulated surplus, which showed that the provision of lights had not previously been kept up to the amount of the tax upon navigation. Still, however, this enabled the commissioners to begin the work with a fund of £45,000. While the proposal was in agitation, various projects for lighthouses were advanced by different individuals; but it was ultimately resolved that the structure should be of stone, somewhat similar to the Eddystone lighthouse, and conducted under the principal superintendence of the late Mr. Rennie. It was well for the stability of the structure, and the benefit of trade, that this eminent and judicious engineer was appointed, for there were other parties who occasionally interfered in the progress of the work; and some of the courses of stone intended for, and actually prepared in the workyard at Arbroath, were; for want of central dovetailing, so faulty, that, had they been used, the work could not have stood. These courses of stone were condemned by Mr. Rennie, and ordered to be broken up for rubble, as appeared by the signature of Mr. Rennie, on the plans. By the necessary condemnation of these faulty courses of stone, a considerable sum of money was lost, but the stability of the lighthouse was not endangered, which was the grand matter; and this shows how very careful eminent engineers, who are not constantly on the spot, ought to be, in examining every working drawing of such structures as this, and allowing no drawing to be used which is not authenticated by their signature. We do not now recollect all the faults of these condemned courses; and since the death of Mr. Logan, who was in possession of the plans with Mr. Rennie's signatures, we know not where these drawings can be referred to, (and reference to them is of little consequence, except as a warning;) but we do remember, that what struck us at the time as the grand imperfection, was the omission of the square central stone with dovetails, to which the four stones next in order were attached, and also joggled by stone to the end joints, thus making the five one mass of stone, to which the whole of the surrounding stones were attached. In place of this central stone, which was of course the key and fastening of the whole, there was substituted in the drawings, a plain hexagon or octagon, we forget which; by means whereof the whole bonding of the course was loosened, and, had water percolated into it, it would have been destroyed by the hydrostatical pressure. An accident of this kind happened to another structure which the engineer to the commissioners of the northern lighthouses had planned, and was in the course of erection upon the Carr rocks, off the east point of Fife. This structure was to be furnished with a bell, to be rung by a float; and in order to contain the float, a hollow column was erected, having a lateral opening at the bottom. The column was, we believe, pretty well secured against the external action of the water, but it should seem that the danger of hydrostatical pressure from within had been overlooked, for, after the work had advanced so far as to be distinctly visible from the land, the sea beating over it during a violent storm, had thrown in rubbish which blocked up the lower aperture, and the hollow of the column filled with water, which burst it into pieces, so that it vanished before it was finished. As this structure is gone, and has left no memorial, it would be of little consequence to inquire into any particulars of it; but the fact is worthy of record, as tending to show how very careful engineers should be in attending to every principle in the planning and executing marine structures; and also how careful those who direct the building of such structures ought to be in the selection of their engineers. To suffer, in any lighthouse or beacon-tower for the warning of mariners of the perils of the sea, any weak portion or point which shall endanger the stability of the structure, may be attended with more calamitous effects, at least for a time, than having no lighthouse or beacon at all; for the lighthouse or beacon gives the seaman a certain security, which prevents him from avoiding the danger so assiduously as he would do, were there no lighthouse there; and, therefore, he is tempted toward the rocks; and wrecked upon them, if the lighthouse falls before his arrival. The Bell-rock lighthouse is as secure against any casualty of this kind as a structure of human erection can be; and, from what we have stated, those who navigate the dangerous coast on which it stands cannot be too thankful to Rennie, who had the superintendence of the building, or hold the memory of that eminent and most judicious engineer in too high estimation.

While, however, this tribute is justly due, and ought to be paid, to the memory of Mr. Rennie, Mr. Logan, under whose care the work was more immediately executed, ought not to be forgotten. Perhaps no man was ever more capable of executing stone-work to bear the violence of the sea; and, let the plan be ever so good, a work may be rendered unstable by ignorant or negligent execution. Logan had been trained from his infancy in aquatic architecture, more especially in the construction of bridges which had to resist the action of violent floods; and, therefore, though a very young man when employed in the Bell-rock Lighthouse, he well knew the nature of the work, and was most faithful in the execution of it. His execution of the Dundee harbour, under Telford, and of the packet harbours between Ireland and Scotland, under Rennie, are lasting monuments of his ability; and had he not been prematurely cut off, there is no doubt that his operations on the Clyde would have been of the greatest benefit to Glasgow, and to all who are any way connected with it. Indeed, his professional zeal may be considered as the real cause which shortened his days; for when laying the foundations of the Dundee harbour, some of which was in very deep water, he was constantly on the ground when the tide permitted, and standing in the water for hours, directing and encouraging the men, whether it was night or day, and whatever was the state of the weather. This labour and exposure, which would very soon have killed most men, brought upon him a severe and long-protracted rheumatic fever; and, though the natural strength of his constitution enabled him to survive this for many years, he never thoroughly recovered from it.

In enumerating those who were chiefly instrumental in making the Bell-rock Lighthouse what it is, there is another and a different character, whom it would be injustice to pass over in silence: this was Watt, the machinist, or, more strictly speaking, the man of all work, or rather of all contrivance in cases of emergency. As is but too frequently the case with workmen of great inventive talent, Watt was somewhat dissipated, and passed not a little of his time in ale-houses. In this matter he was allowed to have his way, only to be always ready at a call; and when the course of the work rendered a crane, or crab, or other engine of peculiar construction, necessary, Watt was sent for, and instantly sketched out, rudely enough in some instances, the very machine which answered the purpose; and having done so, he returned to his potations. Among his contrivances we may mention two cranes, which are certainly superior to any other for laying heavy stone in difficult situations. One of those was a "jib-crane," of great power and easy management: it was supported by four gye-ropes in the usual manner, and traversed freely all round. The jib or arm was jointed to the pillar, so that it could be brought into all positions from horizontal to vertical; and, to prevent it from lapping to the pillar when raised, or beyond a certain elevation, the jib-chain by which it was raised or lowered passed over a pully in the bight, so as always to give a downward pressure on the point of the jib, where the pully of the crane chain was attached. It was worked by wheel and pinion, and, of course, required two sets of "geer"—one for working the jib, and the other for working the crane. By means of these contrivances, the largest stones—some of which were two tons in weight—could be brought to any point within the range of the jib, with great certainty, and very little manual labour.

While the building was solid, and of such moderate height as that the gye-ropes could be fastened, this crane answered exceedingly well; but after the structure had advanced some height, and especially after it began to be hollow, a crane of this description could not be so fastened as to command the whole surface and have sufficient security. Consequently, the invention of Watt had to be called in; and he contrived his counterpoise crane. This crane was supported on a hollow pillar of cast-iron, which was lengthened by adding additional pieces as the progress of the work required. The crane, which was a platform with two equal arms, traversed upon this pillar, and was of sufficient length to command the whole work, and as much more as sufficed for raising the stones. To the one arm was attached the chain for this purpose, while the other carried a hook, upon which weights could be placed, to counterbalance that of the stone; and the working parts were so arranged, that when the stone required to be moved outwards or inwards to bring it to its proper bed, the weights were also moved outwards or inwards, and thus the leverage of both ends of the crane was always equal, as well as the weight. Thus it traversed freely, was easily worked, and perfectly stable. One of the barrels also raised the platform of the crane by means of a pulley and chain on the top of the pillar; and there were apertures through both sides of the pillar, for supporting the platform when raised to the proper height. When the pillar itself required to be lengthened, the pulley was removed from the top of the pillar, a new piece of pillar added, the pulley replaced, and the chain lengthened and passed over it as before. In this way, by adding length after length, the laying of the stones by means of the counterpoise crane was carried on to the required height with ease, expedition, and safety, which could not have been maintained without such an apparatus.

The lighthouse itself is a splendid structure, of which the external contour is good, and also the execution. The height of the masonry is 100 feet, and the light-room or lantern is 15 feet more. The diameter at the base is 42 feet; but at the parapet of the lantern, is only 13 feet. The first 30 feet consist of solid masonry, the lower courses let in, and treenailed to the rock, and all the solid courses are dovetailed, joggled, and treenailed; and as they are laid in strong mortar, which sets readily and firmly, the whole of this 30 feet has very nearly the cohesion of one solid mass of stone.

The entrance and lowest apartment is at the top of this solid masonry, and there is an external stair and platform for landing when the tide suits. The walls of this apartment are 7 feet thick; it is occupied by the water-tanks, fuel, and other heavy necessaries. The second, which is much more ample, in consequence of the reduced thickness of the walls, contains the oil and other stores necessary for the lights. The third floor is the kitchen, and the fourth the bedroom for the keepers; and the fifth room is the library, and place for the reception of such strangers as have hardihood to visit this sea-girt pillar. Over all these is the light-room, with double glazed windows, and wholly fire-proof, except the external dead-lights, which are put on as occasion requires. The balcony around the light-room is well secured by a cast-iron railing, supported with brass, and having a strong top-rail of that metal. The parapet of the light-room is six feet high, and from it a door opens to the balcony. The sashes of the windows are of cast-iron, the glazing strong plate double, as we have said, and the dome is of copper. The lights are revolving ones, and show alternately a white and red light, produced by stained glass. They are very powerful, and can readily be seen at a distance of 20 miles or more, unless when the atmosphere is foggy; and unfortunately, no light has yet been discovered which can so far penetrate a thick fog as to warn a ship of danger in time for even a chance of escaping.

As the best substitute that circumstances admit of, two bells of 12 cwt. each are tolled constantly day and night, when the atmosphere is foggy, by means of the same machinery which moves the lights. In calm weather, during which fogs are most frequent, the sound of these bells can be heard all over the surface of the rock which is absolutely dangerous; and thus they justify the appellation of Bell-rock lighthouse, and remind one of the Abbot of St. Thomas.

The rise of the tide over the foundations of the lighthouse is about 16 feet at ordinary spring floods; and when the sea is perfectly tranquil, the structure seems resting on the waters. Altogether, indeed, the Bell-rock lighthouse is a structure of great interest, and one which has been the means of saving many lives and much property. Considering that the workmen had to contend with the violence of the sea, upon a rock 12 miles from land, and with its highest point 12 feet below the surface of high water; it will be readily understood that the commencement of the work, and all the early stages of it, must have been attended with great difficulty and no small danger. A faithful history of its construction, drawn up with even the tithe of the talent which Smeaton displays in his report on Eddystone, would be an interesting and instructive work; unfortunately, there was no Smeaton conversant with all the details of the Bell-rock; and the result is, that all the published accounts of it are meagre, and some of them perhaps not true.

Another noble erection of this kind is that on the Skerrymore rock, off the west coast of Scotland. This building was constructed from the designs of Mr. Alvan Stevenson, the talented engineer to the Scottish Lighthouse Board, and cost in its erection, with the harbour for the tender and other necessaries, £87,000; it was first illuminated in 1844. The light is 150 feet above the sea, and the structure and its appliances exhibit every refinement and improvement hitherto effected by modern science in the varied particulars of the system.

Although, however, the talent and practical ability of such men as Smeaton and Rennie enabled them to overcome all the difficulties of constructing such buildings as we have described, other situations, where also it was desirable to erect them, presented obstacles of another character, perhaps even still more troublesome to deal with; we allude to the erecting lighthouses on such shifting and dangerous sands as the Goodwin, &c. Here the engineer has no solid rock to build on; instead of a substantial foundation on which to base his work, he has to work on a treacherous material, which slides from under him, and engulfs all that is placed on it.

Of the means for meeting such difficulties, the first to be noticed is the *screw-pile* of Mr. Alexander Mitchell, C. E. of Belfast. This principle was first employed in the construction of the foundation of the Maplin Lighthouse, on the north side of the mouth of the Thames, on which is now exhibited a red light. This was commenced in 1838, and is as firm now as when first erected; it stands on the outer edge of the Maplin Sand. This dangerous shoal is composed of sand at the surface, and afterwards of sand and mud; it is exceedingly soft and penetrable, and therefore the erection of a lighthouse upon such a foundation must be considered as a great achievement.

The principle of this screw-pile lighthouse, is having a series of piles nine in number—eight in the angles of an octagon, and one in the centre. These piles consist of a shaft of hammered iron, five or six inches in diameter, having a single turn of the flange of a screw four feet in diameter. This pile is screwed with great facility into the sand, to the depth of 22 feet; and each, it was calculated, would bear a weight of 64 tons. Nine piles were fixed in nine consecutive days in the summer of 1838, and upon this foundation of Mr. Mitchell's, the light-room was erected under the direction of Mr. Walker, the engineer to the Trinity Board.

A structure similar to this was proposed by Mr. Robert Stevenson in 1800, for the Bell-rock lighthouse. It was intended to affix the foundation to the rocks, and that the iron shafts should support several stories; whereas the Maplin and Wyre lights have but a single story. A similar structure is also now building on the rocks of Minot's Ledge off Boston, in the United States; and another is constructing in London for the Bishop Rock off Scilly, designed by Mr. Walker. Mr. Mitchell previously completed a lighthouse upon a similar foundation at the mouth of the Wyre river, in Morecambe bay, about 30 miles north of Liverpool. It was commenced in November, 1839, and lighted in June, 1840. The foundation is formed of seven screw-piles, six in a circle, and one in the centre, each pile being five inches in diameter, with a screw of three feet diameter. The screws were sunk 13 feet into the bank, which is composed of exceedingly hard sand. On these screws is supported the lighthouse, consisting of one floor only, and the lantern above it.

Another plan has been carried into effect, at the Point of Air lighthouse, at the entrance of the river Dee, near Chester. This, which is similar in superstructure to the Maplin lighthouse, is by Messrs. Walker and Burgess, and consists of nine hollow iron cylinders, 3 feet 9 inches in diameter, sunk 12 feet into the sand by aid of an instrument known to well-sinkers as "the Miser," which extracts the sand contained in the cylinder. In these the bases of the piles are inserted, and then filled with concrete. But this, it must be observed, is erected above low water-mark.

While on this point of the subject we may notice an admirable plan for forming a foundation for a bridge or pier of similar structure described by Mr. Charles Fox, of the firm of Fox, Henderson, and Company, in his evidence before the Committee on the Westminster Temporary Bridge bill in 1850.

This plan has been adopted with great success in the several bridges on different lines of railway, built by Messrs. Fox and Company, under the direction of Mr. Cubitt and other engineers; and though not yet, as we believe, applied to the building of lighthouses, seems well adapted to that purpose.

We cannot better describe this plan than in Mr. Fox's own words, in the following extract from the printed evidence of the Committee above mentioned.

"Will you describe to the Committee the mode of construction?—Perhaps the simplest mode of describing it is to say, that instead of using the old-fashioned wooden coffer-dam, which was always a temporary work, we make use of cylinders of iron, which are in themselves coffer-dams, and which remain permanently as a portion of the structure. We adopt various modes of getting them down, but the more general one is this: we have a large receiver of wrought-iron, very much like a cylindrical high-pressure boiler, and from that receiver we exhaust the atmosphere, and when we get the cylinder put into its place, just carefully lowered down on to the bed of the river, surrounded by temporary frames of timber, so as to be sure that it shall be kept in a vertical position, we put a cap on to the top, having an elastic pipe from the top cap to the exhausted receiver, and we, at the proper time, open the communication between the two, and the pressure of the atmosphere on the surface of the water in the river produces such a rush to fill up the tube, as to get rid of any vacuous space, that it carries on a constant state of excavation under the bottom edge of the cylinder, from the pressure of the atmosphere on the top. The atmosphere takes care to push down the pile, aided by its own weight, so as to take up any little space that may have been excavated. When this mode was first spoken of, it was treated with a great deal of ridicule, and people naturally said, 'Why, if the pressure of the atmosphere will push the pile down, when the pile is down it will not carry more than a weight equivalent to the pressure of the atmosphere;' and a very practical man raised that objection; not a very scientific man, but a man of very great experience; and I said to him, 'Now you are quite wrong, for the principle is, that it acts as a sort of excavating process; it is quite true that the pressure of the atmosphere on the top is useful, as it gets over any little friction on the sides of the tube so as to enable it to follow into the excavated space, and without that principle we could not push the cylinder down at all.' To prove this, we took a six-feet cylinder, and calculated what the pressure of the atmosphere upon that cylinder would be, and taking the whole pressure of the atmosphere, it amounted to about 30 tons. I had 30 tons of iron rails placed on the top of the cylinder, and the only result was, that it pushed it down about three-quarters of an inch into the gravel and brought it to a bearing, but it did no more.

"Was that upon a cylinder of six feet in diameter?—Yes; we then took off the 30 tons of iron-rails and put on the cap and opened the communication with the exhausted receiver, and the cylinder immediately descended into the solid gravel 6 feet 6 inches by one impulse.

"Having descended only three-quarters of an inch before?—Only three-quarters of an inch; it just pressed it a little into the ground with the dead pressure of 30 tons. We then removed the cap, and put on the top of the pile 100 tons of rails; but we could get no depression, except some three-quarters of an inch, which was done by the little compression that you would have from the weight of the edge of the cylinder on the gravel. That is the general mode of sinking these cast-iron cylinders. But as it will be obvious to the Committee, in the event of our meeting with, say, the trunk of an old tree, or a very large stone, we could not proceed any further, and we have had to devise many means of getting over any difficulty of that kind. In the case of the bridge at the Nene, we have had to go through not only a layer or two of gravel, but through 2 feet 6 inches of solid rock, and that rock not lying in a horizontal position, has offered difficulties which, under other circumstances, would be very expensive to overcome. To enable us to get through any unforeseen matter, it is necessary to get into the cylinder and excavate any material that may be within it, and cut through the obstruction; and, to do that, we have devised a means by which we convert the cylinder virtually into a diving-bell; that is to say, we fix a cap on the top of the cylinder, and the air-pumps are constructed so that they are, when required, compressing-pumps, and we can pump just enough air into the cylinder to make it counterbalance the pressure of the column of water without, by which means we keep the work perfectly dry, and the men can get at it just as well as if they were working in this room.

"What is the greatest depth to which you have driven a single cylinder?—I think the greatest depth to which we have driven a single cylinder is about 19 feet; but one has been driven in the Goodwin Sands 65 feet by the same process.

"The Committee understand that the cylinders are not single, but are piled one upon each other to the required depth?—Exactly so; they are generally used in nine-feet lengths; the piles for the bridge at Rochester are of two diameters, they are six feet and seven feet, and they are cast in lengths of nine feet, with flanges at the top and bottom, which are accurately turned and fitted together, so that they drop on to one another; there is a projection.

"The external water will be found to be effectually excluded by such a mode of junction?—Perfectly; we never have a drop through them; they require nothing more than a single coat of paint, and when we use one of the castings we clean the flange carefully and give it one coat of good red lead paint, and put another down upon it, which is prepared in the same way; they never leak a drop.

"Do you recommend as a general principle the adoption of a cylinder or of a square form?—Generally a cylinder, for several reasons.

"Will you state the reasons?—In the first place, because it is the cheapest form to construct in the preparation of the casting itself; and, in the second place, because it is better capable of bearing pressure, and therefore can be cast with a much less quantity of material in it; the object in a foundation being to get the largest bearing surface at the least possible cost; in the third place, because we have found in practice that it is difficult to sink square caissons close together, because, having a very small space between them, one having been sunk, it is very apt to make it difficult to sink an adjoining one; we have no ground between them to work upon.

"The Committee understand, likewise, that there is round each cylinder a girdle of timber, which is necessary in order to keep the cylinder in its perpendicular position?—Yes; I have made use of piles upon which temporary frames are fixed, and put two rows of what we call wallings, forming a square space, in which the cylindrical pile is placed and driven by means of the pressure on the cap of the cylinder.

"Are the Committee to understand that the surface, or the bed of the river, is in the first instance level, in order to receive the cylinder?—Not at all; we deal with it as we find it.

"You use no mechanical means, except in the experiment to which you have adverted, of 30 tons and 100 tons of actual weight; you have recourse rather to physical means of exhausting the air, and of admitting the pressure of the atmosphere?—Yes, because it is so much cheaper. It is a serious job to put 30 tons on to a pile, whereas a simple cast-iron cap, as I have before described, put on to the top is so exceedingly easy."

In another part of his evidence, Mr. Fox says, "There is no doubt that the cheapest foundation you can put in is to use the largest size cylinders, so as to have them within the compass of ordinary means of moving about. If you had a pile two feet in diameter it would bear a certain load, supposing it to be in any semifluid foundation; if you double the diameter, you would only double the weight of the cylinder, but it would carry four times the load." Again,—and this is peculiarly applicable to foundations on sands, &c., for lighthouses—"If you give me a piece of ground, and first there is a layer of mud, and then a layer of gravel, and then a layer of rock, and then a sheet of cast-iron, and then anything else, I will put a cylinder through it. I also will bring up the foundations of the bridge to low-water level, for something like the same cost as would have been expended under the old plan, in the mere material used for that purpose, saving coffer-dams altogether."

Mr. Bush's "Light of all nations," though it failed so signally, deserved notice. This was again a proposal to construct a lighthouse on the Goodwin, ever a locality for experiments of this nature. The site at last chosen was, for any good effect to be derived from it, as bad as could possibly be, being on the middle of the sand, and consequently calculated rather to lead vessels into danger, than to preserve them from it.

"The Light of all nations" was intended to be an iron tower erected by means of an iron caisson, which was to afford the means of forming a substantial foundation. This caisson, the frustum of a cone 30 feet in diameter, and 28 feet high, weighing about 150 tons, was towed out from Deal by one of Her Majesty's vessels to its station, about the centre of the Goodwin Sands, on July 27, 1842. The caisson was made water-tight, in order that, as it settled down, the workmen might be enabled to construct the foundation on the chalk substratum of the sand. This substratum, however, was never reached; the caisson did settle down, but not perpendicularly, and after it had been knocked about by several gales of wind, it was found impracticable to carry out the original design, and it was therefore necessarily abandoned. On the wreck of the caisson, however, Mr. Bush succeeded in erecting a smaller shaft, surmounted by a small light-room, and in this room he and his wife remained during a night in the beginning of 1845.

The lighthouse was never completed. And the Trinity House was at last obliged to interfere, to prevent, from its dangerous situation, its being used as a light-beacon.

Another adaptation of iron to the construction of lighthouses has met with far greater success, and promises to be of the greatest utility, whether as regards economy, or facility of construction. This is the iron lighthouse designed by Mr. Gordon.

It is rather singular that iron should not have been employed in this form before, when we consider the multifarious variety of purposes to which it is now applied. In the year 1805, however, a cast-iron lighthouse was suggested by Mr. Rennie, for the Bell-rock, and also by Mr. Robert Stevenson in 1800. The first tower of this construction, was erected on the eastern end of the island of Jamaica, and another of a similar kind for Bermuda. The latter is 105 feet 9 inches high, formed with iron plates, the entire weight of which is nearly 100 tons. The building has seven stories, and the lower portion is filled in with concrete to the height of 22 feet, to give it stability. Nearly every portion of the edifice is of iron, and the erection of the tower was completed in ten months, finished October 9, 1845. These lighthouses were constructed in London, put together and erected, and then taken to pieces again and forwarded to their destination.

The light in the Bermuda lighthouse is from a beautiful dioptric first order apparatus, constructed by Messrs. Wilkins and Son, of Long Acre; the lenses composing it were made by M. H. Lepaute of Paris, and is one of the most efficient and powerful lights in the world.

Having thus shown some of the different methods employed in the erection of lighthouses, and the improvements which modern art has introduced, we now turn to another important part of our subject, that of the *illumination* of lighthouses.

The first lighthouses, such as the Cordouan, and the North Foreland, were illuminated by open fire-places, or chauffers, placed on the summit of the towers. In the former, they burnt billets of oak-wood; and in the latter, coal. It will be readily seen how incompletely such arrangements must have performed their office. Of course the time at which a lighthouse becomes most serviceable is, during tempestuous weather, and a wind blowing towards the land, causes that dread of mariners—a lee-shore; yet this wind would drive the flames of an open fire away from the very direction in which they were most required to be seen; thus the bars of the grate were often nearly melted to leeward, while towards the sea the coals remained untouched by the fire. One advantage, however, there certainly was sometimes in the open fire, viz., that, during fog or rain, the glare of the fire was visible by reflection in the atmosphere, though the fire itself could not be seen.

The North Foreland lighthouse, between Ramsgate and Margate will be more familiar to many of our readers than any other, and will serve as an excellent example of the progress of illumination. This lighthouse was erected for indicating the proximity of the Goodwin Sands. The first intimation we have of its existence is in 1636, in Charles the First's reign, when license was granted to Sir John Meldrum to renew and continue this and the South Foreland lighthouse for the same purpose. At this time it was merely a large glass lantern on the top of a timber-and-plaister house, which was burnt in 1683. Towards the end of the same century, the present tower was partially erected; a strong octagonal structure, having the iron grate, or chauffer, for burning coals. From the difficulty of keeping up a proper flame in windy or rainy weather, it was covered about the year 1732, with a sort of lantern, with large sash windows, and the coal fire was kept alight by means of large bellows which the attendants blew throughout the night. This was found not to answer, and the reflected glare above-mentioned was thought desirable. Accordingly, the lantern was removed, and the fire restored to its original condition. Matters went on thus till 1790, when the tower was raised to the height of 70 feet, and further improvements made in the lantern, by the introduction of lamps and other apparatus, hereafter to be described.

After some alterations of the Cordouan wood-fire, the mariners complained that they could not see the light at a distance of two leagues, as formerly. But Smeaton informs us, that the coal-fire of the Spurn Point lighthouse, at the mouth of the Humber, which was constructed on a good principle for burning, had been seen thirty miles off.

The only exceptions to the fires were the noble Eddystone lights, which then exhibited a chandelier of twenty-four wax candles, five of which weighed 2lbs., and the Liverpool lighthouses, which had oil lamps, with rude reflectors.

The coal lights are now quite abolished. The last was at one station belonging to Sweden, on the little island of Nidingen, on the east side of the Categat, near the entrance to the Baltic sea. These were two light towers, showing coal fires, but surrounded by sides of glass, to shelter them from the wind, and open at the top. They were altered at the beginning of the year 1846.

The introduction of the Argand lamp was the first great advance towards the perfection of lighthouses. This improvement in artificial light was the greatest, previous to the introduction of gas. It was discovered by M. Argand, a citizen of Geneva, about 1780 or 1785. It has remained as he left it, and in principle appears as perfect as can be looked for. Its perfection as an experiment was almost accidental. The younger brother of Argand thus describes its accidental discovery. "My brother," he says, "had long been trying to bring his lamp to bear. A broken-off neck of a flask was lying on the chimney-piece; I happened to reach it over the table, and to place it over the circular flame of the lamp; immediately it rose with brilliancy. My brother started from his seat in exstasy, rushed upon me with a transport of joy, and embraced me with rapture." Thus originated the Argand lamp.

On the introduction of a more efficient means of illumination, and the consequent abandonment of the coal fires, lighthouses assumed a more important position in maritime affairs, and they were, accordingly, largely increased in number. This extension rendered necessary another improvement—the means of readily distinguishing one light from another. Although many suggestions have been made for doing this more effectually—some practicable, others not so, and some are in actual operation—this part of the science is far from being in a perfect state. Much remains to be done, before the mariner can be certain of determining, by its distinctive features, each light when seen.

The variety of lights that have been proposed and experimented on for lighthouse purposes is very great, particularly, we may mention, the Drummond, the electric, voltaic, &c., but few have stood the test of experience; and the lamps now in universal use are still but modifications of the original Argand burner.

Amongst the means for increasing the intensity of light, the use of reflectors is most important. In the year 1786, reflectors and oil lamps were first proposed at a meeting of the Scottish lighthouse commissioners. The first metallic reflectors used in the northern lighthouses were constructed by Mr. Thomas Smith, of Edinburgh. The figure was given to them by a plaster mould, and the cavity was afterwards filled in, by means of cement, with small facets of mirror-glass. This must have done its work very imperfectly, although the general figure was capable of considerable accuracy. In 1803, the first polished *metal* reflectors used in Scotland, were placed in Inch-Keith lighthouse; since then, various slight alterations and improvements have been made, but substantially, the system of illuminating lighthouses remains the same.

We cannot conclude this article without acknowledging our obligations in its preparation to the valuable paper on lighthouses, &c., by Mr. Findlay.

LIKE ARCS, in the projection of the sphere, the parts of lesser circles containing an equal number of degrees with the corresponding arcs of greater circles.

LIKE FIGURES, in geometry, such as have their angles equal, and the sides about the equal angles proportional.

LIKE SOLIDS, such as are contained under like planes.

LIMESTONE, a calcareous stone, which being sufficiently burned or calcined, falls into powder on the application of water; and being then mixed with water and sand in certain proportions, forms a strong cement.

Limestone is either pure or mixed. The best for the use of building is that which contains a certain portion of clay and iron. *See* CEMENT.

LIME-KILN, a kiln for the purpose of burning lime. Kilns for this purpose are constructed in a variety of ways, to save expense, or to answer to the particular nature of the fuel. *See* KILN.

LIME, *quick*, a term applied to lime in its most powerful or caustic state, before it has been rendered mild by the absorption of carbonic acid gas, or fixed air. *See* CEMENT-KILN.

LINE, (from the Latin, *linea*,) a quantity extended in length only. A line may be conceived to be formed by the motion of a point. Lines have no real existence except at the termination or terminations of the surface of a body: thus, a line is the junction of two surfaces, and therefore can have no thickness.

Lines are of two kinds, viz., *straight* or *curved*. Straight lines are all of the same species; the species of curves, which are infinite, are divided into *geometrical* and *mechanical*.

LINE, also denotes a French measure, containing the 12th part of an inch, or the 144th part of a foot.

LINE, *Equinoctial*, the common intersection of the equinoctial and the dial planes.

LINE, *Geometrical*, in perspective, any straight line in the geometrical or primary line.

Line, *Horary*, or Hour Lines, in dialing, the intersection of the hour-planes with the dial plane.

Line, *Horizontal*, a line parallel to the horizon. In perspective, it is the vanishing line of horizontal planes.

Line, *Vertical*, the intersection of a vertical plane with the picture, passing along the station-line.

Line, *Visual*, a ray of light reflected from the object to the eye.

Line of Direction, in mechanics, the line in which motion is communicated.

Line of Light, in light and shade, a line on the curved surface of a body, such that any point taken in it will be lighter than an adjacent point taken out of it indefinitely near.

Line of Measures, a term used by Oughtred to denote the line on the primitive circle, in which the diameter of any circle to be projected falls.

In the stereographic projection of the sphere, the line of measures is that in which the plane of a great circle perpendicular to the plane of projections, and the oblique circle which is to be projected, intersect the plane of projection; or, it is the common section of a plane passing through the eye and the centre of the primitive at right angles to any oblique circle to be projected, in which the centre and pole of such circle are to be found.

Line of Shade, in light and shade, a line on the curved surface of a body, formed by a tangent surface of rays from the luminary to that of the body.

Line of Station, the intersection of a plane passing through the eye perpendicular to the picture and to the geometrical or primary plane, with the primary plane itself.

Lines, *Division*, or *Gradation of*, the various proportions into which lines may be divided; as arithmetical proportion, geometrical proportion, the squares of the distances from the beginning, and harmonical proportion.

Lines of the Proportional Compasses, are those of lines, of circles, of polygons, of planes, and of solids.

Lines on the Plain Scale, are the following, viz., of chords, of sines, of tangents, of secants, of semi-tangents, and of equal parts.

Lines of the Sector, are the following, viz., of equal parts, of lines, of chords, of sines, of tangents, of secants, of polygons, of numbers, of hours, of latitudes, of meridians, of planes, and of solids.

LINEAR PERSPECTIVE, the title given by Brook Taylor to his two celebrated essays on perspective.

LINING, the covering of the interior surface of a hollow body. When the exterior surface is covered with any thin substance, the body is said to be *cased*.

Lining, in canal making, the thickness or coat of puddle sometimes applied to the bottoms and sides of canals, to prevent them from leaking.

Lining of a Wall, a timber boarding, the edges of which are either rebated or grooved and tongued. Shops are generally lined; as are likewise water-closets, to the height of five or six feet.

Lining-out Stuff, the drawing of lines on a piece of timber, board, or plank, so as to cut it into boards, planks, scantlings, or laths.

Linings of Boxings, for window-shutters, the wooden boards or wainscoted framings which form the backs of the recesses into which the shutters are depressed. In good work, the linings are not only grooved and tongued into the inside lining of the sash-frame, but also into the framed ground around the margin of the window, and inner surface of the wall.

Linings of a Door, the internal facings of joinery surrounding the aperture of a door, placed in the thickness, and at right angles to the face of the wall, through which the aperture is made. The linings which cover the sides of the door are called *jambs*, or *jamb-linings*, and that which covers the head is called the *soffit*.

Lining of a Sash Frame, the vertical pieces of wood, parallel to the surface of the wall. In good work, the linings are always grooved to receive the tongues in the pulley-piece.

LINTEL, (from the French, *linteau*,) a beam of timber over an aperture, for sustaining the superincumbent part above, and the soffit, whether of wood or plaster, underneath.

The number of timbers required to lintel an aperture depends on the thickness of the wall: their depth, or altitudinal dimension, consists, in general, of as many inches as there are feet in the horizontal dimension of the aperture under them. If the wall be solid, without apertures above, the depth should be still greater. Lintels should be laid close to each other.

Lintels, are also a species of wall-timbers, and which, with bond-timbers and wall-plates, are all called by the general name of Fir-in-Bond.

Lintels, in some old books on carpentry, are also called *wall-plates;* but the word is not now used in this sense unless the joisting or tie-beams rest upon it; and then it is both a lintel and a wall-plate.

LIST, (from the Saxon, *lystan*,) or Listelo, (Italian.) *See* Fillet.

LISTING, in carpentry and joinery, the act of cutting away the sap-wood from one or both edges of a board.

LOBBY, (from the German *laube*,) a small hall or waiting-room, or the entrance into a principal apartment, where there is a considerable space between it and a portico or vestibule, but the length or dimensions will not allow it to be considered as a vestibule or ante-room.

LOCK, (from the Saxon, *loc*) a well-known instrument used for fastening doors, chests, &c., generally opened by a key. The lock is reckoned the master-piece in smithery; a great deal of art and delicacy being required in contriving and varying the wards, springs, bolts, &c., and adjusting them to the places where they are to be used, and to the several occasions of using them. From the various structure of locks, accommodated to their different intentions, they acquire various names. Those placed on outer doors are called *stock-locks;* those on chamber-doors, *spring-locks;* those on trunks, *trunk-locks*, *padlocks*, &c. Of these the spring-lock is most considerable, both for its frequency and the curiosity of its structure. Its principal parts are the main-plate, the cover-plate, and the pin-hole: to the main-plate belong the key-hole, top-hook, cross-wards, bolt-toe, or bolt-knab, drawback-spring tumbler, pin of the tumbler, and the staples; to the cover-plate belong the pin, main-ward, cross-ward, step-ward, or dap-ward; to the pin-hole belong the hook-ward, main cross-ward, shank, the pot or bread-bow-ward and bit.

The principle on which all locks depend is the application of a lever to an interior bolt, by means of a communication from without; so that by means of the latter, the lever acts upon the bolt, and in such a manner as to secure the lid or door from being opened by any pull or push from without. The security of locks in general therefore depends on the number of impediments we can interpose betwixt the lever (the key) and the bolt which secures the door; and these impediments are well known by the name of *wards*, the number and intricacy of which alone are supposed to distinguish a good lock from a bad one. If these wards, however, in an effectual manner, preclude the access of all other instruments beside the proper key, it is still possible for a mechanic of equal skill with the lockmaker, to open it without the key, and thus to elude the labour of the other. The excellence of locks consists in the security they afford; and as numberless schemes are continually brought forward by designing men, to elude every contrivance of the most ingenious mechanics, the invention of a durable lock, so constructed as to render it impossible for any person to open it without its proper key, has ever been an object of considerable importance.

Lock, or Weir, in inland navigation, all those works of wood or stone, or of both combined, for the purpose of confining and raising the water of a river.

The term *lock*, or *pound-lock*, more particularly denotes a contrivance, consisting of two gates, or two pairs of gates, called the *lock-gates*, and a chamber between them, in which the surface of the water may be made to coincide with that of the upper or lower canal, according as the upper or lower gates are opened; by which means boats are raised or lowered from one level to another.

Lock Paddles, the small sluices used in filling and emptying locks.

Lock Sills, the angular pieces of timber at the bottom of the lock, against which the gates shut.

Lock Weirs, or Paddle Weirs, the over-falls behind the upper gates, by which the waste water of the upper pond is let down through the paddle-holes into the chamber of the lock.

LOCKER, a small cupboard.

LOCUS (Latin), in geometry, the line described by the intersection of two lines in motion.

LOFT, a raised gallery, or room in roof.

LOG HOUSES, the huts constructed by the Americans of the trunks of trees.

LOGARITHMS, are series of artificial numbers, so arranged with reference to a set of natural numbers, that the addition of the logarithms shall correspond with the multiplication of the natural numbers belonging to them; and subtraction of logarithms answers for division; while involution, or the raising of powers, is performed by the multiplication of logarithms; and evolution, or the extraction of roots, by the division of logarithms.

LOGEUM, that part of the theatre where were placed the chorus, and others who were not to take an active part in the performance.

LOGGIA, a gallery or avenue, with open colonnade or arcade, on one or both sides.

LOGISTIC SPIRAL, or Proportional Spiral, one whose radii are in continued proportion where the radii are at equal angles; or it may be defined, a spiral whose radii everywhere makes equal angles with the tangents.

LOMBARDIC ARCHITECTURE, a style of architecture prevalent in Italy from the commencement of the seventh to the thirteenth century; it succeeded the debased Roman, and forms the intermediate link between it and the Gothic. It derives its name from the circumstance of its prevalence during the supremacy of the Lombards in Italy, and not from any notion of its invention or introduction by that people, for they had no architecture of their own, as is evident from the fact of their being compelled to employ native artists in the construction of their works. The style is indeed nothing more than a natural and gradual development of Roman architecture; and the principles involved in it had already begun to manifest themselves ere the fall of the empire. This mode of building, as well as those which preceded and followed it, owe their existence to the invention and adaptation of the arch to constructive purposes; and as the latest exhibits this new principle perfected and fully developed, so does the second manifest an improvement to and more perfect development than the earliest.

The Lombards, during whose dynasty this style prevailed, established themselves in Italy at the close of the sixth century, and remained in undisturbed possession of the country for two hundred years, when it was wrested from them by Charlemagne, who in 774 put an end to that dynasty, and united Italy to the new western empire. Italy does not seem to have suffered much, but rather the reverse, from their government, and during their possession, the arts flourished and were cultivated with greater success than during the periods either immediately preceding or following. It is certain that they gave a great impetus to building, for during the two hundred years of their sway, the northern and central portions of Italy had become studded with churches and baptisteries, amongst which we may give as examples, San Michele, Pavia; San Thomaso in limine, near Bergamo, and the baptistery at Florence. The influence of the style does not seem, however, to have been much felt at Rome, for during all this period, we know of only one Lombardic building in that city, the church of San Giovanni é Paolo.

The change of dynasty in A. D. 774, does not appear to have had any very great effect upon the arts, during the existence of the Carlovingian line, but when that line became extinct, A. D. 875, the troubles caused by the disputed claims of rival princes in the north, and by the incursions of the Saracens in the south, greatly impeded the progress of architecture. Matters were not greatly improved by the government of the German emperors, for at this time Italy was distracted with discord and civil commotions. The Carlovingian dynasty ceased, A. D. 875, and the German emperors acquired sovereignty in Italy about the middle of the tenth century, during all which time, and for half a century longer, architecture made but little or no progress. When the arts again flourished in the eleventh century, some little alterations had been introduced into the style of architecture, which were again increased and multiplied in the twelfth. Many churches were built in the Lombardic style during these two centuries, but in the next the Pointed style began to make appearance, and partially superseded its predecessor; we say partially, for the Pointed style never took very deep root in Italy, nor were the features of the Round style ever entirely effaced.

The Lombardic style may be classed under the general title of Romanesque, which comprises the debased Roman and all those styles which emanated from it, until we come to the Pointed or Gothic, including the Byzantine and Lombardic, as also the Norman and Saxon, which are essentially Lombardic in character, and may be considered as forming a subdivision of that style. The last two, however, will not be considered in the present article, but will be treated of separately.

The style under consideration, was employed almost exclusively in ecclesiastical structures; to them therefore we must look for its characteristic peculiarities. It was the adaptation of the arch to purposes of construction, as we have before stated, which gave rise to the grand revolution in classical architecture; it was the various modifications of the same feature which gave origin to the subdivisions of the new system. Of these, the Lombardic is characterized by the constant use of the semicircular arch for the purposes of construction and decoration, and more especially by the excessive employment for the latter purpose in the exteriors of buildings. The external walls were frequently almost covered by a series of arcades rising in stories one above the other, on one or more sides, and sometimes all round the building. These were either blank arcades, that is, attached to the surface of the wall, and employed solely for ornament, or else they were detached and stood out from the wall, forming a sort of gallery or portico; they were more frequent in the façades of buildings than elsewhere, in which situation may sometimes be observed five or more tiers one above the other, as at Pisa cathedral, and in other examples, in which the front is literally covered with them. There is another peculiarity observable in the arrangement of these arcades, where they run under gables or raking cornices; for in such cases the arcades follow the line of the gable, the arches rising in succession one above another; and this is effected either by raising the shafts which support the arches on steps rising with the slope of the roof, or else by elongating the shafts as they approach the apex, their bases being upon the same horizontal line. These arches are supported on shafts, either plain or ornamented, with capitals and bases, the arches likewise being with or without archivolts: sometimes the arcade itself and the spandrels are elaborately enriched. This peculiar arrangement of arcades under the gable, forms a very decided characteristic of the style, such decoration being generally found in this part of the building, if nowhere else: another position in which it is commonly seen, is round the angular or semicircular apsides which were frequent at the east end of churches in this style; but we not unfrequently find the same decoration employed on the sides of the building, covering the entire surface of wall as at Pisa cathedral. Corbel-tables at the top of the walls immediately under the roof, are also very common, and these again follow the same rule as arcades when carried under a gable; they are generally formed of a series of very small arches, sometimes interlaced, so as to present a scolloped appearance underneath. Each story of a building is generally marked by a horizontal string-course.

The face of the wall, whether ornamented with arcades or left plain, but more especially in the latter case, is generally divided into panels as it were by pilasters or buttresses, if we may so term them, being carried vertically up the face of the building without interruption, and projecting slightly in front of the general surface of the wall. Such projecting strips of wall are generally plain, but sometimes very much ornamented, as in the front of San Michele at Pavia. They are very narrow in comparison to their height, except at the angles of buildings, where they are usually wider; they reach also from the top to the bottom of the building, breaking through horizontal cornices, arcades, and anything which comes in their way, all of which are for the most part stopped by them, except the corbel table into which they merge, the surfaces of both being flush. They certainly give an appearance of strength, especially when placed at the angles, and resemble buttresses to some extent, but probably were not intended to serve their purpose; they would appear to be added rather for ornament than for any other end, as they are too shallow to afford much real strength to the walls.

Pinnacles are by no means frequent, and when present have the appearance of being set on the part they rise above, from which they are divided by horizontal string-courses; they are also very low, and look more like pedestals than pinnacles.

Windows in this style are generally very narrow, and sometimes mere slits. They consist of one, two, or more lights divided by shafts, and having semicircular heads. Where there are more than two lights, the centre one is not unfrequently higher than the others, and the whole are often included under one larger arch. At a late period in the style we find wheel or circular windows common in the west façades; they are composed of spokes radiating from a centre, connected at the further extremities by small arches, and enclosed within a moulded circle. These windows were first introduced in this style, and though adopted in later styles, may be said to be characteristic of Lombardic architecture.

While windows were sparingly introduced, and of small dimensions, and at the same time seldom enriched, so as to contribute but slightly towards the embellishment of the buildings; doorways, on the other hand, became important features, and were much decorated. The aperture was mostly plain and square-headed, but it was enclosed in a recess formed by a series of arches standing one behind and within the other, and supported upon columns. The spandrel also above the openings, was sometimes enriched with sculpture. The dressing to the doorway was occasionally so deep as to be nearly as wide at the opening. The façade had frequently a central and two side doors.

The stone used in the construction of the walls, consisted of comparatively small blocks, but these were well tooled and put together. In the latter part of the eleventh century, the walls were composed of alternate courses of materials of different colours; sometimes stone alternating with marble, and sometimes marbles of different hues being employed in the same manner. The walls were often white and black, and sometimes red and brown. During the twelfth century, brick was in general use, but still preserved the same parti-coloured appearance, by alternating with stone or marble. It is not improbable that this practice was borrowed from the Saracens.

In the eleventh century, another feature of some importance and character was introduced, which was a projecting porch of imposing appearance, some such porches consisting of two stories in height. They had a large arched aperture, and were usually covered with a vaulted roof supported on pillars, of which the two foremost rested on the back of lions or other animals, a feature which is characteristic of the style. Some of these porches are of the most elaborate description.

In the interior of churches, the peculiarities of style are not so readily observed, but are to be sought for rather in matters of detail, which are equally observable on the exterior. The arrangement is much the same as in the preceding methods of building. The plan is usually if not universally cruciform, the intersection of the two arms of the cross being covered by an octagonal or circular dome, somewhat similar to the Byzantine practice; but the shape of the cross generally differs from the Byzantine, in having one of the arms longer than the other, whereas, in the other case, the arms are all of equal length. Hence one form is termed the Greek, the other the Latin cross. Here we observe a mixture of the Byzantine and Roman styles, the dome of the one and the ground plan of the other being combined, and this is not the only particular in which the combination of the two styles is observable; the triforia, which are common in Lombardic churches, are an emanation from the Byzantine, while a great many minor features are essentially Roman. The east end is for the most part terminated in an apse, either semicircular or octagonal, as are also occasionally the aisles. Crypts are seldom omitted. The windows, as we before observed, are of small dimensions, and hence the buildings have a somewhat gloomy appearance in the interior.

In matters of detail are to be found some of the principal characteristics of the style. The shape of the arch still remains for the most part semicircular, but other forms are also found; such are the horse-shoe, the trefoiled, and stilted arch, the last being by no means uncommon, especially in the external arcades which run beneath the gable. In some instances, the stilting is effected by raising the arch on one or more blocks or abaci, placed upon the capitals of the columns, and upon these blocks again are sometimes added small heads or masks, so as to fill up the space between the arches, and continue the vertical line of the columns. Such abaci are not ungraceful, for they give a greater appearance of strength to the construction, than if the arch sprung immediately from the capital; the practice of stilting also has its advantages, in adding to the importance of small arches, which being narrow, would appear depressed and heavy if mere semicircles. Large arches were mostly semicircular, and differed from those of the preceding period, inasmuch as they sprang directly from the columns, without the intervention of entablature or architrave. It is true this practice had been introduced once or twice in the Roman examples, but it was not by any means common, and even in cases where the entablature was omitted, there was usually a square block between the arch and the capital. Two or more arches are frequently included under one common arch, the smaller ones being separated by small shafts: the same arrangement is not uncommon in Byzantine architecture. Arches were very often perfectly plain, without archivolt mouldings of any kind, but not unfrequently finished with an archivolt, which consisted either of a simple moulding enclosing a plain band round the arch, or else divided into faciæ, and otherwise enriched. Arched corbel-tables were very frequently employed, and the arch used for every purpose of decoration. Compound arches, consisting of a series, placed in recession one behind and projecting beyond the other, are frequent in this style.

The bases of pillars were sometimes mere blocks, round at the summit, and square at the sides, but frequently moulded in rude imitation of the Attic base. Sometimes, as we observed in speaking of projecting porches, the pillars were supported on figures of animals, and this peculiarity is almost confined to this situation. but we have examples of it in other positions; at Worms' cathedral, an entire colonnade is supported in this manner. It has been suggested that the use of this kind of base was occasioned by the employment of materials and fragments taken from the ruins of more ancient edifices. where columns being found too short for their intended situation, were raised or stilted up by being set on other fragments, for which purpose remains of sculpture may have been adopted, either because they chanced to be at hand, or because considered more ornamental, and as adding richness to the column itself, and it is supposed that this irregularity, thus occasioned in the first instance, grew by degrees to be a matter of taste, and was adopted out of choice. This supposition is ingenious, and not without some show of reason on its side; but if such were indeed the case, it would seem strange that this practice was not adopted earlier, for it is a characteristic of late work, and seems to be almost peculiar to the projecting porches, which were not introduced for two centuries after the commencement of Lombardic architecture. The fact of such columns being almost invariably found in this situation, and seldom in any other, would give some weight to the supposition which discovers their origin and use in symbolism, the two lions being placed at the entrance as the guardians of the church, or else as representing the strength and vigilance of the church.

The shafts were of various shapes and proportions, they are by far the most frequently cylindrical, without being tapered, but some few examples of tapered shafts are to be found, which are probably of an early date. Instances of fancifully-shaped and decorated shafts are not uncommon, especially in the smaller columns, or such as are applied to merely ornamental purposes. Of these, some are polygonal in plan, some fluted or reeded, some twisted or cut into spiral grooves or mouldings, of which some consists of more than one slender shaft rising from a common base, and twisted round each other as they rise, and others of a single shaft twisted like a spiral: other examples again are zigzagged horizontally, and sculptured in various devices. Tall slender shafts are not unfrequently banded in the middle.

Capitals are of equal diversity, and sometimes there are scarcely to be found two capitals of the same design in one building. They were frequently formed of foliage; and these, as regards the general mass and outline, and also the decoration, bear some resemblance to the Corinthian: the foliage, however, is usually of a more stiff and formal character than the classic, more heavy, and not so graceful. Scroll-work is frequently introduced, as a means of ornamentation for capitals; monsters, too, and grotesque and other images, are so commonly used for this purpose, as to become characteristic of the style. Some capitals, however, are nearly plain, and these are often in the shape of an inverted cone, cut so as to present four flat faces, which are occasionally more or less ornamented. Monstrous imagery was very prevalent in this and other situations, until the eleventh century, when a more classical taste prevailed, and figures of dragons and demons gave way to sculpture of a more graceful design; this remark applies, however, only to the south of Italy.

The bulk of columns had no reference to the height, as we find pillars of all proportions, from the low, stunted shaft to the long, slender moulding, as it may be termed; the pilasters on the external walls are often so slender, in proportion to their height, as to have the appearance of mere strips; and half-columns of a similar proportion are not unfrequently carried up the internal walls, to support the vaulting. Columns are often single, especially when massive, but they are not unfrequently doubled in breadth or depth, and sometimes quadrupled. Compound piers, in lieu of single columns, are of very common occurrence, and serve to distinguish this from preceding styles; such arrangement is very usual where great strength is required, and clustered columns are not unfrequently placed against walls. Nook-shafts are common in doors, windows, and other apertures, as are also edge-shafts.

Buttresses are not employed in this style, unless indeed we choose to apply the term to the slightly projecting strips or pilasters which appear to divide the walls into panels.

There is one feature common to Lombardic churches, of which we have not taken notice; it is the campanile, or bell-tower, which was a common and picturesque addition. There is a remarkable difference in the design of these towers in the different parts of Italy; at Ravenna they are cylindrical, with a horizontal string-course at each floor, some of which are lighted by single round windows, others by clusters of two or three: they have low roofs. At Venice all the steeples are square, and without string-courses, each side being divided into two or three panels running uninterruptedly from base to top. At Rome such towers are square, but have horizontal string-courses, the divisions or stories between each two having a number of small arches with or without columns. These towers have low roofs.

Having now given a rapid sketch of the main features and peculiarities of the style under consideration, it will be well to give a short description of a few of the more remarkable examples executed in that style; and in this division, as well as in the preceding, we must express ourselves greatly indebted to the standard works of Gally Knight and Hope, on the subject, to which works we would also refer the reader for more detailed information and more copious illustrations. The former work is beautifully got up.

The church of San Michele, at Pavia, is of the basilican plan, and is provided with transepts; it measures 189 feet in length by 81 in extreme width, the nave being 45 feet wide. The chancel has a semicircular apse, and is approached by several steps, and beneath it is a crypt, a very common addition to Lombardic churches. Above the intersection of nave and transept rises a Byzantine cupola. "The walls of the building are of stone, massive and thick, and on the exterior are ornamented, with small open galleries, which follow the shape of the gable in front, and crown the semicircular apse. The portals are covered with imagery, nor are the ornaments confined to the portals. Bands enriched with imagery are carved along the whole of the front, and modillions are let into the walls. The windows are round-headed, and are divided by small pillars. The drum of the dome is enriched externally with two tiers of arcades.

In the interior, the arches on either side of the nave are supported by compound piers, all the capitals of which are enriched with capitals and symbols. Above the aisles, on each side of the nave, is a triforium, and, above it, the roof is vaulted in stone, but the pilasters which run up to support the vault are of later character than the older portions of the building, and confirm the impression suggested by the nature of the roof itself, that the present vaulted roof must have been substituted for an older roof of wood.

The plan of San Thomaso in limine is circular, and on the exterior, the walls are divided into compartments by pilasters, and have an arcaded corbel-table under the roof. A rectangular portion projects from the circle, and is terminated by a semicircular apse, which is decorated in a similar manner to the other part of the church. Above the circular part rises a dome, which is not supported by pendentives, but by a drum or circular wall rising above the roof: the whole is surmounted by a cupola. The windows throughout are small and insignificant. Internally, the drum of the dome is supported on eight pillars, which are simple, round, and stunted with capitals grotesquely carved; the arches spring immediately from the capitals. The walls are very thick.

The church of San Ambrogio, Milan, is a very good example. The plan is basilican, the arcade of the nave being supported on compound piers, above which runs an arcaded corbel-table, and above this again a triforium, the arches being supported on very stunted compound pillars. The roof is vaulted with the pointed arch, but this is of late date. The capitals of the arches are almost, in all cases, foliated, and there is considerable freedom from the monstrous imagery usually apparent. This is one of the few churches which retains the atrium, which consists of an arcade resting on a series of compound pillars with capitals, and covered with a roof, under which is an arcaded corbel-table.

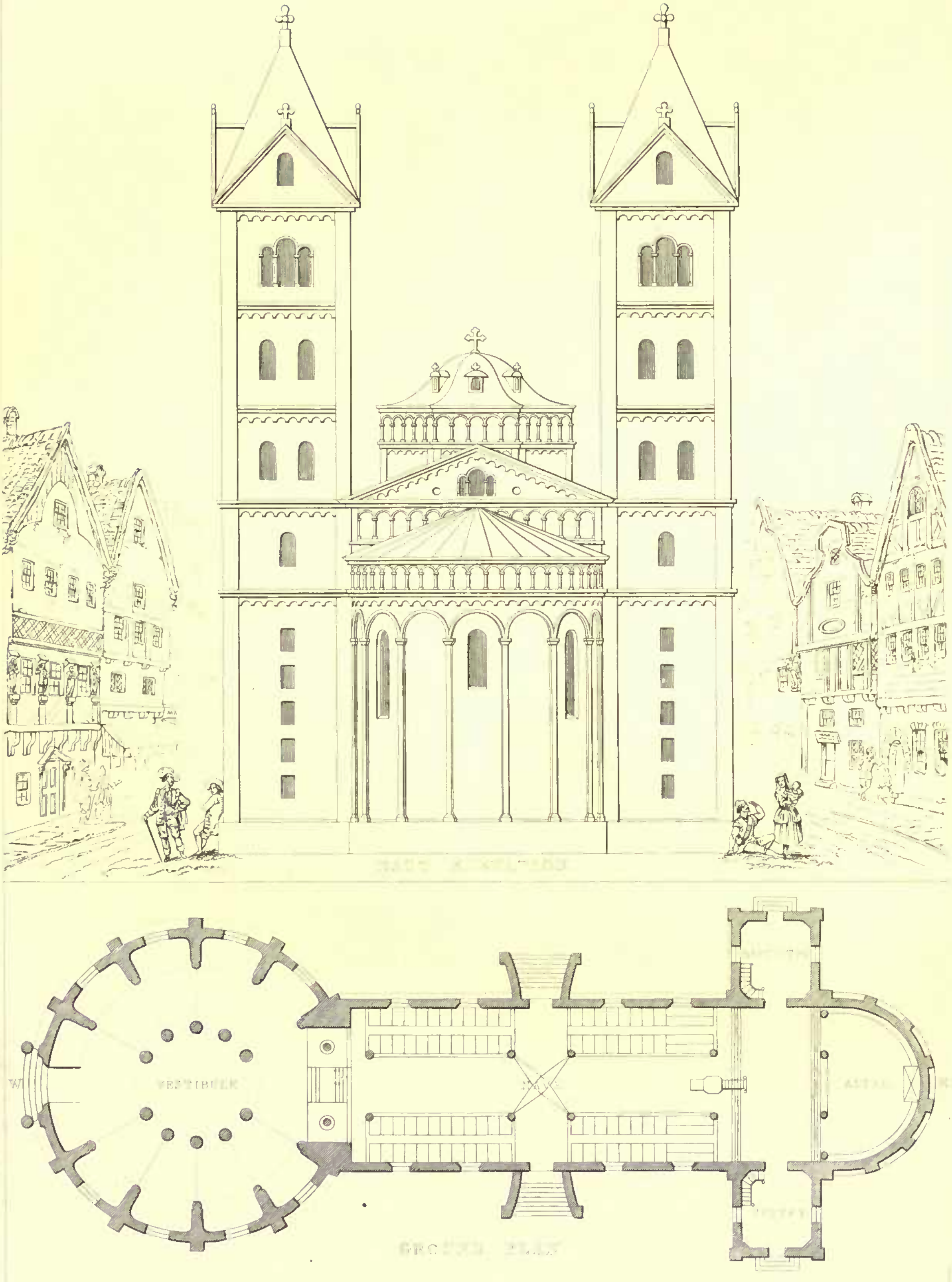
S. Geron's church presents a somewhat curious plan, consisting of a vast circular vestibule, with a rectangular nave behind it, terminating in a semicircular apse, on each side, and a little in front of which is a campanile. Above the circle rises an octagonal cupola, the supporting pillars of which are prolonged upwards in ribs, which, centering at the summit, meet at one point. Opposite the entrance, in the interior, are steps leading to the church, at the further end of which are steps leading to the apse or altar. In the baptistery and vestry are steps leading to the area between the two high square towers, and to the roof of the apse, over the semicircular east end, which is belted round, as well as the cupola, by galleries with small arches, and pillars on a panelled balustrade. The entrance-door at the vestibule has a square lintel, low pediment, and pointed arch, which are elegant, and the crypts show some remains of handsome mosaics; but the porphyry columns were carried away by the French. Several of the finishings in the interior are pointed.

The Cathedral of Pisa is a very remarkable building, erected during the latter half of the eleventh century; and although it presents to us features of the Lombard style on the exterior, in the interior the details approach more nearly to the Roman, the columns being all simple, and finished with Corinthian caps; the style, too, is throughout the interior more simple than that of Lombardic buildings in general. The plan is that of a Latin cross, having two aisles on each side of the nave transepts, and a cupola over the intersection. The colonnade on each side of the nave consists of 12 columns of a single block of marble, and of 24 feet 10 inches in height, and 2 feet 3 inches in diameter, with Corinthian capitals skilfully worked. The total height, including capitals and base, is 30 feet 10 inches. An architrave is carried all along the nave above the arches, which spring from the capitals, and above this is a triforium consisting of a series of arcades, each arch containing two arched apertures divided by a shaft with Corinthian capital. Above the triforium is a clere-story of semicircular-headed windows. The four aisles have also Corinthian columns, but they are much smaller, and raised on plinths. The walls are composed of alternate courses of red and white marble. The width of nave and four aisles is 106 feet, of the nave 41 feet, the total internal length 311 feet, and the width across the transepts 237 feet 4 inches; the width of the transepts, with its aisles, 58 feet, height of nave 91 feet, of transept 84, of aisles 35 feet. In the centre of the nave are four piers, from which rise four large arches supporting the elliptical cupola.

On the exterior, the entire church is raised upon a series of steps which gives increased grandeur to its magnificent elevation. The width of the western façade is no less than 116 feet, and its height 112 feet. It comprises five stories, of which the first or lowermost consists of seven arches supported by six Corinthian columns and two pilasters, the middle arch being larger than the others. There are three entrances or doorways in the central and alternate arches. The second story contains twenty-one arches supported by twenty columns and two pilasters. At the third story the façade contracts where the two aisles finish, and form two lateral inclined planes, whence towards the centre are columns with arches on them as below, but the columns on each side under the inclined planes gradually diminish in height. The fourth story is contracted, and contains only eight arches similar to those below. The fifth forms the pediment, and consists likewise of eight arches, the columns which support them gradually diminishing in height as they recede from the centre. The sides all round the building have two orders of pilasters one above the other. The roof of the nave is supported externally by a wall decorated with columns and arches; and the drum of the cupola is enriched with eighty-eight columns and arches, each of which is surmounted by a pediment.

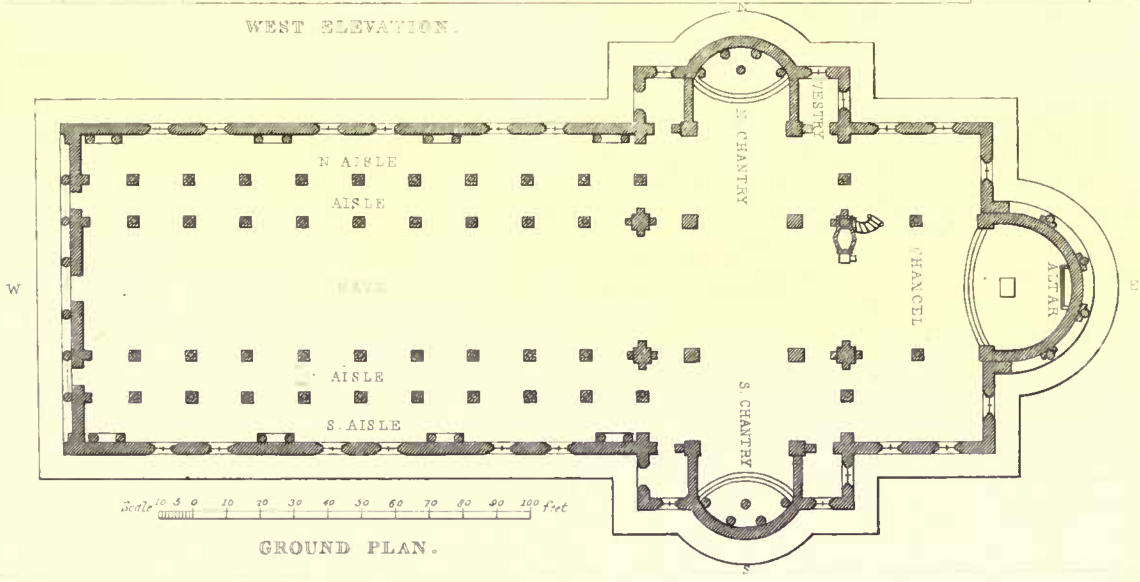
The Duomo Modena is a good specimen of the Lombard style, and belongs to the close of the 11th century. "External arcades ornament both the west end and the great semicircular apse. In the interior, monsters and grotesque images are still retained in the capitals of some of the pillars. But a feature which is not found in old Lombard churches, may be remarked here, in a large projecting porch two stories in height, which advances before the principal entrance; and in the lions, on the backs of which the pillars of the porch repose. Though projecting porches were an essential part of the primitive churches, they seem to have been abandoned

ST GERON'S CHURCH AT COLOGNE. LOMBARD SACRED ARCHITECTURE.



PISA CATHEDRAL, LOMBARD ARCHITECTURE.

WEST ELEVATION.



GROUND PLAN.

R. Brown Arch.

under the Lombard dynasty, and not to have been resumed till the 11th century, when they became universal. The lions are symbolical. They were intended to represent the strength and vigilance of the church. At a later period, the animals which were introduced in the porches, often represented the arms of the state to which the building belonged." "On either side of the nave of this cathedral are galleries. Under the chancel there is a lofty crypt, the chancel being approached by several steps, as at San Miniato and other churches."

The campanile is 315 feet high, and is one of the four towers of which the north of Italy has reason to be proud. The date is uncertain, but the tower must have been complete in the early part of the 13th century. The upper portion is of later date.

S. Zenone, Verona, was finished in the latter part of the 12th century, and forms a fair specimen of the style. The plan is that of a Latin basilica, without transepts. The walls are constructed of alternate courses of marble and brick, but the façade is entirely of marble. The entire face of the building is divided vertically into bays by long strips or pilasters, and horizontally by arched corbel-tables and arcades. The façade is remarkable for containing one of the earliest specimens of wheel-windows, as also for a very rich projecting porch, profusely decorated with sculpture. There is a good bas-relief within the portal over the door. The pillars as usual rest on the backs of lions. In the interior the nave is divided from the aisles by an arcade, each bay containing two arches supported by a central single shaft, and by compound shafts at the sides, so that pillars and piers alternate in the length of the arcade; the capitals of the single shafts still retain the monstrous imagery of an earlier period. There is no triforium, and the clere-story is lighted by small windows. There is a campanile, of somewhat later date.

San Michele, Lucca, is a very rich example of the Lombard style, but although the building itself is of early date, the enrichments are much later. The principal feature is the enriched façade which was added in 1188 by Guidetto. It is somewhat similar to the façade of Pisa cathedral, but of a more florid description. The lower story is ornamented with attached arcades, and above this are four tiers of galleries with detached arcades, the shafts, capitals, archivolts, and spandrels being enriched with elaborate carving. In the third gallery is a rose window. The sides of the building contain two tiers of arcades, of which the upper one was added at a late period, and is of very good design.

For further particulars on this subject, we must refer to Saxon, Norman, and Romanesque Architecture.

LONGIMETRY, (from the Latin, *longus*, length, and Greek, *μετρέω*, *to measure*,) the art of measuring lengths, accessible and inaccessible.

LOOP HOLES, the small narrow windows in castellated buildings, from which to discharge missiles. They were usual near entrances, and sometimes on the merlons of the battlement. They are sometimes in the shape of a cross, and usually have a circular enlargement at top and bottom, and sometimes in the middle. When splayed, they were also used to give light.

LORME, PHILIBERT DE, an eminent French architect, born at Lyons, in the early part of the sixteenth century. He went to Italy when he was but fourteen years of age, to study the art for which he seemed to have a natural taste, and there his assiduity attracted the notice of Cardinal Cervino, afterwards Pope Marcellus II., who took him into his palace, and assisted him in his pursuits. He returned to France in 1536, and was the means of banishing the Gothic taste in buildings, and substituting in its place the Grecian. He was employed by Henry II., for whom he planned the Horseshoe at Fontainebleau, and the châteaus of Anet and Meudon. After the demise of that king, he was made inspector of the royal buildings by Catharine de Medicis; and, under her direction, he repaired and augmented several of the royal residences, and began the building of the Tuileries. In 1555 he was created counsellor and almoner in ordinary to the king; and, as a recompense for his services, he was presented with two abbacies. These honours, it is said, made him arrogant, which occasioned the poet Ronsard to satirize him in a piece, entitled *La Truelle Crossée*, or "The Croziered Trowel." De Lorme took his revenge, and shut the garden of the Tuileries against him; but the queen took part with the poet, and severely reprimanded the reverend architect. De Lorme died in 1577. He published *Dix Livres d' Architecture*, and *Nouvelles Inventions pour bien Bâtir et à petits Frais*.

LOUVRE, a turret or lantern on the top of roofs, open to the interior of the building, and also to the external air by means of apertures in the sides. They were formerly used for carrying off the smoke, when the hearth was in the centre of the hall; probably also for ventilation in general.

LOZENGE, (from the French,) a quadrilateral figure of four equal sides with oblique angles.

Lozenge Moulding, a moulding in the shape of a lozenge, common in Norman work.

LUCULLEUM MARMOR, a hard stony kind of marble, of a good fine black, and capable of an elegant polish, but little regarded from its want of variegations. When fresh broken, it is seen to be full of small but very bright shining particles, appearing like so many small spangles of talc. It had its name from the Roman consul Lucullus, who first brought it into use in that city. It is common in Italy, Germany, and France. We have much of it imported, and our artificers call it the *Namur marble*; the Spaniards call it *marble of Buga*.

LUFFER BOARDING, a series of boards placed in an aperture so as to admit air into the interior, but to exclude rain. It is frequently used in lanterns. A very celebrated one is that upon the church of St. Martin Outwich, in Bishopsgate street, opposite the City of London Tavern. The plan is circular, and the apertures four in number, with pilasters between them.

LUNE, or Lunula, (from the Latin, *luna*, the moon,) the space between two unequal arcs of a circle.

LUNETTE, (French,) apertures in a cylindric, cylindroidic, or spherical ceiling, the head of the aperture being also cylindric or cylindroidic, as the upper lights in the nave of St. Paul's Cathedral.

LUTHERN, (from the Latin *lucerna*, light or lantern,) a kind of window over the cornice in the roof of a building, standing perpendicularly over the naked of the wall, and serving to illuminate the upper story.

The French architects distinguish them into various forms, as square, semicircular, bull's eyes, flat arches, and Flemish.

LYCH-GATE, or Lich-Gate, a covered gate at the entrance of church-yards, at which the bier was rested.

LYING PANELS, those in which the fibres of the wood are placed horizontally.

M.

MACHICOLATIONS, openings made through the roofs of portals to the floor above, or in the floors of projecting galleries, for the purposes of defence, by pouring through them boiling lead, pitch, &c., upon the enemy. In the galleries they are formed by the parapet, or breast-work, being set out on corbels beyond the face of the wall, the spaces between that open throughout are the machicolations. From its striking appearance, the corbelled parapet was frequently used where machicolations were not required for the purposes of defence, and the apertures so called were omitted. Machicolations do not appear to have been used earlier than the end of the twelfth century.

MACHINE, signifies anything used to augment or to regulate moving forces or powers; or it is any instrument employed to produce motion, in order to save either time or force. The word is of Greek origin, and implies *machine*, *invention*, *art;* it is therefore properly applied to any agent, in which these are combined, whatever may be the strength or solidity of the materials of which it is composed. The term *machine* is, however, generally restricted to a certain class of agents, which seem to hold a middle place between the most simple tools or instruments, and the more complicated and powerful engines; this distinction, however, has no place in a scientific point of view; all such compound agents being generally classed under the term *machines*, the simple parts of which they are compounded being termed MECHANICAL POWERS.

Machines are again classed under different denominations, according to the agents by which they are put in motion. the purposes they are intended to effect, or the art in which they are employed, as—*Electric*, *Hydraulic*, *Pneumatic*, *Military*, *Architectural*, &c., Machines.

The maximum effect of machines, is the greatest effect which can be produced by them. In all machines, working with a uniform motion, there is a certain velocity and a certain load of resistance that yield the greatest effect, and which are therefore more advantageous than any other. A machine may be so heavily charged, that the motion resulting from the application of any given power will be only sufficient to overcome it; and if any motion ensue, it will be very trifling, and the effect small. Again, if the machine is very lightly loaded, it may give great velocity to the load; but, from the smallness of its quantity, the effect may still be very considerable, consequently between these two loads there must be some intermediate one that will render the effect the greatest possible. And this is equally true in the application of animal strength, as in machines, and both have been submitted to strict mathematical investigation, the former being founded on numerous experiments and observations on the best method of applying animal strength, and the measure of it when applied in different directions.

MADERNO, CHARLES, an eminent Italian architect, born at Bissona, in Lombardy, in 1556. He went at a very early age to Rome, where his uncle, Dominico Fontana, was at that time in full employment as an architect. His genius for sculpture became manifest, and he was placed with an artist in that branch of the fine arts. His progress in modelling was such as led his uncle to confide to him the management of some buildings then in hand, which he executed with so much skill, that he was advised to devote himself entirely to architecture. On the death of Sixtus V., Maderno was appointed to design and execute the magnificent tomb for his interment. The public works which were carried on under Clement VIII. were chiefly committed to the care of this artist, and so high was his reputation in the succeeding pontificate, that, on the succession of Paul V. in 1605, he was appointed to finish the building of St. Peter's; his plans being preferred to those of eight competitors, and the work was placed under his direction. He was afterwards employed upon the pontifical palace on the Quirinal mount. Another work, for which he is celebrated, was the raising a fine fluted column found in the ruins of the Temple of Peace, and placing it on a marble pedestal in the square of St. Maria Maggiore. His genius was by no means confined to architecture, he was sent by the pope on a commission to examine the ports of the Ecclesiastical States, and afterwards surveyed the lake of Perugia, and surrounding country, in order to divert the inundations of the river Chiana. He was consulted upon most of the great edifices undertaken in his time in France and Spain, as well as in the principal towns of Italy. His last work of consequence was the Barberini palace of Urban VIII., which he did not live to complete. He died of the stone in 1629, when he had attained to the age of seventy-three. He had seen ten popes, by most of whom he had been regarded with favour.

MAGAZINE, *Powder*, a building constructed for keeping large quantities of powder. These magazines were formerly towers erected in the town-walls; but many inconveniences attending this situation of them, they are now placed in different parts of the town. They were at first constructed with Gothic arches; but M. Vauban, finding these too weak, constructed them in a semicircular form, of the following dimensions: 60 feet long within, and 25 broad; the foundation 8 or 9 feet thick; and 8 feet high from the foundation to the spring of the arch; the floor about two feet from the ground, to prevent damp; and consequently six feet for the height of the story.

The thinnest part, or haunch of the arch, is three feet thick, and the arch made of four lesser ones one over the other, the outside of the whole terminating in a slope to form the roof; from the highest part of the arch to the ridge is eight feet, which makes the angle somewhat greater than ninety degrees; the two wings, or gable ends, are four feet thick, raised a little higher than the roof, as is customary in other buildings: the foundations are five feet thick, and as deep as the nature of the ground required. The piers, or long sides, are supported by four counterforts, each six feet broad, and four feet long, and their interval twelve feet; between the intervals of the counterforts are air-holes, in order to keep the magazine dry, and free from dampness; the dices of these air-holes are commonly a foot and a half every way, and the vacant round them three inches, the insides and outsides being in the same direction. The dices serve to prevent an enemy from throwing fire in to burn the magazine; and, for a farther precaution, it is necessary to stop these holes with several iron plates, that have small holes in them like a skimmer, otherwise fire might be tied to the tail of some small animal, and so drive it in that way; this would be no hard matter to do, since, where this precaution had been neglected, egg-shells have been found within, that have been carried there by weasels.

To keep the floor from dampness, beams are laid lengthwise, and to prevent these beams from being soon rotten, large stones are laid under them; these beams are eight or nine inches square, or rather ten high and eight broad, which is better, and eighteen inches distant from each other; their interval is filled with dry sea-coal, or chips of dry stones; over these beams are others laid crosswise, four inches broad and five high, which are covered with two-inch planks.

M. Belidor would have brick walls made under the floor, instead of beams, and a double floor laid on the cross-beams; but the plan above described is, we think, preferable.

To give light to the magazine, a window is made in each wing, which is shut up by two shutters of two or three inches thick, one within and the other without it; that which is on the outside is covered with an iron plate, and is fastened with bolts, as well as that on the inside. These windows are made very high, for fear of accidents, and are opened by means of a ladder, to give air to the magazine in fine dry weather.

There is likewise a double door, made of strong planks, the one opens on the outside, and the other within; the outside one is also covered with an iron plate, and both are locked by a strong double lock; the store-keeper has the key of the outside, and the governor that of the inside: the door ought to face the south nearly, if possible, in order to render the magazine as light as can be, and that the wind blowing in may be dry and warm. Sometimes a wall of ten feet high is built round the magazine about twelve feet distant from it to prevent anything from approaching it without being seen. Mr. Muller has proposed some alterations, by way of improvement, in M. Vauban's construction.

If large magazines are required, the piers or side walls which support the arch should be ten feet thick, seventy-two feet long, and twenty-five feet high; the middle wall, which supports the two small arches of the ground floor, eight feet high, and eighteen inches thick, and likewise the arches: the thickness of the great arch should be three feet six inches, and the counterforts, as well as the air-holes, the same as before. Magazines of this kind should not be erected in fortified towns, but in some inland part of the country near the capital, where no enemy is expected.

It has been observed, that after the centres of semicircular arches are struck, they settle at the crown and rise up at the haunches; now, as this shrinking of the arches must be attended with ill consequences, by breaking the texture of the cement after it has been partly dried, and also by opening the joints of the voussoirs at one end, Dr. Hutton proposed to remedy this inconvenience, with regard to bridges, by the arch of equilibration; and as the ill effect is much greater in powder magazines, he also proposed to find an arch of equilibration for them also; and to construct it when the span is twenty feet, the pitch or height ten, which are the same dimensions as those of the semicircle, the inclined exterior walls, at top, forming an angle of 113°, and the height of their angular point above the top of the arch equal to seven feet; this curious question was answered, in 1775, by the Rev. Mr. Wildbore, and the solution of it may be found in Hutton's *Miscellanea Mathematica*.

MAHOGANY, the beautiful reddish-brown coloured wood, of which household furniture is now chiefly made. It is a native of the warmest parts of America and the West Indies. It thrives in most soils in the tropical climates, but varies in texture and grain according to the nature of the soil. On rocks it is of a smaller size, but very hard and weighty, of a close grain, and beautifully shaded; while the produce of the low and richer lands is observed to be more light and porous, of a paler colour, and open grain; and that of mixed soils, to hold a medium of both.

The mahogany-tree is stated to be of very rapid growth, and makes a very fine appearance. Its trunk often exceeds 40 feet in length, and 6 feet in diameter. The Honduras mahogany is cut down at two periods in the year; that is, at Christmas, and in the autumn; the trees are cut off at about 12 feet from the ground, the workmen having a stage to work upon. The trunk furnishes wood of the largest dimensions; but for ornamental purposes, the branches are preferable, the grain in them being closer and the veins more variegated. Mahogany was first brought to London in the year 1724.

In a dry state, mahogany is very durable, and not subject to worms. It does not last long when exposed to the weather. It is a kind of wood that would make excellent timbers for floors, roofs, &c., but on account of its price its use is chiefly confined to furniture and doors for rooms, for which purposes it is the material most in use. It is sometimes used for some parts of window-frames, and for sashes, but from its not standing the weather well, it is not so fit for these purposes. It has also been extensively used in the framing of machinery for cotton-mills, &c.

The variety called Spanish mahogany, is imported from Cuba, Jamaica, Hispaniola, and some other of the West India islands, and in smaller logs than the Honduras. The size of the logs is in general about 20 to 26 inches square, and about 10 feet in length. The Spanish mahogany is close-grained and hard, generally of a darker colour than Honduras; free from black specks, and sometimes strongly figured; and its pores appear as if chalk had been rubbed into them.

The Honduras mahogany is imported in logs of a larger size, that is, from 2 to 4 feet square, and 12 or 14 feet in length; sometimes planks have been got 6 or 7 feet wide. The grain of the Honduras kind is generally very open, and often irregular, with black or gray spots. The veins and figures are frequently very fine and showy; the best kind is that which is most free from gray specks, and of a fine golden colour. It holds with glue better than any other wood.

The cohesive force of a square inch of Spanish mahogany is 7560 pounds, and of Honduras mahogany 11475 pounds.

The weight of the modulus of elasticity of mahogany, is 1,255,500 pounds, for a square inch for Spanish; and 4,593.000 for Honduras. The weight of a cubic foot of mahogany is from 35 to 53 pounds. Representing the—

Strength of oak by 100, that of Span. mahog. is	67; of Honduras is	96.
Stiffness of oak by 100,	73;	93.
Toughness of oak by 100	61;	99.

MAIN COUPLES. *See* Couples.

MALLET, (from the Latin *malleus*) a large kind of hammer, made of wood, much used by artificers who work with a chisel, as stone-cutters, masons, carpenters, joiners, &c.

MANSARD ROOF. *See* Curb Roof. The word is derived from Mansart, the inventor.

MANSART, FRANCIS, an eminent French architect, born at Paris in 1598, was son of the king's carpenter, and received those instructions which led him to eminence as an architect, from the celebrated Gautier; but for the high rank to which he attained in his profession, he was indebted to the force of his own genius. His taste and judgment, united with a fertile imagination and sublime ideas, enabled him to equal the greatest masters in his plans; he was, however, too apt to alter his designs, and even, in aiming at perfection, to demolish what was already not only well done, but scarcely to be surpassed. This character was the means of preventing him the honour of finishing the fine abbey of Val-de-Grace, founded by Anne of Austria, which he had commenced in 1645, and which, when raised to the first story, the queen put into other hands, to prevent its destruction by him who had reared it. He was employed by the president Longueil to build his great Château des Maisons, near St. Germain's; and, when a considerable part of it was erected, he pulled it down again, without acquainting the master with his intentions. After this, it is to his credit, that he finished it in a very noble style, and it is reckoned one of the finest architectural monuments of that age. A better idea cannot be given of his character than this: Colbert applied to him for a design of the principal front of the Louvre, and Mansart produced many sketches of great beauty, but when told he must fix upon one to be invariably followed, if approved, he declined the business. His last work was the portal of the Minims in the Place Royale; he died in 1666, at the age of sixty-nine. He is known as the inventor of a particular kind of roof, called the *mansarde.* He had a nephew, Jules-Hardouin, who was also eminent in his profession as an architect, and was educated by his uncle. He became a favourite of Louis XIV., and was enabled, under his patronage, to realize a large fortune. Some of his principal works were the Château de Clugny, the palace of Versailles, the house of St. Cyr, the gallery of the Palais Royal, the places of Louis-le Grand and des Victoires, and the dome and finishing of the Invalides. He died suddenly at Marly, in the year 1708.

MANSION, (from the Latin *mansio*, an inn) a dwelling-house, or habitation, especially in the country. Among the ancient Romans, *mansio* was a place appointed for the lodging of the princes, or soldiers, in their journey; and in this sense we read *primum mansionem*, &c. It is with us most commonly used for the lord's chief dwelling-house within his fee, otherwise called the capital messuage, or manor-place: and mansion-house is taken in law for any house or dwelling of another, in case of committing burglary, &c.

MANTLE-TREE, or MANTEL-TREE, (from the Welsh) the lower part of the breast of a chimney; formerly consisting of a piece of timber, laid across the jambs, for supporting the breastwork; but, by a late act of parliament, chimney-breasts are not to be supported by a wooden mantle-tree, or turning piece, but by an iron bar, or brick or stone arch.

MARBLE, a variety of lime-stone, of so compact a texture as to admit of a beautiful polish. The different kinds of marble are infinite, therefore any attempt to describe them in detail would necessarily occupy much more space than we can allow to this article: they all agree in being opaque, excepting the white, which becomes transparent when cut into thin pieces. In the Borghese palace, at Rome, are some specimens of marble exquisitely white, so flexible, that if poised horizontally on any resisting body placed on a plane, a salient curve will be formed by the two ends touching the plane. A similar property is acquired in a small degree by statuary marbles exposed to the action of the sun, which no doubt weakens the adhesion of the particles. It is this which frequently occasions the exfoliation of projecting parts, and the artist would do well to ascertain, by experiments, the kind of marble that has the least tendency to this desiccation.

The greater part of the quarries, which supplied the ancients with marble, are entirely unknown; in the Napoleon Museum are preserved the most exquisite specimens of many of them, the grand repositories of which are consigned to oblivion, unless chance should guide some penetrating eye to their dark recesses.

Da Costa, in his "Natural History of Fossils," gives a large catalogue of marbles, disposed in a methodical order, which we shall follow in the following brief notices of this extensive subject:—

Division I.—Marbles of one plain colour.

Section 1.—Black marbles. Most of these contain bitumen, and are fetid when bruised.

Examples.—The Namur Marble, the marble of Ashford in Derbyshire, Dent in Yorkshire, near Crickhowell, Tenby, Kilkenny, &c. The marble, anciently called Marmor Luculleum, and now Nero Antico.

Section 2.—White Marbles.

Examples.—The marble of Poros, in which the Laocoon and Antinous are executed; the Carrara marble, of finer grain, much used in modern sculpture; the Skye marble, noticed by Dr. MacCulloch; that of Inverary, Assyut, Blair Athol, &c.

Section 3.—Ash and gray marbles.

Examples.—A beautiful marble, of compact oolitic texture, at Orelton, near the Clee Hills, in Shropshire, deserves mention.

Section 4.—Brown and red marbles.

Examples.—The Rosso Antico, a rival to which, at least in colour, has been found on the estate of the Duke of Devonshire, near Buxton. The mottled brown marble of Beetham Fell, near Milnthorp, is of good quality.

Section 5.—Yellow marbles.

Example.—The Giallo Antico. Siena marble, also dug at Mafra, near Lisbon. That used in ancient Rome is said to be from Numidia.

Section 6.—Blue marbles.

Example.—Near St. Pons, in Languedoc.

Section 7.—Green marbles.

Example.—The Marmor Lacedæmonicum of Pliny. It is dug near Verona.

Division II.—Marbles of two colours.

Section 1.—Black marbles, variegated with other colours.

Example.—Near Ashburton, in Devonshire; Torbay, in the same county; Bianco, or Nero Antico, the African Breccia of the ancients; Giallo e Nero Antico.

Section 2.—White marbles, variegated with other colours.

Example.—Marble imported from Italy. Marbles of this general character occur in Siberia; at Plymouth; at Killarney; in Sweden, &c.

Section 3.—Ash and gray marble, variegated with other colours. These are very numerous, and occur in various parts of Europe.

Section 4.—Brown and red marbles, variegated with other colours.

Section 5.—Yellow marbles, variegated with other colours.

Section 6.—Green marbles, variegated with other colours.

Example.—Egyptian marbles. The Marmor Tiberium and Augustum of Pliny; some Verde Antico, as that dug near Susa, in Piedmont; the beautiful marble of Anglesey (called Mona marble); the marble of Kolmerden, in Sweden.

Division III.—Marbles variegated with many colours.

Example.—Some of the Plymouth marble; the beautiful brocatello, or brocade marble, of Italy and Spain.

Marbles containing shells, corals, and other extraneous bodies.

In this division of marbles, the British islands are rich. Some of the Plymouth, Ashburton, and other Devonian limestones, are extremely beautiful, from the abundance of fine corals exquisitely preserved in them; the crinoidal marbles of Flintshire, Derbyshire, and Garsdale in Yorkshire, are elegant examples of the carboniferous limestone; the shell marbles of Rance, Northamptonshire, Buckingham, Whichwood Forest, Stamford, Yeovil, may be noticed from the oolitic rocks; that of Petworth and Purbeck, from the Wealdon strata, has been extensively used by the architects of the middle ages. In general, the working of the English marbles is costly, and their use limited.

Marble, *Polishing of.* The art of cutting and polishing marble was, of course, known to the ancients, whose mode of proceeding appears to have been nearly the same with that employed at present; except, perhaps, that they were unacquainted with those superior mechanical means which now greatly facilitate the labour, and diminish the expense of the articles thus produced.

An essential part of the art of polishing marble is the choice of substances by which the prominent parts are to be removed. The first substance should be the sharpest sand, so as to cut as fast as possible, and this is to be used till the surface becomes perfectly flat. After this the surface is rubbed with a finer sand, and frequently with a third. The next substance after the finest sand is emery, of different degrees in fineness. This is followed by the red powder called tripoli, which owes its cutting quality to the oxide of iron it contains. Common ironstone, powdered and levigated, answers the purpose very well. This last substance gives a tolerably fine polish. This, however, is not deemed sufficient. The last polish is given with putty. After the first process, which merely takes away the inequalities of the surface, the sand employed for preparing it for the emery should be chosen of a uniform quality. If it abounds with some particles harder than the rest, the surface will be liable to be scratched so deep as not to be removed by the emery. In order to get the sand of uniform quality, it should be levigated and washed. The hard particles, being generally of a different specific gravity to the rest, may by this means be separated. This method will be found much superior to that of sifting. The substance by which the sand is rubbed upon the marble is generally an iron plate, especially for the first process. A plate of an alloy of lead and tin is better for the succeeding processes, with the fine sand and emery. The rubbers used for the polishing, or last process, are of coarse linen cloths, such as hop-bagging, wedged tight into an iron plane. In all these processes, a constant supply of small quantities of water is absolutely necessary.

The sawing of marble is performed on the same principle as the first process of polishing. The saw is of soft iron, and is continually supplied with water and the sharpest sand. The sawing, as well as the polishing of small pieces, is performed by hand. The large articles, such as chimney-pieces and large slabs, are manufactured by means of machinery, working by water or steam.

Several patents have been taken out for sawing and polishing marble. In 1822, Sir James Jelf patented a combination of machinery for cutting any description of parallel mouldings upon marble slabs, for ornamental purposes; in which tools, supplied with sand and water, are made to traverse to and fro. Mr. Tullock obtained a patent, in 1824, for improvements in machinery for sawing and grooving marble; and in 1829, Mr. Gibbs, also, for an invention for working ornamental devices in marble.

MARGIN (from the Latin *margo*) of a door or shutter, the surface surrounding the frame between the moulding and the extreme arris which terminates the face.

MARQUETRY (from the French), inlaid work; a curious kind of work, composed of pieces of hard fine wood, of different colours, fastened in thin slices on a ground, and sometimes enriched with other matters, as tortoise-shell, ivory, tin, and brass.

There is another kind of marquetry made, instead of wood, of glasses of various colours; and a third, where nothing but precious stones and the richest marbles are used; but these are more properly called *mosaic work.* The art of inlaying is very ancient, and is supposed to have passed from the east to the west, among the spoils brought by the Romans from Asia. Indeed, it was then but a simple thing; nor did it arrive at any tolerable perfection till the fifteenth century, among the Italians. It seems finally to have arrived at its height in the seventeenth century, among the French.

MASONRY, the art of preparing stones, so as to tooth or indent them into each other, and form regular surfaces, either for shelter, convenience, or defence: as the habitations of men, animals, the protection and shelter of goods, &c.

The chief stone used in London is Portland, which comes from the island of Portland, in Dorsetshire. It is used for public edifices, not only in ornaments, mouldings, and strings, but in all the exterior parts. In private buildings, where brickwork predominates, it is used in strings, window-sills, balusters, steps, copings, &c. It must be observed, however, that under a great pressure it is apt to splinter or flush at the joints, and for this reason the joints cannot be made so close as many other kinds of stones will admit of. When it is recently quarried it is soft, and works easily, but acquires great hardness in length of time. The cathedral of St. Paul, Westminster-bridge, and almost every public edifice in London, are constructed wholly, or in part, of Portland stone.

Purbeck stone comes from the island of Purbeck, in Dorsetshire also. It is mostly employed in rough work, as steps and paving.

Yorkshire stone is also used where strength and durability are requisite, as in paving and coping. Ryegate stone is used for hearths, slabs, and copings.

In Edinburgh, a very fine stone, called Craigleith, brought from a village of the same name, in the neighbourhood of that city, is most commonly used in the construction of edifices. They have also very good stone from the Hails quarry, but rather inferior in point of colour.

The Craigleith quarry produces two kinds of rock, one of a fine cream or buff colour, called the *liver rock*, which is almost unchangeable, even though exposed in a building to the weather.

The city of Glasgow is built of various kinds of stone, the best of which are the Possel and the Lord President's quarry; most other kinds are not only perishable, but liable to change their colour.

In the north of England, stone fit for hewn work is chiefly of a reddish colour. There is a very good white stone, however, in the vicinity of Liverpool, of which several of the public buildings are constructed.

All the stone fit to be squared, or squared and rubbed smooth, for the use of building, is mostly composed of sand. The stone used for the same purposes in the south of England is, in some parts, entirely chalk, and in other parts limestone. The Bath and Oxfordshire stone has so little grit in its texture, as to be wrought into mouldings with planes, as in joinery, and the surfaces are finished with an instrument called *a drag.*

Marbles, with regard to their contexture and variegation of colour, are almost of infinite variety: some are black, some white, some of a dove colour, and others beautifully variegated with every kind of rich colour. The best kind of white marble is that called *statuary*, which, when cut into thin slices, becomes almost transparent, a property the others do not possess. The texture of marble, with regard to working, is not generally understood, even by the best workmen, though upon sight they frequently know whether it will receive a polish or not. Some marbles are easily wrought, some are very hard, and other kinds resist the tools altogether.

Mortar is another principal material used in cementing the stones of a building. The reader who wishes to obtain a full knowledge of this department of masonry, may consult the articles CEMENT, MORTAR.

Wherever it is intended to build upon, the ground must be tried with an iron crow, or with a hammer: if found to shake, it must be pierced with a borer, such as is used by well-diggers; and if the ground generally prove to be firm, the loose or soft parts, if not very deep, must be excavated until a solid bed appears.

If the ground prove soft in several places to a great depth under apertures, and firm upon the site of the piers, inverted arches must be turned under the apertures, so that if the foundation sink, the arches may resist the re-action of the ground: and then the whole wall will sink uniformly, or descend in one body. And even where the ground is of a uniform texture, it is always eligible to turn inverted arches under apertures, wherever there is a part of a wall carried up from the foundation to the sill of that aperture: it is from neglect in this circumstance, that the sills of windows in the ground-stories of buildings are frequently broken; indeed it is seldom or never otherwise.

Arches adequate to this purpose should rather be of a parabolic form than circular, the figure of the parabola being better adapted to preserve an equilibrium than the arc of a circle, which is of uniform curvature. If unfortunately the soft parts of the ground prove to be the site of the piers, and, consequently, the hard places under the apertures, piers should be built under the apertures, and arches suspended between the piers, with their concave side towards the trench, as usual.

The use of concrete has, however, made a great change in the art of preparing foundations, the general practice now being to excavate the trenches for the footings of the walls, and put in a bed of concrete, on which is laid the masonry.

For more information upon this subject, see the articles FOUNDATION, CONCRETE.

In walling, the bedding joints have most commonly an horizontal position in the face of the work, and this disposition ought always to take place when the top of the wall terminates in an horizontal plane or line. In bridge building, and in the masonry of fence-walls upon inclined surfaces, the bedding-joints on the face sometimes follow the upper surface of the wall or terminating line.

The footings of stone-walls ought to be constructed of large stones, which, if not naturally nearly square, should be reduced by the hammer to that form, and to an equal thickness in the same course; for if the beds of the stones in the foundation taper, the superstructure will be apt to give way, by resting upon mere angles or points with inclined beds instead of horizontal. All the vertical joints of any upper course should break joint, that is, they should fall upon the solid part of the stones in the lower course, and not upon the joints.

When the walls of the superstructure are thin, the stones which compose the foundation may be so disposed, that their length may reach across each course, from one side of the wall to the other. In thicker walls, where the difficulty is greater in procuring stones of sufficient length to reach across the foundation, every second stone in the course may be a whole stone in the breadth, and each interval may consist of two stones of equal breadth, that is, placing header and stretcher alternately. But when those stones cannot be had conveniently, from one side of the wall, lay a header and stretcher alternately, and from the other side lay another series of stone in the same manner, so that the length of each header may be two-thirds, and the breadth of each stretcher one-third of the breadth of the wall, and so that the back of each header may come in contact with the back of an opposite stretcher, and the side of that header come in contact with the side of the header adjoining the said stretcher. In broad foundations, where stones cannot be procured for a length equal to two-thirds of the breadth of the foundation, build the work so that the upright joints of any course may fall on the middle of the length of the stones in the course below, and so that the backs of each stone in any course may fall upon the solid of a stone or stones in the course below.

The foundation should consist of several courses, of which each superior course should be of less breadth than the inferior one, say four inches on each side in ordinary cases, and the upper course project four inches on each side of the wall. The number of courses must be regulated by the weight of the wall, and by the size of the stones of which the foundation consists.

A wall, which is built of unhewn stone, is called a *rubble-wall*, whether with or without mortar. Rubble work is of two kinds, coursed and uncoursed. Coursed rubble is that of which the stones are gauged and dressed by the hammer, and thrown into different heaps, each heap containing stones of the same thickness; then the masonry is laid in courses or horizontal rows, which may be of different thicknesses. The uncoursed rubble is that where the stones are laid promiscuously in the wall, without any attention to placing them in rows. The only preparation which the stones undergo, is that of knocking off the sharp angles with the thick end of the scabbling hammer.

Walls are most commonly built with an ashlar facing, and backed with brick or rubble work. Brick backings are common in London, where brick is cheaper; and stone backing in the north of England and in Scotland, where stone is plentiful. Walls faced with ashlar, and backed with brick or uncoursed rubble, are liable to become convex on the outside from the greater number of joints, and from the greater quantity of mortar placed in each joint, as the shrinking of the mortar will be in proportion to the quantity; and therefore a wall of this description is much inferior to one of which the facing and backing are of the same kind, and built with equal care, even though both sides were uncoursed rubble, which is the worst of all walling. Where the outside of a wall is an ashlar facing, and the inside coursed rubble, the courses of the backing should be as high as possible, and set with thin beds of mortar. In Scotland, where stone abounds, and where perhaps as good ashlar facings are constructed as any in Great Britain, the backing of their walls most commonly consists of uncoursed rubble, built with very little care. In the north of England, where the ashlar facings of walls are done with less neatness, they are much more particular in the coursing of their backings. Coursed rubble and brick backings are favourable for the insertion of bond timbers: but in good masonry, wooden bonds should never be in continued lengths, as in case of fire or rot, the wood will perish, and the masonry, being reduced by the breadth of the timber, will be liable to bend at the place where it is inserted. When it is necessary to have wall timber for the fastening of battens for lath and plaster, the pieces of timber ought to be built with the fibres of the wood perpendicular to the surface of the wall, or otherwise in unconnected short pieces, not exceeding nine inches in length.

In an ashlar facing, the stones generally run from twenty-eight to thirty inches in length, twelve inches in height, and eight or nine inches in thickness. Although both the upper and lower beds of an ashlar, as well as the vertical joints, should be at right angles to the face of the stone, and the face-bed and vertical joints at right angles to the beds in an ashlar facing, where the stones run nearly of the same thickness, it is of some advantage, in respect of bond, that the back of the stone be inclined to the face, and that all the backs thus inclined should run in the same direction, as this gives a small degree of lap in the setting of the next course; whereas, if the backs were parallel to the front, there could be no lap where the stones run of an equal depth in the thickness of the wall. It is of some advantage likewise to select the stones, so that a thicker one and a thinner one may follow each other alternately. The disposition of the stone in the next superior course should follow the same order as in the inferior course, and every vertical joint should fall as nearly as possible in the middle of the stone below.

In every course of ashlar facing, with brick or rubble backing, *thorough-stones*, (as they are technically termed,) should be introduced, and their number should be proportioned to the length of the course, and every such stone of a superior course should fall in the middle of every two similar stones in the course below; this disposition of bonds should be strictly attended to in all long courses. Some wallers, in order to show or demonstrate that they have introduced sufficient bonds in their work, choose their bond-stones of greater length than the thickness of the wall, and knock or cut off their ends afterwards. This method is far from being eligible, as the wall is not only liable to be shaken by the force applied to break the end of the stone, but the stone itself is apt to be split.

In every pier where the jambs are coursed with the ashlar in front, every alternate jamb-stone ought to go through the wall, with its beds perfectly level. If the jamb-stones are of one entire height, as is frequently the case when architraves are wrought upon them, and upon the lintel crowning them, in the stones at the ends of the courses of the pier which are to adjoin the architrave jamb, every alternate stone ought to be a thorough-stone; and if the piers between the apertures be very narrow, no other bond-stones will be necessary in such short courses. But where the piers are wide, the number of bond-stones must be proportioned to the space; thorough-stones must be particularly attended to in the long courses below and above windows.

Bond-stones should have their sides parallel, and of course be perpendicular to each other, and their horizontal dimension in the face of the work should never be less than the vertical one. All the vertical joints, after receding about three quarters of an inch from the face with a close joint, should widen gradually to the back, and thereby form hollow wedge-like figures for the reception of mortar and packing. The adjoining stones should have their beds and vertical joints filled with oil putty from the face to about three-quarters of an inch inwards, and the remaining part of the beds with well-prepared mortar. Putty cement will stand longer than most stones, and will even remain prominent when the stone itself is in a state of dilapidation from the influence of the corroding power of the atmosphere. It is true that in all newly-built walls cemented with oil putty, the first appearance of the ashlar work is rather unsightly, owing to the oil of the putty disseminating itself into the adjoining stones, which makes the joints appear dirty and irregular: but this disagreeable effect is soon removed; and if care has been taken to make the colour of the putty suitable to that of the stone, the joints will hardly appear, and the whole work will seem as if one piece. This is the practice in Glasgow, but in London and in Edinburgh fine water putty is used instead of it.

All the stones of an ashlar facing should be laid on their natural beds. From a neglect of this precaution, the stones frequently flush at the joints, and this disposition of the laminæ sooner admits the corrosive power of the atmosphere to take effect.

In building walls or insulated pillars of very small horizontal dimensions, every stone should have its bed level, and without any concavity in the middle; because if the beds are concave, when the pillars begin to sustain the weight of the fabric, the joints will in all probability flush. It ought likewise to be observed, that every course of masonry of such piers ought to consist of one stone.

An arch, in masonry, is a part of a building suspended over a given plan, supported only at the extremities, and concave towards the plan.

The supports of an arch are called the *spring walls*.

The whole of the under surface of the arch opposite to the plan is called the *intrados* of the arch; and the upper surface is called the *extrados*.

The boundary line or lines of the intrados or those common to the supports and the intrados, are called the *springing lines* of the arch.

A line extending from any point in the springing line on one side of the arch, to the springing line on the opposite side of the arch, is called the *chord* or *span* of the arch.

If a vertical plane be supposed to be contained by the span and the intrados of the arch, it is called the *section of the hollow* of the arch.

The vetrical line drawn on the section from the middle of the spanning line to the intrados, is called the *height* of the arch, as also the *middle line* of the arch; and the part of the arch at the upper extremity of this line is called the *crown* of the arch.

Each of the curved parts on the top of the section, between the crown and either extremity of the spanning line, is called the *haunches* or *flanks* of the arch.

The section of almost every given arch used in building has the following properties: the upper part is one continued curve, concave towards the span, or two curves forming an interior angle at the crown, both concave towards the spanning line. Every two vertical lines on the section equidistant from each extremity, and parallel to the middle line, are equal.

The foregoing definitions and propositions not only apply to arches with level bases, but also to arches which stand upon inclined bases.

When the base of the section or spanning line is parallel to the horizon, the section will consist of two equal and similar parts, so that if one were conceived to be folded upon the other, the boundaries of both would coincide.

Arches, whose intrados is the surface of a geometrical solid that would fill the void, are variously named, according to the figure of the section of that solid perpendicular to the axis, as *circular*, *elliptical*, *cycloidal*, *catenarian*, *parabolical*, &c.

Arches of the circular kind have two distinctions, viz., the *semicircular*, and those of segments less than a semicircle; the latter are called *scheme* or *skene* arches.

There are also *pointed*, *composite*, *lancet*, or *Gothic* arches, which are formed in the face of the wall, or in sections parallel thereto, with the intrados of the arch.

When the extremities of an arch rise from supports at unequal heights, it is called a *rampant* arch.

When vertical lines are drawn upwards, through each extremity of the spanning line, so as to cut off equal and similar parts of the intrados, the arch is called a *horse-shoe* arch, or *moresque* arch. Hence, in this kind of arch, the spanning line is less than any other line or chord drawn parallel to the span, but under the top of each of the vertical lines.

When the upper line or side of an arch is parallel to the under line or side, it is called an *extradossed* arch.

A simple vault is an interior concavity extended over two parallel opposite walls, or over all the diametrically opposite parts of one circular wall. An arch or vault is frequently understood as synonymous; but the distinction which we shall here observe is, that an arch, though it may be extended over any space, has a very narrow intrados, not exceeding four or five feet; whereas a vault may be extended to any limit more than four or five feet. Thus we frequently say an arch in a wall, but we never say a vault in a wall; though nothing is more common than to say a vaulted apartment, a vaulted room, a vaulted cellar, &c. So that a vault, as Sir Henry Wotton has observed, is an extended arch; we shall therefore apply *arch* to the head of the aperture in a wall which shows curvilinear intersections with the faces of the wall, and the word *vault* to arched apartments. We frequently, however, call the stone-work suspended over an apartment an arch as well as a vault; so that every vault is an arch, but every arch is not a vault.

The intrados of a simple vault is generally formed of the portion of a cylinder, cylindroid, sphere, or spheroid, never greater than the half of the solid; and the springing lines which terminate the walls, or where the vault begins to rise, are generally straight lines parallel to the axis of the cylinder, or cylindroid, or the circumference of a circle or ellipsis.

A circular wall is generally terminated with a spherical vault, which is either hemispherical, or a portion of a sphere less than a hemisphere.

A vaulted apartment, surrounded by an elliptic wall, is generally covered with a spheroidal vault, which is either a hemispheroid, or a portion less than a hemispheroid.

A conic surface is seldom employed in vaulting; but when the vault is to have this kind of intrados, the intrados should be the half of a cone with its axis in a horizontal position, or a whole cone with its axis in a vertical position.

All vaults which have a horizontal straight axis, are called *straight vaults.*

Besides what we have already denominated an arch, the concavities which two solids form at an angle, are called *an arch.*

If one cylinder pierce another of a greater diameter, the arch is called a *cylindro-cylindric arch;* the cylindro being applied to the cylindric part which has the greater diameter, and the cylindric to that which has the less.

If a cylinder pierce a sphere of greater diameter than the cylinder, the arch is called *a sphero-cylindric arch;* and, on the contrary, if a sphere pierce a cylinder of greater diameter than the sphere, the arch is denominated *a cylindro-spheric arch.*

If a cylinder pierce a cone, so as to make a complete perforation through the cone, two complete arches will be formed, called *cono-cylindric arches;* and, on the contrary, if a cone pierce a cylinder, so as to make the interior concavity through the cylinder a complete conic surface, the arch is called *a cylindro-conic arch.*

If a straight wall be pierced with a cylindric aperture quite through, two arches will be formed, called *plano-cylindric arches.*

Every species of arches is thus denoted by two preceding words; the former ending in *o*, signifying the principal vault or surface cut through, and the latter in *ic*, signifying the kind of aperture which pierces the wall or vault.

When two cylindric vaults, or two cylindroidic vaults, or a cylindric or cylindroidic vault, pierce each other, and also their axis, so that the diameter of each hollow may be the same, when measured perpendicular to a plane passing through the axis of both surfaces, the figure so formed is called a *groin;* but for more particular information on this point see the article GROIN.

The formation of stone arches, in various cases, has always been looked upon as a most curious and useful acquisition to the operative mason, or to the architect, or other person who is appointed to superintend the work. In order to remove the difficulties experienced in the construction of cylindric or cylindroidic arches, both in straight and circular walls, we shall here show an example of each.

First, let it be required to construct a semi-cylindroidic arch, cutting a straight wall with its axis oblique to the surface of the wall, but parallel to the horizon.

Plate I. Figure A.—Let A B C D be the plan of the aperture, A D and B C being the plan of the jambs, and A B and D C the plan of the sides of the wall; produce D A and C B to G and F; draw the straight line I G M F E at right angles with A G and C F; bisect G F at M; draw M H K perpendicular to C F; make M H equal to the height of the intrados of the arch, and describe the semi-ellipsis G H F, which is the section of the intrados of the arch; make G I, H K, and F E, equal to the breadth of the beds of the arch-stone, and describe the semi-ellipsis I K E, which is the section of the extrados of the arch. Now, suppose the distances between the joints around the intrados of the arch to be all equal, and all the joints to tend to the centre M; divide the semi-ellipsis into such an odd number of equal parts, that each part may be in breadth equal to what is intended for the thickness of the stones at that part; produce E I to S, and extend the whole number of these parts from O to S; and through the points of division draw lines perpendicular to G S, or parallel to A G. Through all the points of division of the ellipsis G H F, draw lines parallel to G A to meet A B; then take the lengths of all the parts of the lines so drawn that are terminated by G F and A B, as follows, viz., make the first line on the left of G A equal to the first on the right of G A, and the point *b* will be obtained; make the second on the left of G A equal to the second on the right of G A, and the point *c* will be obtained; proceed in this manner, until all the other points are obtained; then a curve being drawn through all the points A, *b*, *c*, *d*, &c. to T, will give the one edge of the envelope of the intrados of the arch; and by producing the perpendiculars erected upon G S to the points *e*, *f*, *g*, &c., and making the several distances *b e*, *c f*, *d g*, &c. equal to A D or B C, the points D, *e*, *f*, *g*, &c. to U, will give the other edge of the envelope by tracing a curve through them; then A *b c d*, *b c f e*, *c d g f*, &c. are the soffits of the stones.

To find any bevel which the joints on the face of the arch makes with that on the intrados.

Let *p q* be one of the joints tending to the centre, M, of the section of the arch; with the radius M G describe an arc, G N O, cutting *p q* at N; draw N P parallel to G A, cutting A B at P; draw P Q parallel to F G, cutting G A at Q; draw M L parallel to G A, cutting A B at L, and join L O; then Q L M is the bevel required. In the same manner may all the remaining bevels be found.

Again, let *p q r s* be the section of an arch-stone; then making two bevels, one to *q p s*, and the other to *r s p*, will be all the bevels that are necessary for that stone. Having obtained the several bevels, we shall now proceed to work the arch-stone, whose section is *p q r s:* first work the lower bed of the stone corresponding to the joint *p q*, then draw a

Fig. A.

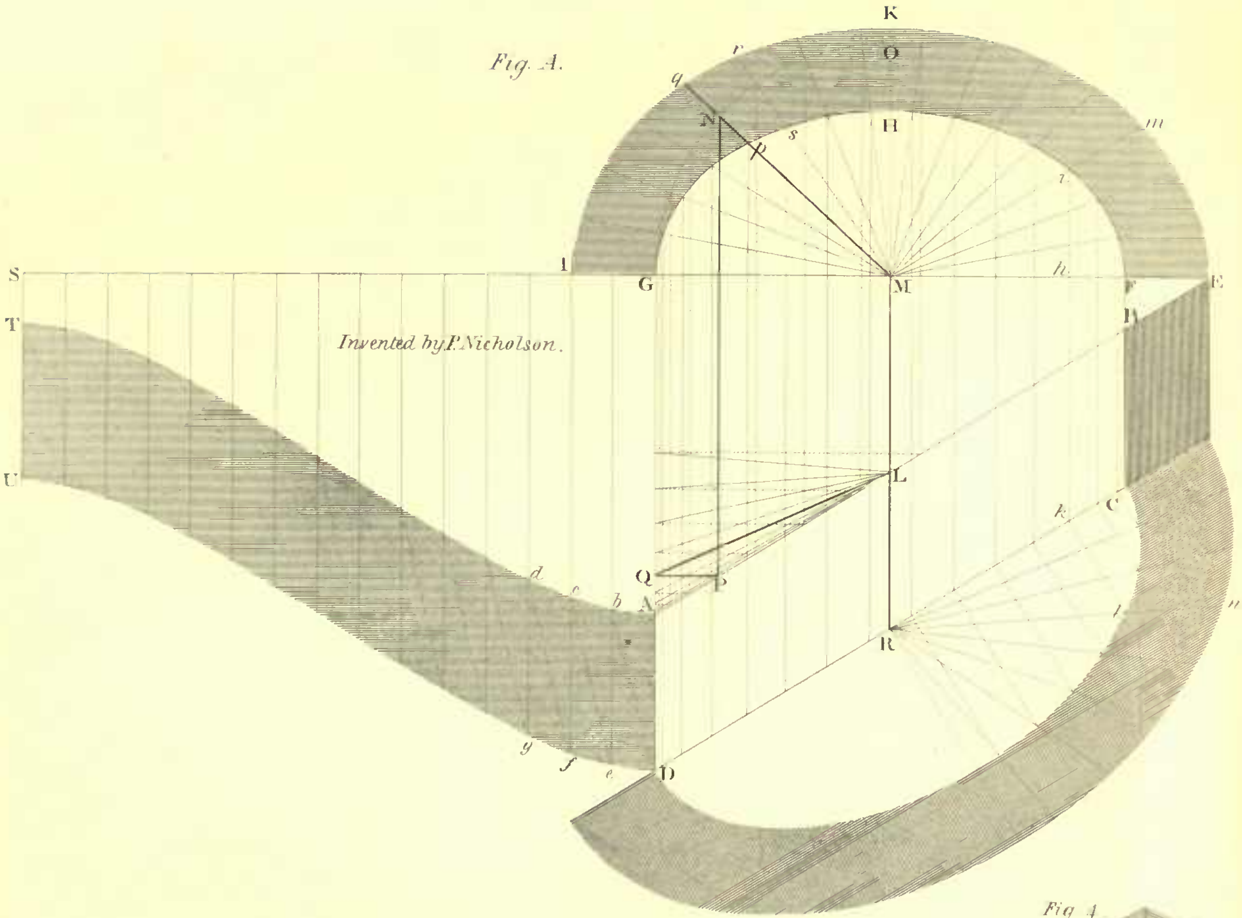


Fig. 1.

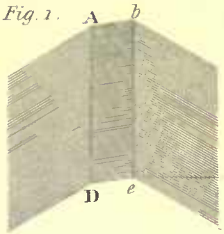


Fig. 2.

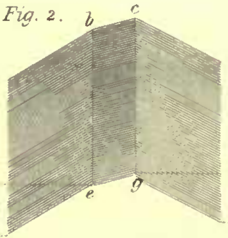


Fig. 3.

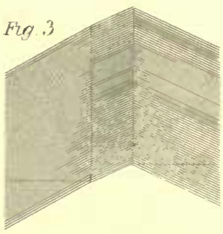
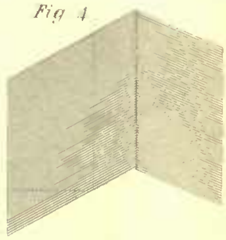


Fig. 4.



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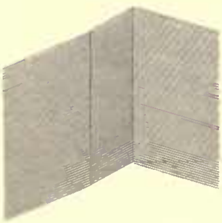


Fig. 6.

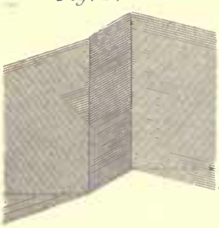


Fig. 7.

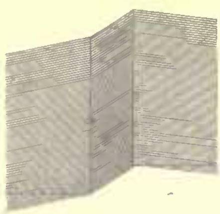
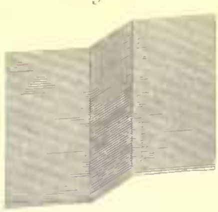
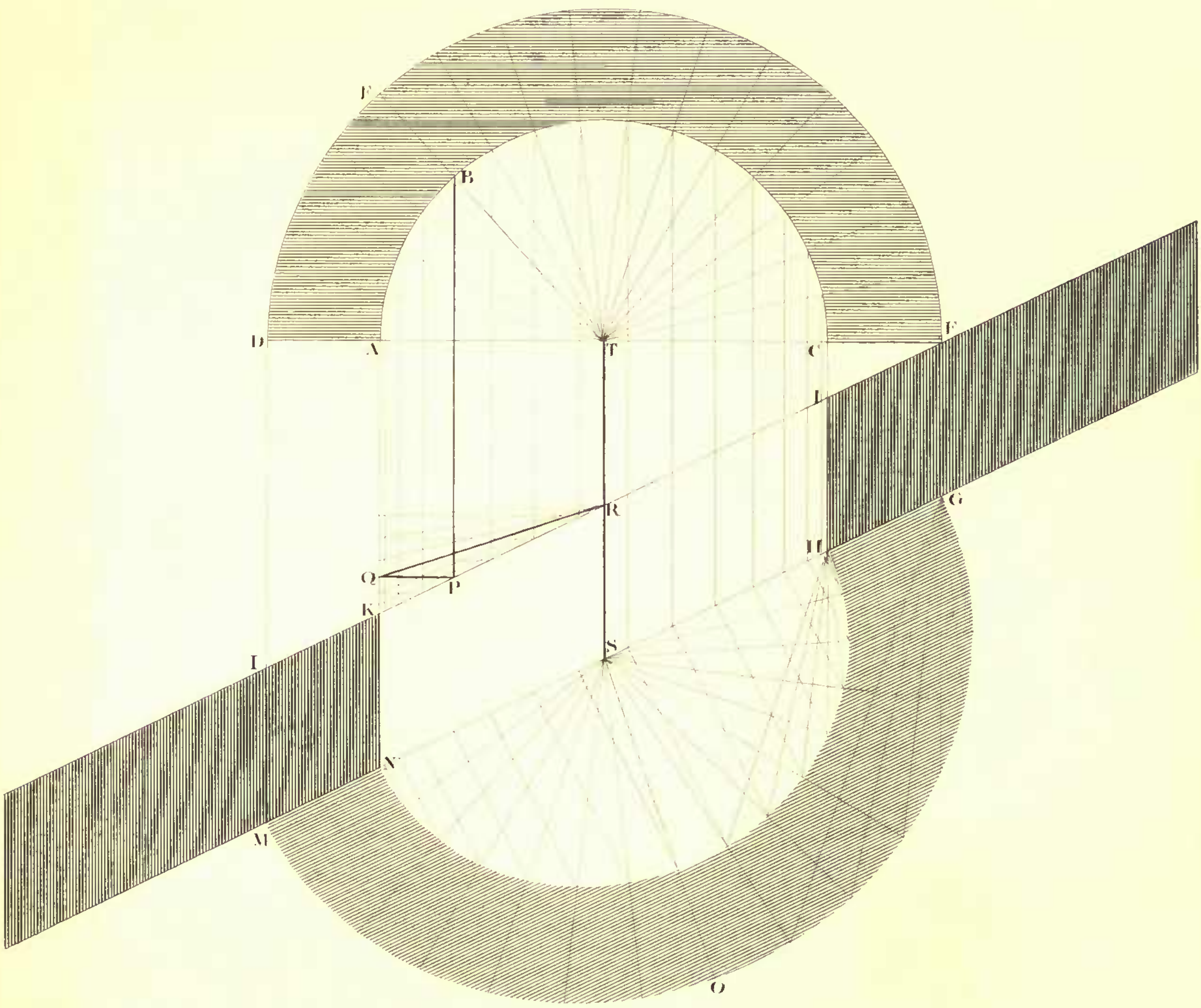


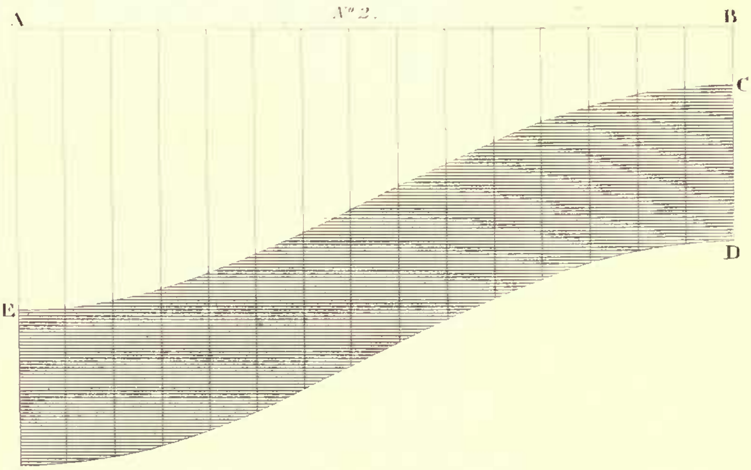
Fig. 8.



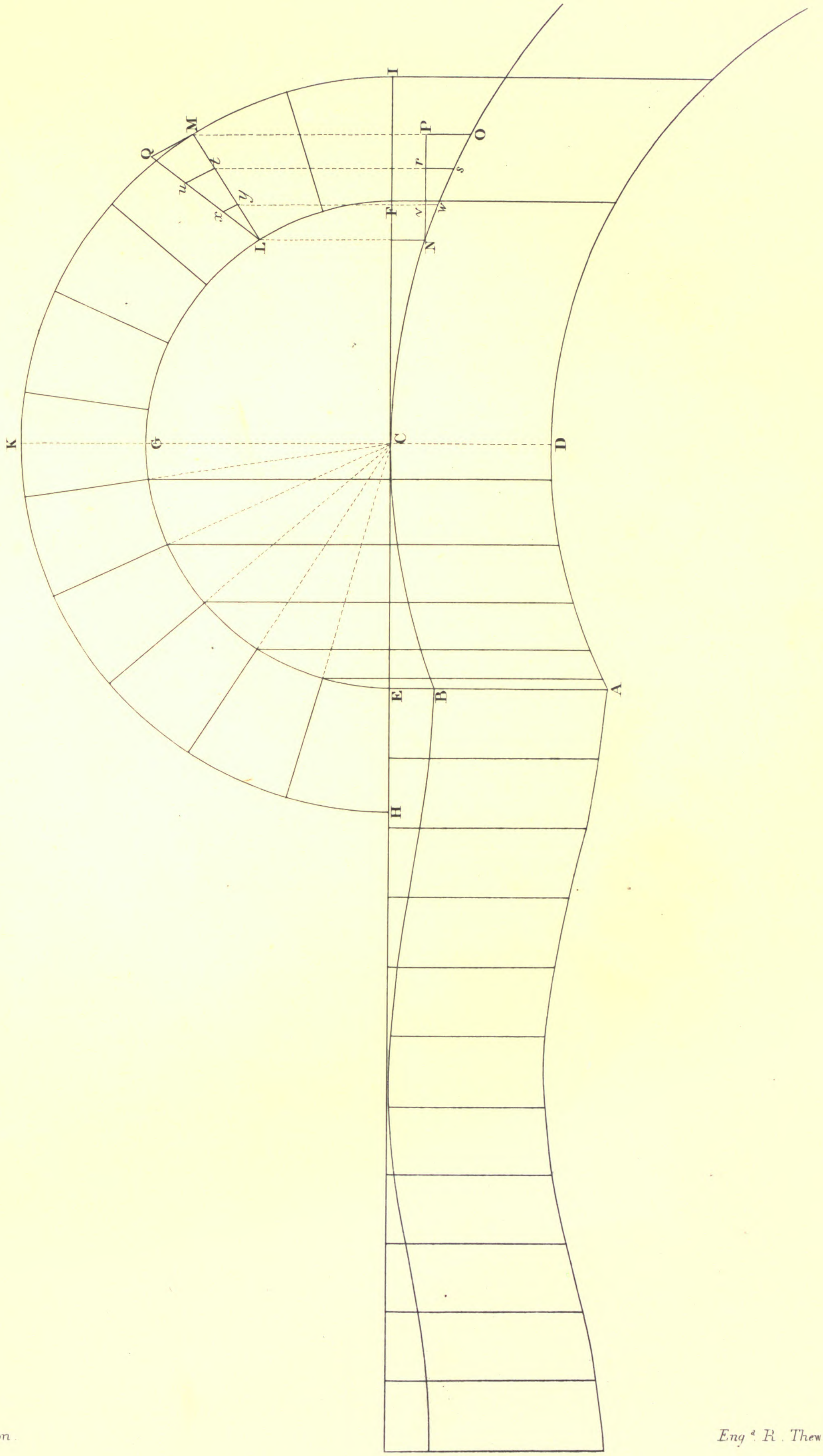
Drawn by M. A. Nicholson. Eng.d by R. Thew

N° 1





Drawn . by P. Nicholson . Eng^d. by R. Thew .



Drawn by P. Nicholson.

Engd. R. Thew.

line for the soffit, which work also by means of the bevel *q p s;* then gauge the soffit to its breadth, and work the upper bed of the stone by means of the bevel *r s p;* take the soffit mould from the envelope, and draw the ends of the stone which coincide with the faces of the wall; with the face bevels Q L M and V L M work the face of the stone.

Note.—That finding the bevels for half the arch will be sufficient, by reversing them.

Plate II. shows the construction of a semi-cylindric arch, which is performed by a similar process to the preceding.

The other arch, standing upon D C, shows the ends of the stones in the face of the wall; its boundaries are two ellipses of equal height to those of the section.

To construct a cylindro-cylindric arch, or a cylindric arch, in a cylindric wall, the axis of the aperture being at right angles to the axis of the cylindric wall. See PLATE III.

Let A B C D be the half plan of the wall; B C being half of the convex curve, A D half of the concave curve, C D the middle line of the aperture tending to the centre of the concentric circles which form the plan; and A B parallel to C D, being the jamb. Through C draw E F perpendicular to C D; make C E and C F half the breadth of the aperture; from the centre, C, with the radius C E or C F, describe the semicircle E G F, which will be the section of the intrados; produce C E and C F to H and I, making E H and F I each equal to the breadth of the beds, and describe the semicircle H K I; divide the intradossal curve, E G F, into the number of parts answering to the number of arch-stones, and proceed to find the envelope, as described, for the straight wall, which will give the moulds for the soffits of the stones, as before.

To find the curves of the ends of the beds upon the face of the arch.

Let L M represent a joint: draw L N and M O perpendicular to H I, cutting the plan of the wall at N and O: draw N P parallel to C I, cutting M O at P: in L M take any number of points, *t* and *y*, and draw *t s* and *y w* parallel to L N, cutting the plan at *s* and *w*, and N P at *r* and *v*: draw M Q, *t u*, *y x*, perpendicular to L M: make M Q, *t u*, *y x*, respectively equal to P O, *r s*, *v w*, and L *x u* Q will be the curve of the joint required, which gives the face-line of the upper bed of the lower stone, and the face-line of the lower bed of the upper stone. In the same manner all the other face-lines of the beds are to be found. The templet must be cut in the shape of L M Q.

To form an arch-stone.

First make one of the beds; make the soffit, form the other bed, and the face-lines of each bed; then run a draught round the three face-lines, and between them work the face of the stone in lines perpendicular to the horizon. This will be easily found by drawing a vertical line upon the section of each stone.

It is only necessary to draw the moulds for one half of the arch, as the reversing of them in their application gives the other half.

The joints of any arch whatever may be found in the same manner, provided the planes of the beds intersect a vertical plane perpendicular to the curve in the middle of the aperture.

It is obvious, on finding the face-lines of the beds, that the lowest face-line is the quickest, and part of the plan of the wall itself; the next face-line is flatter, or has less curvature, and thus each successive face-line has less curvature as it comes nearer to the top; and, if there were a joint in the top, the face-line of the beds would be quite a straight line. Indeed, the face-lines of two or three courses might be wrought with straight edges, as the difference could hardly be perceived. For the tools used by masons. *See* TOOLS.

MATERIALS, (from the French, *materiel,*) in architecture, the different kinds of bodies, or substances, used in the construction of edifices, as wood, stone, brick, mortar, &c.

It is chiefly from the valuable work of Vitruvius, that we are furnished with information respecting the nature of the materials used by the Greeks and Romans, and of the particular modes in which they were disposed in their buildings. From the accounts published by modern travellers and scientific artists, we are also furnished with farther information respecting the practice of these people.

The materials chiefly made use of by them were timber, marble, stone, bricks, lime, and metals.

With regard to timber, the proper time for felling was reckoned from the beginning of autumn to the latter end of February, when the moon was in the wane. They considered wood, when quite green, or too much dried, as equally unfit for working. For joists, doors, and windows, they required that it should have been cut three years, and kept for a considerable time covered with cow-dung.

The Greeks most usually made use of white marbles as Pentelic, Parian, and that of Chios. The latter was very transparent.

The Romans employed many sorts, of various colours, and procured from different countries under their sway in Asia, Africa, and Europe.

The ancients frequently included, under the term *marble,* all hard stones which would receive a smooth fine polish; the moderns confine the name to such calcareous stones as are capable of receiving a fine polish.

Alabaster resembles marble in taking a smooth fine polish, but is much softer and more easily worked. Gypseous alabaster, when polished, is slippery to the touch; and frequently contains so much carbonate of lime as to cause it to effervesce with acids; it was procured from Upper Egypt between the Nile and Red Sea, also from Syria and Caramania. The calcareous alabaster is white, yellow, red, and bluish gray; the fracture is striated or fibrous, in hardness inferior to marble; it is known under the denomination of *common* and *oriental;* Italy and Spain produce the best.

The stone which was employed appears to have differed very materially in its qualities; some, becoming considerably harder on being exposed to the air, was worked immediately on being taken from the quarry; but there was some of a softer kind, which, previous to being used, required to have its quality proved by two years' exposure to the effects of the atmosphere.

Of tiles, they had, 1. The unburnt kind, which were dried five years in the sun; and, 2. Those baked by fire, after having been made two years.

In the manufacture of these, they preferred a white chalky earth, dug in the autumn, exposed during the winter, and made into tiles and bricks in the spring. The Greeks proportioned the size of their bricks to the nature of the edifice: the largest for public buildings, were five spans each way; those of the middle class were four spans; and the smallest called by Vitruvius, *diodori,* or by Pliny, *lydii,* were two spans long and a foot broad; the last were for private houses.

It appears that the bricks dried in the sun were mixed with chopped straw. Dr. Pococke describes one of the pyramids constructed of brick: he measured some thirteen inches and a half long, six inches and a half broad, and four inches thick; others were fifteen inches long, seven inches broad, and four inches and three-quarters thick. At Rome they were found by De Quincey of three different sizes; the least were seven inches and a half square, and one inch and a half thick; the middle-sized were sixteen inches and a half square, and eighteen to twenty lines in thickness; and the largest were twenty-two inches square, and twenty-one to twenty-two lines in thickness.

Three kinds of sand are mentioned, that is, pit, river, and sea sand; of these, pit sand was reckoned the best; the white was preferred to the black or red coloured, and the carbuncle to all; of the river sand, that was considered best which was found near torrents; the least value was put upon sea sand, and it was required to be well washed, to dissolve the saline matter, before it was used in plastering or rough-casting walls.

Lime for plastering walls was made from shells, river pebbles, or a sort of pumice-stone; the best sort of lime was accounted that made from white stone, which was dense and hard, and lost one-third of its weight in burning in a kiln, where it was kept about sixty hours. Their mortar was composed of one part lime and three parts of pit, or two of river sand.

Metals used were, 1. Iron for chains, hinges, handles, and nails. 2. Lead for roofs and pipes. 3. Copper and brass were still more used for many of these purposes: or, 4. Copper, brass, and lead, mixed into a bronze for statues, bases, and capitals of columns, and in doors.

Amongst the moderns, change of climate, the convenience of local productions, and the habits of mankind, have from time to time led to considerable changes in the kinds of materials used for the various purposes of architecture, as well as in their modes of preparation, and the application of them. With regard to timber, oak, for the greatest strength and durability, should be chosen from those soils where it has taken the longest time in arriving at maturity; and of two pieces equally dry, that should be chosen which has the greatest specific gravity, or that which will have its specific gravity least changed by being soaked in water: this observation will indeed apply to timber in general. A decay of the top is almost a certain indication of a decay of the tree; and a decayed branch, or rotten stump, bespeaks a defect in that part of the tree where it is situated. In a similar soil, trees which grow near the outside of a forest will be more durable than those near the middle of it; and in the same tree, the side which grew towards the north will be stronger than the south side.

When perfection of strength and texture is alone consulted, all sorts of timber are cut down in the winter, being at that time freest of sap, and most readily seasoned, and rendered fit for the purposes of building; but on account of the bark of the oak being of great use in tanning leather, that wood is always, in England, cut in the spring, from April to June, according to the state of the season, and soon after the sap begins to ascend and the leaf to appear; if cut before the sap rises, the bark adheres to the wood, and cannot be stripped off, and if left until the leaf is quite expanded, the bark is less valuable; when the tree is felled and suffered to lie in the trunk, it will shrink in size; but this is probably from its discharging water, because, if a dry tree be laid in a damp place, it will increase both in weight and size. The part called *sap* varies in quantity in different trees; it is least in bad soils, where the growth is slow, and is of very little use.

Oak used in damp situations, appears to decay gradually from the external surface to the centre of the tree; the outside ring or addition it received in the last year of its growth decaying first, and afterwards that next within it, and then the following one. This appears to proceed from two causes; first, from the outward ring being, where whole trees are used, first exposed to the action of the atmosphere, which cannot reach the second until the first is destroyed; secondly, from the central part of the tree having arrived at a greater degree of maturity than the outward rings, which are many years younger. But this must be understood only of trees which are not past their prime before they are cut down; for when a tree begins to decay from age, that part of the tree which is oldest, namely, the central part, decays first; to this succeeds the parts which are next oldest, being the ring next the centre, and the other annual rings in succession gradually approaching the bark. A judicious builder will, therefore, in the choice of his timber, always carefully examine the central part of the tree, especially that part which is next the root, and more particularly if the tree be large, and have the appearance of great age.

The best mode of seasoning oak is to put it in water. This, if in the log, should be done for a whole year or more, but, if cut in planks, less time is necessary; in either case alternate soaking and drying is to be preferred. This, in planks, is very practicable; but, in regard to logs, one soaking and drying gradually in the shade, is, on account of the great labour attending the operation, most generally practised. After the planks have been soaked in water, they are dried by placing a strong pole in a horizontal position, at such a height as will admit of one end of each plank being placed on the ground, and the other to rest against it edgewise; placing a plank first on one side of the pole, and another on the other side alternately, thus leaving a space for the air to pass freely between them; and being exposed edgewise to the sun, they are not liable to split.

Modern science, however, has discovered many other ways of seasoning timber than these. The processes of Sir W. Burnett, Kyan, and others, are now generally resorted to for this purpose; and are found effective to a certain extent, if not quite realizing all their advocates claim for them.

In ash, there is little difference in the quality through the whole thickness of the tree, the outside is rather the toughest: it soon rots when exposed to the weather, but will last long when protected.

Of elm, some sorts will decay sooner than the brown or red. It is improper for roofs or floors, being generally cross-grained, and very liable to warp; it also shrinks very considerably, not only in breadth, but lengthwise; but it answers well when used under water; is not liable to split; and bears the driving of bolts and nails better than any other timber.

Beech is hard and close. There is a black or brown, and a white kind: the brown is tough, and sometimes used as a substitute for ash; it is improper for beams, because a small degree of dampness in the walls very soon rots the ends; it is most suitable for furniture, or for works constantly under water.

Poplar, though of a very close quality, is liable to the same objections as the beech in beams, but is well adapted for floors and stairs, being not easily ignited: however, it rots soon when exposed to the weather.

Ash resembles the poplar in appearance; is soft and tough; lasts when exposed to the weather; and is equally good through the body of the tree. The sycamore and lime are subject to the same objections, in roofing and flooring timbers, as the poplar and beech. The lime is something like the ash in quality, and, like it, is greasy when worked smooth: it is suitable for furniture.

Birch is equal in quality quite across the body of the tree; is very tough, but does not last when exposed to the weather; it is also subject to be destroyed by worms.

Chesnut, viz., the sweet, or Spanish, (not the horse-chesnut,) is frequently found in old buildings in England: and although difficult to be distinguished from oak, differs from it in this respect, wherever a nail or bolt has been driven into oak before it was dry, a black substance appears round the iron, which is not the case in chesnut.

The walnut-tree is now, in this country, too valuable to be used in the framings of roofs or floors; and in furniture it has long been superseded by mahogany; it is used chiefly in stocks of firelocks, fowling-pieces, pistols, &c.

Mahogany is used chiefly in furniture, and also sometimes in doors and window-sashes; it is sawn out and seasoned by perching out in the winter, and drying in the open air; the use of fire is not advisable. This beautiful timber was introduced into England about the beginning of the last century: its first application was in a box for holding candles, made by a Mr. Wollaston for a Dr. Gibbons, who had afterwards a bureau of it; the Duchess of Buckingham had the second bureau. It very soon came into general use. It is divided chiefly into Jamaica and Honduras; the former is by much the hardest and most beautiful; they may be readily distinguished before they are oiled; the pores of the Honduras appear quite dark, those of the Jamaica as if filled with chalk. *See* MAHOGANY.

Fir, being cheaper, and more easily wrought than oak, and next to it in usefulness, is more used in Britain than any other kind of timber. That most generally employed in carpentry is distinguished by the name of Memel, (which includes Dantzic and Riga;) Norway, (which also includes Swedish,) is much used for the smaller timbers, and answers well either when exposed to the air, or under ground. Dranton, or Dram, is suitable for flooring. All these are very durable. American fir is much softer, but suits inside joinery work, such as panels and mouldings. What is termed in England *white deal*, and in Scotland *pine-wood*, that is, fir deprived of its resinous part, being very durable when kept dry, is much used by cabinet-makers; but, as it will not stand the weather, it is little used in carpentry or joinery.

Evelyn makes the following observation on the use of fir:—"That which comes from Bergen, Swinsund, Mott, Longland, Dranton, (called Dram,) being long, straight, and clear, of a yellow and more cedary colour, is esteemed much before the white for flooring and wainscot; for masts, those of Prussia, which we call spruce, and Norway, especially from Gottenburg, and about Riga, are the best."

The *torulus*, as Vitruvius terms it, and heart of deal, kept dry, rejecting the alburnum or white, is everlasting; nor is there any wood which so well agrees with the glue, or which is so easy to be wrought. It is also excellent for beams, and other timber-work in houses, being both high and exceedingly strong, and therefore of very great use for bars and bolts of doors, as well as for doors themselves; and, for the beams of coaches, a board of an inch and a half thick will carry the body of a heavy coach with great ease, by reason of a natural spring, which is not easily injured. It was formerly used for carts and other carriages, and also for the piles to build upon in boggy grounds. Most of Venice and Amsterdam is built upon such piles. For scaffolding also, there is none comparable to it. Under the head of fir may be classed cedar, a wood of great durability, but too expensive to be used in Britain.

Evelyn makes the following observations upon timber; some of which are well worthy of attention:—

"Lay up your timber very dry, in an airy place, yet out of the wind or sun, and not standing upright, but lying along, one piece upon another, interposing some short blocks between them, to preserve them from a certain mouldiness which they usually contract while they sweat, and which frequently produces a kind of fungus, especially if there be any sappy parts remaining.

"Some there are yet, who keep their timber as moist as they can by submerging it in water, where they let it imbibe to hinder the cleaving; and this is good in fir, both for the better stripping and seasoning, yea, and not only in fir, but other timber. Lay, therefore, your boards a fortnight in the water, (if running the better, as at some mill-pond head,) and then setting them upright in the sun and wind, so as it may freely pass through them, (especially during the heats of summer, which is the time of finishing buildings,) turn them daily, and thus treated, even newly-sawn boards will floor far better than many years' dry-seasoning, as they call it. But, to prevent all possible accidents, when you lay your floors, let the joints be shot, fitted, and tacked down only for the first year, nailing them for good and all the next; and by this means they will lie stanch, close, and without shrinking in the least, as if they were all one piece. And upon this occasion, I am to add an observation, which may prove of no small use to builders; that if one take up deal-boards that may have lain in the floor a hundred years, and shoot them again, they will certainly shrink, (*toties quoties.*) without the former method. Amongst wheelwrights, the water-seasoning is of especial regard; and in such esteem amongst some, that I am assured the Venetians, for their provision in the arsenal, lay their oak some years in water before they employ it. Indeed, the Turks not only fell at all times of the year, without any regard to the season, but employ their timber green and unseasoned; so that, though they have excellent oak, it decays in a short time by this only neglect.

"Elm felled ever so green, for sudden use, if plunged four or five days in water, (especially salt water,) obtains an admirable seasoning, and may immediately be used. I the oftener insist on this water-seasoning, not only as a remedy against the worm, but for its efficacy against warping and distortions of timber, whether used within or exposed to the air. Some, again, commend burying in the earth, others in wheat; and there be seasonings of the fire, as for the scorching and hardening of piles, which are to stand either in the water or in the earth.

"When wood is charred, it becomes incorruptible; for which reason, when we wish to preserve piles from decay, they should be charred on their outside. Oak posts, used in enclosures, always decay about two inches above and below the surface. Charring that part would probably add several years to the duration of the wood, for that to most timber it contributes much to its duration. Thus, do all the elements contribute to the art of seasoning.

"And yet even the greenest timber is sometimes desirable for such as carve and turn, but it chokes the teeth of our saws; and for doors, windows, floors, and other close works, it is altogether to be rejected, especially where walnut-tree is the material, which will be sure to shrink. Therefore, it is best to choose such as is of two or three years' seasoning, and that is neither moist nor over dry; the mean is best. Sir Hugh Plat informs us, that the Venetians used to burn and scorch their timber in a flaming fire, continually turning it round with an engine, till they have gotten upon it a hard black coaly crust; and the secret carries with it great probability, for the wood is brought by it to such a hardness and dryness, that neither earth nor water can penetrate it; I myself remembering to have seen charcoal dug out of the ground amongst the ruins of ancient buildings, which had in all probability lain covered with earth above fifteen hundred years.

"Timber which is cleft is nothing so obnoxious to reft and cleave, as what is hewn; nor that which is squared, as what is round; and therefore, where use is to be made of huge and massy columns, let them be bored through from end to end. It is an excellent preservative from splitting, and not unphilosophical; though, to cure the accident, painter's putty is recommended; also, the rubbing them over with a wax-cloth is good; or before it be converted, the smearing the timber over with cow-dung, which prevents the effects both of sun and air upon it, if, of necessity, it must lie exposed. But, besides the former remedies, I find this for the closing of the chops and clefts of green timber, to anoint and supple it with the fat of powdered beef-broth, with which it must be well soaked, and the chasms filled with sponges dipt into it. This to be twice done over.

"Some carpenters make use of grease and sawdust mingled; but the first is so good alway," says my author, "that I have seen wind-shock timber so exquisitely closed, as not to be discerned where the defects were. This must be used when the timber is green.

"We spake before of squaring; and I would now recommend the quartering of such trees as will allow useful and competent scantlings, to be of much more durableness and effect for strength, than where (as custom is, and for want of observation) whole beams and timbers are applied in ships or houses, with slab and all about them, upon false suppositions of strength beyond these quarters. For there is in all trees an evident interstice or separation between the heart and the rest of the body, which renders it much more obnoxious to decay and miscarry, than when they are treated and converted as I have described it; and it would likewise save a world of materials in the building of great ships, where so much excellent timber is hewed away to spoil, were it more in practice. Finally,

"I must not omit to take notice of the coating of timber in work used by the Hollanders, for the preservation of their gates, portcullises, draw-bridges, sluices, and other huge beams and contiguations of timber, exposed to the sun and perpetual injuries of the weather, by a certain mixture of pitch and tar, upon which they strew small pieces of cockle and other shells, beaten almost to powder, and mingled with sea-sand, or the scales of iron, beaten small and sifted, which encrusts, and arms it, after an incredible manner, against all these assaults and foreign invaders; but if this should be deemed more obnoxious to firing, I have heard that a wash made of alum has wonderfully protected it against the assault even of that devouring element; and that so a wooden tower or fort at the Piræum, the port of Athens, was defended by Archelaus, a commander of Mithridates, against the great Sylla.

"Timber that you have occasion to lay in mortar, or which is in any part contiguous to lime, as doors, window-cases, groundsels, and the extremities of beams, &c., have sometimes been capped with molten pitch, as a marvellous preserver of it from the burning and destructive effects of the lime; but it has since been found rather to heat and decay them, by hindering the transudation which those parts require: better supplied with loam, or strewings of brick-dust, or pieces of boards; some leave a small hole for the air. But though lime be so destructive whilst timber lies thus dry, it seems they mingle it with hair, to keep the worm out of ships, which they sheath for southern voyages, though it is held much to retard their course. Wherefore, the Portuguese scorch them with fire, which often proves very dangerous; and, indeed, their timber being harder, is not so easily penetrable.

"For all uses, that timber is esteemed the best which is the most ponderous, and which, lying long, makes deepest impression on the earth, or in the water, being floated; also, what is without knots, yet firm, and free from sap, which is that fatty, whiter, and softer part, called by the ancients *alburnum*, which you are diligently to hew away.

"My Lord Bacon, Exper. 658, recommends for trial of a sound or knotty piece of timber, to cause one to speak at one of the extremes, to his companion listening at the other; for if it be knotty, the sound, says he, will come abrupt.

"For the place of growth, that timber is esteemed best which grows most in the sun, and on a dry and hale ground; for those trees which suck and drink little, are most hard, robust, and longer-lived instances of sobriety. The climate contributes much to its quality; and the northern situation is preferred to the rest of the quarters; so as that which grew in Tuscany was, of old, thought better than that of the Venetian side; and yet the Biscay timber is esteemed better than what they have from colder countries; and trees of the wilder kind and barren, than the over much cultivated and great bearers."

Dr. Parry published an excellent paper on the causes of the decay of wood, and the means of preventing it, which, though written many years ago, is worth a careful perusal by those who wish for further information on the subject.

Wood, Dr. Parry supposes to be subject to destruction from two causes—rotting, and the depredations of insects. Of rot there are two supposed kinds: the first takes place in the open air; the second under cover.

When perfectly dry, and in a certain degree of temperature, both animal and vegetable matters seem scarcely capable of spontaneous decay. On this principle, fish and other animal matter is often preserved.

"Similar causes produce the same effect on wood. Even under less rigid circumstances of this kind, as in the roofs and other timber of large buildings, it continues for an astonishing length of time unchanged. Witness the timber of that noble edifice, Westminster-hall, built by Richard II. in 1397; and the more extraordinary instance quoted by Dr. Darwin, in his ingenious work, the *Phytologia*, of the gates of the old St. Peter's Church in Rome, which were said to have continued without rotting, from the time of the Emperor Constantine to that of Pope Eugene IV., a period of eleven hundred years. On the other hand, wood will remain for ages, with little change, when continually immersed in water, or even when deeply buried in the earth, as in the piles and buttresses of bridges, and in various morasses. These latter facts seem to show, that if the access of atmospherical air is not necessary to the decay of wood, it is at least highly conducive to it."

Putrefaction is the cause of rotting; and putrefaction is occasioned by stagnant air and moisture. The moisture of the air, coming in contact with wood of a lower temperature, is condensed in the same manner, as is more visible in our glass windows. In order to prevent the bad effects of this condensation, currents of dry air ought to be made to pass in contact with the timber. Of the advantages of this, the Gothic architects seemed aware; for it was common with them to leave openings for this purpose; a practice which we would strongly recommend in cellars, &c.

"It appears that the contact of water and air are the chief causes of the decay of wood. If, therefore, any means can be devised by which the access of moisture and air can be prevented, the wood is so far secure against decay. This principle may be illustrated, by supposing a cylinder of dry wood to be placed in a glass tube or case which it exactly fills, and the two ends of which are, as it is called, hermetically sealed, that is, entirely closed, by uniting the melted sides of each end of the tube. Who will doubt that such a piece of wood might remain in the open air unchanged! Or let us take a little more apposite illustration of this fact, that of amber, a native bitumen or resin, in which a variety of small flies, filaments of vegetables, and others of the most fragile substances, are seen imbedded, having been preserved from decay much longer probably than a thousand years, and with no apparent tendency to change for ten times that period."

These observations lead to the theory of painting timber, for the purpose of preserving it.

Mr. Batson of Limehouse is of opinion, that the dry-rot proceeds from a plant, called *boletus lachrymans*, one of the fungus tribe, and is one of the few that have leaves, as the mistletoe. But Dr. Parry justly observes, that these plants "begin merely because decayed wood is their proper soil."

"The smell which we perceive in going into vaults or cellars, where this process is going on, arises partly from the extrication of certain gases, mingled perhaps with some volatile oil, and partly from the effluvia of those vegetable substances which have already been said to grow on it, and which, though they begin merely because the decayed wood is their proper soil, yet afterwards tend probably to the more speedy decomposition of the wood itself.

"The following, then, appears to be the whole theory of the dry-rot, that it is a more or less rapid decomposition of the substance of the wood, from moisture deposited on it by condensation, to the action of which it is more disposed in certain situations than in others; and that this moisture operates most quickly on wood which most abounds with the saccharine or fermentable principles of the sap." *See* DRY-ROT.

Charring of wood is known to be a most effectual mode of preservation against rotting.

The incorruptibility of charcoal is attested by numerous unquestionable facts. At the destruction of the famous temple at Ephesus, it was found to be erected on piles that had been charred; and the charcoal in Herculaneum, after almost 2,000 years, was entire and undiminished.

To this property of charred wood Sir C. Wren does not seem to have attended, when about to build St. Paul's. It is said, he thought piles were not to be depended on for a foundation, excepting when always wet; and therefore dug to a great depth through a dry soil, in order to come at a solid foundation for part of that cathedral.

Charcoal has also been found useful as a defence to the surface of wood, when used as a paint. We lately had a good instance of the effect of sand used for this purpose. At Studly Royal, we saw a temple to appearance of stone, but which, on examination, we found to be wood covered with paint and dusted over with sand. We were informed it had stood about 50 years; and the deception was still so complete, that the spectators supposed the pillars to be stone, till minutely examined.

The following table of the properties of different kinds of timber is extracted from Tredgold's valuable work on Carpentry, and will be found to contain, in a condensed form, every information as to the comparative merits of the various descriptions of wood used for building or similar purposes:—

Table of the Properties of different kinds of Timber.

		Kind of wood, and State.	Specific gravity.	Weight of the modulus of elasticity in pounds per sq. inch.	Cohesive force in pounds per sq. inch.	Comparative.		
						Stiffness.	Strength.	Resilience.
Class I.	Div. I.	Common oak (*Quercus robur*) dry	.750	1,714,500	11,880	100	100	100
		Riga oak, dry	.688	1,610,496	12,888	93	108	125
		Dantzic oak, seasoned	.755	1,998,000	12,780	117	107	99
		American oak	.867	1,958,700	10,253	114	86	64
	Div. II.	Beech (*Fagus Sylvatica*) dry	.690	1,316,000	12,225	77	103	138
		Alder (*Betula alnus*) dry	.555	1,086,750	9,540	63	80	101
		Plane (*Platanus occidentalis*) dry	.648	1,343,250	10,935	78	92	108
		Sycamore (*Acer pseudo-platanus*) dry	.590	1,036,000	9,630	59	81	111
Class II.	Div. I.	Chesnut (*Fagus castanea*) dry	.535	1,147,500	10,656	67	89	118
		Ditto, green	.875	924,570	8,100	54	68	85
		Ash (*Fraxinus excelsior*) dry	.753	1,525,500	14,130	89	119	160
		Elm (*Ulmus campestris*) dry	.544	1,343,000	9,720	78	82	86
		Acacia (*Robinia pseudo-acacia*) green	.820	1,687,500	11,227	98	95	92
	Div. II.	Spanish mahogany, dry	.853	1,255,500	7,560	73	67	61
		Honduras ditto, dry	.560	1,593,000	11,475	93	96	99
		Walnut (*Juglans regia*) green	.920	837,000	8,775	49	74	111
		Teak (*Tectona grandis*)	.744	2,167,074	12,915	126	109	94
		Poona, dry	.613	1,689,800	12,350	99	104	82
		Turtosa, or African Teak, dry	.954	1,728,000	17,200	101	144	138
		Poplar, (*Populus dilatata*) dry	.374	763,000	5,928	44	50	57
		Abele (*Populus alba*) dry	.511	1,134,000	10,260	66	86	112
	Div. III.	Cedar of Libanus (*Pinus cedrus*) dry	.486	486,000	7,420	28	62	106
		Riga fir (*Pinus sylvestris*) dry	.480	1,687,500	9,540	98	80	64
		Memel fir (ditto) dry	.544	1,957,750	9,540	114	80	56
		Mar Forest fir (ditto)	.684	845,066	7,323	49	61	76
		Planted Scotch fir (ditto) dry	.460	951,750	7,110	55	60	65
		Christiana white deal (*Pinus abies*) dry	.512	1,804,000	12,346	104	104	104
		American white spruce (*Pinus alba*) dry	.465	1,244,000	10,296	72	86	102
		Planted Spruce (*Pinus abies*) dry	.555	1,393,975	8,370	81	70	60
		Weymouth pine (*Pinus strobus*) dry	.460	1,633,500	11,835	95	99	103
		Pitch pine	.660	1,252,200	9,796	73	82	92
		Larch (*Pinus larix*) dry	.643	1,363,500	12,240	79	103	134
		Cowrie (*Dummara australis*)	.79	1,982,400	10,960	116	92	74

In the last three columns of this table, oak is made the standard of comparison.

For marble, being plentiful in Italy and France, these countries have been able to make a considerable use of it, even in the main walls of their edifices; but being seldom found in sufficient quantities, and of proper quality, in the more northern parts of Europe, it has been here chiefly confined to interior columns, pavements, chimney pieces, and sometimes stairs.

The kinds of stone are as various as the countries in which the buildings are constructed. Sand-stone being very generally found stratified, even in thin laminæ, being readily cut into different forms, and being, if properly selected and used, sufficiently durable, it has, in northern countries, been in most frequent use. It is a general accompaniment of coal strata, and is also often found where the latter does not occur. It varies in its component parts, being at different places argillaceous, siliceous, and calcareous. Its position in the earth assumes all directions, from the horizontal to a vertical plane. The proportional thickness of its strata, laminæ, or beds, varies from that of thin slate to many feet each. The upper beds are usually very thin or soft, or both; if sufficiently hard, they are employed in floor pavements, and for covering roofs. Under these the beds generally, in useful quarries, increase in thickness, hardness, and tenacity. The position of the laminæ always requires strict attention, that the worked stone may, if possible, be laid in the building upon its natural bed; for although some instances occur, as in the Isle of Portland and at Grinshill, in Shropshire, where the difference is not apparently great, yet in all stone (even granite) it is sufficiently well known to workmen. Some stone, as that of Bath, is so soft when taken out of the quarry as to be very conveniently worked with tools resembling those used by carpenters; yet when exposed for some time to the atmosphere, it becomes hard and durable. This last, indeed, cannot be deemed sand-stone, being nearly altogether calcareous.

Besides the before-mentioned, there is a very beautiful stone, dug in the hills near Dunstable, in the parish of Tottenhoe, from whence the stone receives its name. It has the appearance of indurated chalk. It is easily worked, and hardens by exposure to the weather. It should, however, be placed upon a plinth of some other stone, or kept by other means from contact with the ground; otherwise it is, in this situation, liable to be injured by the frosts. The house of the Duke of Bedford, at Woburn Abbey, is built chiefly with this stone, as are various other large houses in the neighbourhood of the quarries. Proofs of its durability may be seen in many old churches. From the closeness of its texture, the beauty of its colour, and the facility with which it is worked into mouldings, &c., it is peculiarly fit for house-building, both externally and internally.

The very perfect preservation of many beautiful churches in the countries of Lincoln, Rutland, and Northampton, are evidences of the excellence of the stone of which they are built.

In the central parts of Scotland, different varieties of sand-stone, which accompany coal, are used extensively in building houses, &c.; and this circumstance has not a little contributed to the fine appearance of the new streets, squares, and public buildings in the cities of Edinburgh and Glasgow. Flints, where they abound, and where other stone is scarce, are sometimes used in walls of considerable height; and notwithstanding their small size and irregularity of shape, are broken so as to compose a face of considerable smoothness. The church and steeple of Rickmansworth, in Hertfordshire, affords a fine specimen of this kind of building. But brick or squared stones are generally used as quoins of this sort of work.

In Scotland and Sweden, granite is made use of as a building material. It lies in large masses, generally separated by gunpowder into moderate, though still large dimensions, which are again cut into suitable scantlings, by means of iron instruments called *plugs and feathers.* They are not only worked into plain square forms, but also mouldings of considerable delicacy, by means of pointed tools, of different size and weights. At Aberdeen, in Scotland, where excellent granite is produced, and the working of it brought, perhaps, to the greatest perfection, there are handsome porticos, consisting of columns, bases, caps, and entablatures, executed in granite with great nicety. In the middle of the city, a public building, whose front is composed of a full Doric order, is wholly completed with this excellent material. There are two sorts of granite, the one gray and the other red; the last, being the hardest, is most difficult to work—consequently the former is most frequently employed; it consists of feldspar, mica, and quartz. It is much employed for paving the carriage-way of streets, and in the curbing of the flat side-pavements; also for piers and footpaths of bridges; and for facings and copings to quays and wharfs. At Aberdeen, it is employed in constructing very extensive piers, for protecting the entrance of the harbour; and in the Eddystone and Bell-rock lighthouse, it composes the facings, where they are exposed to the action of the sea.

Whin, basalt, and schistus, are also used in rubble work. The former dressing freely with the hammer, in one direction, may readily be formed with good faces, but not being stratified, their beds are uncertain, and not easily improved by art; the latter—that is, schistus—is just the reverse, having naturally good beds, but being in few instances willing to dress square across the laminæ: they are, indeed, where expense is not an object, worked to a face by the laborious operation of striking perpendicularly with a wedge-mouthed hammer or stone axe: both kinds are laid, sometimes promiscuously, and at others in regular courses.

Limestone, where found regularly stratified, affords good building stone, and combines the advantages of both the former, having naturally good beds, and dressing readily for a face.

A species of schistus affords a covering for roofs, totally unknown to the ancients, and which, when good of its kind, and properly prepared and laid on, is both very effectual and beautiful; for a farther account of which, *see* Slate.

Bricks have, in England, become a material very generally employed in constructing all kinds of buildings. The country is provided by nature with abundant supplies of coal for burning bricks, which can, by means of the sea or numerous inland navigations, be, with great facility, conveyed to the large towns and populous districts, where the demand has long been very great. Clay of proper quality is usually found either upon the spot or immediate vicinity; a very limited number of workmen, properly arranged, can manufacture a great number of bricks in a stated time; these can readily be removed to the place where they are to be employed; being light to handle, and of a rectangular shape, the workmen lay them with facility and ease. By means of bricks, walls can be made much thinner than with almost any kind of stone; they are therefore cheaper, and occupy less space; in forming doorways, windows, chimneys, apertures, and angles of all kinds, the facility they afford is greater than that of any other durable material. A building whose walls are made with bricks dries soon, is free from damp; and, if properly made and thoroughly well burnt, bricks endure equal to most, and longer than many kinds of stone. For the best modes of manufacturing them, *see* Brick.

Tiles having long been employed in England for covering the roofs of buildings situated in towns, and of farm-houses and cottages in the country; but of late years the use of them has been much circumscribed by the extension of that of slates. For the mode of manufacturing and using them, *see* Tile.

Respecting sand, the ancient and modern practices agree nearly in all that need be said; that which is of an angular shade, hard texture, and perfectly free from earthy particles, is admitted to be best. For the circumstances necessary to be attended to in employing it, as well as lime, *see* Cement.

In regard to metals, in modern times, the use of copper and bronze has, for building purposes, been mostly abandoned. Brass has been continued in locks, pulleys, sash-windows, handles, sliding plates, connected with bells, and sundry other purposes in fitting up the interior of apartments.

Iron has been applied to many purposes unthought of in former times. The improvement and general introduction of cast-iron bids fair to create a totally new school of architecture. It has already been extensively employed in bridges, pillars, roofs, floors, chimneys, doors, and windows; and the facility with which it is moulded into different shapes will continue to extend its application. The before-mentioned purposes, to which it has already been applied, are more particularly noticed in the discussions of practice in the different branches of architecture, under their respective heads.

Glass, as a building material, was little if at all known to the ancients; and its introduction alone has been productive of comforts and elegances to which the most refined of the Greeks and Romans were utter strangers. Their oiled paper, transparent horn, talc, shells, and linen, would now, even to an English peasant, appear a miserable expedient. For an account of its manufacture, and application to architectural purposes, *see* Glass.

Besides the materials which have already been enumerated as composing the principal members, as walls, roofs, floors, doors, windows, chimneys, stairs, and pavements; hair is also necessary in the composition of mortar for plastering the surface of walls and ceilings; likewise various paints and papers, for covering them and other parts of the work; all which are described, with the modes of applying them, in their proper places.

MATHEMATICS (from the Greek μαθηματικῄ), the science which treats of the ratio and comparison of quantities, whence it is defined the *science of ratios;* some writers call it the *science of quantities;* but this is inacurate, since quantities themselves are not the subject of mathematical investigation, but the ratio which such quantities bear to each other.

The term *mathematics* is derived from μαθησις, *mathesis*, discipline, science, representing with justness and precision, the high idea that we ought to form of this branch of human knowledge. In fact, mathematics are a methodical concatenation of principles, reasonings, and conclusions, always accompanied by certainty, as the truth is always evident, an advantage that particularly characterizes accurate knowledge and the true sciences, with which we must be careful not to associate metaphysical notions, conjectures, nor even the strongest probabilities.

The subjects of mathematics are the comparisons of magnitude, as numbers, velocity, distance, &c. Thus, geometry considers the relative magnitude and extension of bodies; astronomy, the relative velocities and distances of the planets; mechanics, the relative powers and force of different machines, &c. &c., some determinate quantity being fixed upon in all cases, as a standard of measure.

The study of mathematics is highly useful to the architect, particularly arithmetic, geometry, mensuration, and mechanics. Geometry enables him to take his dimensions under the most difficult circumstances, and to lay out the various parts of his design, while it furnishes him with rules for executing the same. Mensuration is the application of arithmetic to geometry, and shows him how to find the exact proportion of his labour, according to the difficulty of executing a certain uniform portion of a work, and to estimate the quantity of materials employed therein: that branch of mathematics called *mechanics*, enables him to compute the strength and strain of the materials he employs. In short, without the aid of mathematics, he is unfit for his profession; and the more he understands, the fewer difficulties he will have to encounter in the prosecution of his art.

Mathematics are naturally divided into two classes; the one comprehending what we call *pure* and *abstract;* and the other the *compound* or *mixed*. Pure mathematics relate to magnitudes generally, simply, and abstractedly, and are therefore founded on the elementary ideas of quantity. Under this class are included arithmetic, or the art of computation; geometry, or the science of mensuration and comparison of extensions of every kind; analysis, or the comparison of magnitudes in general; to which we may add geometrical analysis, which is a combination of the two latter. Mixed mathematics are certain parts of physics, which are, by their nature, susceptible of being submitted to mathematical investigation. We here borrow from incontestable experiments, or otherwise suppose bodies to possess some principal and necessary quality, and then, by a methodical and demonstrative chain of reasoning, deduce from the principles established conclusions as evident and certain as those which pure mathematics draw immediately from axioms and definitions, observing, that these results are always given with reference to the experiments on which they are founded, or the hypothesis which furnished the first datum. To illustrate this by an example: numberless experiments have shown us, that all bodies near the earth's surface fall with an accelerated velocity, and that the spaces passed through are as the squares of the time they have occupied in falling. This, then, the mathematician considers as a necessary and essential quality of matter, and with this datum he proceeds to examine what will be the velocity of a body after any given time, in what time it will have acquired a given velocity, what time is necessary for it to have generated a given space, &c., and in all these investigations his conclusions are as certain and indisputable as any of those which geometry deduces from self-evident truths and definitions. Again, in optics, having established it as a principle of light, that it is transmitted in right lines while no obstacle is opposed to the passage of the rays; that when they become reflected, the angle of incidence is equal to the angle of reflection; that in passing from one medium to another, of different density, they fly off from their first direction, but still follow a certain geometrical law; these principles, or qualities of light, being once admitted, whatever may be its nature, be it material or immaterial, or whatever may be the medium through which it passes, or the surface by which it is reflected, are matters totally indifferent to the mathematician; he considers the rays only as right lines, the surfaces on which they impinge as geometrical planes, of which the form only enters into his investigation: and from this point all his inquiries are purely geometrical, his investigation clear and perspicuous, and his deduction evident and satisfactory. To this class of mathematics belong mechanics, or the science of equilibrium and motion of solid bodies: hydrodynamics, in which the equilibrium and motion of fluids are considered; astronomy, which relates to the motion, masses, distance, and densities, of the heavenly bodies; optics, or the theory and effects of light; and, lastly, acoustics, or the theory of sounds.

Such are the subjects that fall under the contemplation of the mathematician; and, as far as a knowledge of these may be considered beneficial to mankind, so far, at least, the utility of the science on which they depend, must be admitted. It is not, however, the application of mathematics to the various purposes of society, that constitutes their particular excellency; it is their operation upon the mind, the vigour they impart to our intellectual faculties, and the discipline which they impose upon our wandering reason. "The mathematics," says Dr. Barrow, "effectually exercise, not vainly delude, nor vexatiously torment studious minds with obscure subtilties, but plainly demonstrate everything within their reach, draw certain conclusions, instruct by profitable rules, and unfold pleasant questions. These disciplines also inure and corroborate the mind to a constant diligence in study; they wholly deliver us from a credulous simplicity, and most strongly fortify us against the vanity of scepticism; they effectually restrain us from a rash presumption, most easily incline us to a due assent, and perfectly subject us to the government of right reason. While the mind is abstracted and elevated from sensible matter, it distinctly views pure forms, conceives the beauty of ideas, and investigates the harmony of proportions; the manners themselves are sensibly corrected and improved, the affections composed and rectified, the fancy calmed and settled, and the understanding raised and excited to more divine contemplations."

List of the most celebrated Mathematicians, with the names of their works, or the sciences in which they were eminent, and the countries where they flourished; chronologically arranged.

B. C.	Name.	Science.	Country.
960	Chiron the Centaur.	Astronomy	Thessaly
747	*Era of Nabonassar*		Babylon
722	Confucius	Ethics	China
600	Thales	Prediction of an Eclipse	Greece
	Anaximander	Celestial Globes	Ditto
500	Cleostratus	Astronomy	Ditto
	Anaxagoras	Philosophy	Ditto
	Anaximenes	Sun-dial	Ditto
	Pythagoras	47 Euc. Syst. of Astron.	Ditto
400	Euctemon	Astronomy	Ditto
	Meton	Metonic Cycle	Ditto
	Plato	Geometry and Philos.	Ditto
	Hippocrates	Quadrant of Lunes	Ditto
	Œnopides	Geometry	Ditto
	Zonodorus	Ditto	Ditto
300	Aristotle	Philosophy	Ditto
	Calippus	Astronomy	Ditto
	Dinocrates	Architecture	Ditto
	Theophrastus	History and Mathem.	Ditto
	Xenocrates	Architecture	Ditto
	Eudoxus	Geometry and Astron.	Ditto
	Pytheas	Navigation and Astron.	Gaul
	Archytas	Mathematics & Philos.	Greece
	Aristæus	Conic Sections	Ditto
	Dinostratus	Quadratix	Ditto
	Menechmus	Geometry	Ditto
200	Apollonius	Geometry & Conic Sect.	Ditto
	Archimedes	Geometry & Mechanics	Sicily
	Aristarchus	Astronomy	Greece
	Eratosthenes	Measure of a Degree	Ditto
	Euclid	Elements of Geometry and Optics	Ditto
	Aratus	Poetry and Astronomy	Greece
	Aristillus	Philosophy and Astron.	Ditto
	Nicomedes	Conchoid	Ditto
100	Hipparchus	Length of Year, Number of the Stars	Ditto
	Ctesibius	Water Pumps	Ditto
	Hero	Hero's Foun. Clepsydra	Egypt
	Manilius	Poetry and Astronomy	Rome
	Manlius	Astronomy	Ditto
	Julius Cæsar	Calendar reformed	Ditto
	Sosigenes	Astronomy	Egypt
	Posidonius	Mechanics & Mathem.	Rome
	Theodosius	Spherics	Ditto
A. D.			
0	Cleomedes	Astronomy	Ditto
	Geminus	Geometry & Astronomy	Rhodes
	Vitruvius	Architecture	Rome
	Menelaus	Spherical Trigonometry	Ditto
100	Frontinus (Sixtus)	Enginery	Rome
	Nicomachus	Mathematics	Greece
	Hypsicles	Ditto	Ditto
	Ptolemy	Almagest	Egypt
200	Diophantus	Diophan. Analysis	Greece
300	Iamblicus	Philosophy	Syria
	Pappus	Geometrical Loci	Greece
	Theon	Philosophy	Ditto
400	Hypati, daughter of Theon	Commentary on Diophanes	Ditto
	Proclus	Commentary on Euclid	Ditto
	Diocles	Cissoid	Ditto
	Serenus	Geometry	Ditto
500	Marinus	Ditto	Naples
	Anthemius	Architecture; Domes.	Rome
	Eutocius	Geometry	Greece
	Isidorus	Architecture	Rome
600	The Venerable Bede		England
642	*Alexandrian Library destroyed.*		
700	Almansor, the Victorious	Astronomy	Saracen
	Hero the Younger	Geometry	Greece
800	Almaimon, Calif	Astronomy	Arabia
	Alraschid	Ditto	Persia
	Alwamon	Ditto	Ditto
	Alfragan	Ditto	Arabia
	Albategni	Ditto	Ditto
	Thebit Ibn Chora	Ditto	Ditto
900	(Gebert) Silvester II	Mathematics	Spain
1000	Ibn Ionis	Astronomy	Arabia
	Geber Ben Alpha	Comment on Almagest	Ditto
1100	Alhazen	Optics and Astronomy	Ditto
1200	Leonard (de Pisa)	First Euro. Algebraist	Italy
	Nassir Eddin	Astronomy	Persia
	Alphonso, King of Castile	Alphonsine Tables	Spain
1200	Halifax, or Sacrobosco	Mathematics	England
	Jordanu Nemorarius	Mathematics	
	Bacon	Philosophy	England
	Campanus	Theory of Planets	
	Vitella and Pecam	Optics	
1300	Albano	Physic & Mathematics	Italy
	Ascoli	Mathematics	Ditto
	John of Saxony	Astronomy	
1400	Bianchini	Ditto	Ditto
	Moscholpulus, Mod.	Magic Square	Greece
	Purbach	Astronomy	Vienna

A.D.	Name.	Science.	Country
1400	Regiomontanus	Ditto	Ditto
	Cusa, Cardinal	Astronomy	
	Henry, Duke of Visco	Sea Charts	
	Uleugh Beigh, Prince	Astronomy	Tartary
	Bernard of Granolachi	Ditto	
	Lucas de Burgo	Geometry & Algebra	
	Novera, Dominic	Astronomy	Italy
1500	Copernicus	System of Astronomy	Germany
	Apian, Peter	Math. & Cosmogony	Ditto
	Apian, Philip	Sun-dials	Ditto
	Buteo	Geometry	France
	Cardan	Ditto	Italy
	Commandine	Mathematics	Ditto
	Durer, Albert	Geom. & Perspective	Germany
	Vieta	Angular Sections	France
	Brahe, Tycho	Astronomy	Denmark
	Bacon, Lord Francis	Philosophy	England
	Galileo	Law of falling Bodies	Italy
1600	Briggs	Present System of Logarithms	England
	Des Cartes	Equation of Curve Lines	France
	Kepler	Laws of Celes. Motion	Germany
	Napier	Logarithms	Scotland
	Torricelli	Gravity of Atmosph.	Italy
	Cavalerius	Indivisibles	Milan
	Brounker	Continued Fractions	Ireland
	Fermat	Max. et Min. Theory of Numbers	France
	Pascal	Doct. of Probabilities	Ditto
	Wallis	Arithmet. of Infinites	England
	Bernouilli, James	Mathematics	Swiss
	Barrow	Ditto	England
	Hooke	Philos. & Mechanics	Ditto
	Huygens	Evolute of Curves	Holland
	Leibnitz	Differential Calculus	Germany
	L'Hôpital	Mathematics	France
	Roemer, Dan.	Progress. Mot. of Light	Denmark
1700	Newton, Sir I.	Various	England
	Bernouilli, John	Mathematics	Swiss
	Bradley	Aberration of Stars	England
	Cotes	Mathematics	Ditto
	Taylor	Increments	Ditto
	Clairaut	Mathematics	France
	Maclaurin	Ditto	Scotland
	De Moivre	Ditto	England
	Simpson	Ditto	Ditto
	D'Alembert	Partial Differences	France
	Euler	Mathematics	Germany
	Landen	Residual Analysis	England
	Waring	Mathematics	Ditto

Besides the foregoing, who were mostly celebrated in the branches affixed to their names, the following were so multifarious in their studies and productions, that it would be injustice to their talents to give a preference by noticing any one to the exclusion of the rest. We therefore merely subjoin a list of their names, and the countries in which they were born.

A.D.	Name.	Country.	A.D.	Name.	Country.
1500	Maurolycus	Sicily	1500	Ramus	France
	Nonius	Portugal		Recorde	Ditto
	Sturmius	France		Reinhold	Germ.
	Tartaglia	Venice		Rothman	Ditto
	Werner	Germany		Stiffelius	Ditto
	Ferrari	Italy		Ubaldi, Guido	Italy
	Mercator	Denmark		Porta, Baptista	Naples

A.D.	Name.	Country.	A.D.	Name.	Country.
	Byrgious	Italy	1700	Brackenridge	England
	Clavius	Ditto		Cassini, D.&J.	Nice
	Castel	France		Craig, J.	Scotland
1600	Bayer	Prussia		Gravesande	Holland
	Beauregard	France		Hire, Philip De la	France
	Beaume, De	Italy			
	De Dominis	Ditto		Keill	Scotland
	Gassendi	France		Laloubere	France
	Gellibrand	England		Lomsberg	
	Gundling	Germany		Manfredi	Italy
	Halifax, or Longomontanus	Denmark		Marchetti	Ditto
				Meibomius	Germany
	Harriot	England		D'Omerique, H	France
	Horrox	Ditto		Pemberton	England
	Kircher	Germany		Prestet	France
	Lucas Valerius	Italy		Saunderson	England
	Metius	Holland		Saurin	France
	Oughtred	England		Stirling	Scotland
	Pitiscus, Barthelemi	Germany		Ulloa	Spain
				Varignon	France
	Romanus	Flanders		Verbiest	
	Ursinus	Germany		Wolfius	Prussia
	Bartholin	Denmark		Bellidor	
	Borelli	Naples		Bernouilli, Js. Jn. & Daniel	Swiss
	Bullialdus				
	Dechales	Savoy			
	Frenicle	France		Bougainville	France
	Girard, Albert	Holland		Bogner	
	Gregory, J.&D.	England		De la Caille	France
	Henrion	France		Clarke, Dr. S.	England
	Hevelius	Poland		Collins	Ditto
	Horrebow	Denmark		Courtivron	France
	Mersennus	France		Cramer	Geneva
	Riccioli	Italy		Dodson	England
	Roberval	France		Dollond	Ditto
	Slusius	Flanders		Fatio	
	Snellius, R.&W.	Holland		Fountain	England
	Tacquet	France		Goldbach	
	Tchirnhausen			Guisnée	
	Vincent, St. Gré			Herman	Swiss
	Viviani	Tuscany		Halley	England
	Vlacq			Jacquier	France
	Ward, Seth	England		Koenig	Swiss
	Witt, John de	Holland		Long	France
	Amontons	France		M'Laurin	Scotland
	Auzout	Ditto		Mairan	France
	Bachet	Ditto		Mariotte	Ditto
	Fagnani	Italy		Maupertuis	Ditto
	Flamsteed	England		Mayer	Germany
	Grimaldi	Italy		Montmort	France
	Guido Grandi	Ditto		Nicole	Ditto
	Hudde	Holland		Riccati	Italy
	Keri	Hungary		Robins	
	Kinghuysen			Simson	England
	Lagnay	France		Walmsley	
	Lieutard	Ditto		Agnesia Donna	Spain
	Meraldi	Italy		Atwood	England
	Molyneux	Ireland		Bailly	France
	Oldenburgh	Bremen		Bezout	Ditto
	Ozanam	France		Borda	Ditto
	Pell	England		Carnot	Ditto
	Picart	France		Emerson	England
	Reyneau	Ditto		Horsley	Ditto
	Schooten	Holland		Harris	Ditto
	Wren	England		Herschel	Ditto
1700	Billi, De	France		Kestner	

A.D.	Name.	Country.	A.D.	Name.	Country.
1700	Lalande	France	1700	Steward	Scotland
	Maskelyne	Ditto		Vandermond	
	Montucla	Ditto		Vega	
	Pingree	Ditto		Wargentin	
	Robison	Scotland			

Mathematical Instruments, see Instruments.

MAUSOLEUM, is the term now generally used to designate a sepulchral chapel or edifice erected for the reception of a monument; but it originally applied only to the magnificent structure raised by Artemisia, as the tomb of her husband Mausolus, king of Caria, at Halicarnassus, B.C. 352. Of this monument, once reckoned among the wonders of the world, no remains now exist; but from Pliny's description (xxxvi. 5,) it appears to have been nearly square in its plan, measuring 113 feet on its sides, and 93 on each of its ends or fronts, and to have been decorated with a peristyle of 36 columns (supposed by Hardouin to have been 60 feet, or upwards), above which the structure was carried up in a pyramidal form, and surmounted, at its apex, by a marble quadriga, executed by Pythis, who, according to Vitruvius, was joint architect with Satyrus in the building. It was also richly decorated with sculptures and reliefs, by Scopas, Bryaxis, Timotheus, and Leochares. The entire height was 140 feet.

The mausoleum erected at Babylon by Alexander the Great, in honour of Hephæstion, appears to have been still more magnificent, and somewhat extravagant in its decorations, as far as can be gathered from the account of it by Diodorus (xvii. 115). Below it was adorned by the gilded rostra, or beaks, of 240 ships, and every successive tier or story was enriched with a profusion of sculpture, representing various animals, fighting centaurs, and other figures, all of which were gilt. On the summit were statues of sirens, made hollow, in order that the singers who chanted the funeral dirge might be concealed within them.

Those of Augustus and Hadrian, at Rome, were also structures of great magnitude and grandeur, and resembled each other in form, being circular on the plan. The first stood in the Campus Martius, where remains of it yet exist in the two concentric circles forming the first and second stories of the building, and the vaulted chambers between, which supported the first or lowest terrace. Of these terraces there were three, consequently four stages in the building, gradually decreasing in diameter, the uppermost of which was crowned by a colossal statue of the emperor. The terraces themselves were planted with trees. From traces of something of the kind that yet remain, it is conjectured that there was originally an advanced portico attached to the building, in the same manner as that of the Pantheon, though considerably smaller in proportion to the rest of the plan, as it could not have been carried up higher than the first stage of the building. According to Hirt's representation of it, in his "Baukunst bei den Alten," it was a Corinthian hexastyle, advanced one intercolumn before the side-walls connecting it with the circular edifice behind it.

Hadrian's mausoleum, now converted into the Castello di St. Angelo, in which shape it is familiar to almost every one, is a work of most massive construction, and originally presented an unbroken circular mass of building, erected upon a larger square basement, lofty in itself, yet of moderate height in proportion to the superstructure, the latter being about twice as high as the former. This nearly solid rotunda, which was originally coated with white marble, had on its summit numerous fine statues, which were broken to pieces, and the fragments hurled down by the soldiers of Belisarius upon the Goths, who attempted to take the building by storm. Neither are any remains now left of the uppermost stage of the edifice, which assumed the form of a circular peripteral temple, whose diameter was about one-third of the larger circle. According to tradition, its peristyle consisted of the 24 beautiful Corinthian columns, which afterwards decorated the basilica of San Paulo fuori delle Mura (partially destroyed some years ago by fire, but now nearly restored); and its tholus or dome was surmounted by a colossal pine-apple in bronze, now placed in the gardens of the Vatican.

Such places as Henry VII.'s chapel, and the Pantheon of the Escurial, may also be considered as mausoleums; but the term is generally restricted to a detached edifice erected merely as a private burying-place, or to contain tombs. There are several structures of the kind in the parks of our nobility; among the most remarkable is that at Castle Howard, the seat of the earl of Carlisle, and one of Hawksmoor's best works, a noble circular edifice in the Roman-Doric style, elevated upon a basement, and crowned by a dome: plans, sections, &c. of this structure have been beautifully engraved by Moses. The marquis of Rockingham's mausoleum, by Carr, is another ornamental structure of the kind, composed of three stories, Doric, Ionic, and Corinthian. We may also mention those at Cobham, in Kent, and Brocklesby, in Lincolnshire, by the late James Wyatt. The mausoleum of Louisa, queen of Prussia, at Charlottenburg, near Berlin, has a Grecian-Doric portico, but is not so remarkable as a building as for containing the sarcophagus, on which is the recumbent figure of that princess, the chef d'œuvre of Rauch's chisel.

MEASURE (from the Latin *mensura*), in geometry, any certain quantity assumed as one, or unity, to which the ratio of other homogeneous or similar quantities is expressed.

This definition is somewhat more agreeable to practice than that of Euclid, who defines measure as "a quantity, which, being repeated any number of times, becomes equal to another;" which only answers to the idea of an arithmetical measure, or quota part.

Measure of an Angle, an arc described from the vertex in any place between its legs. Hence angles are distinguished by the ratio of the arcs, described from the vertex between the legs, to the peripheries.

Angles, then, are distinguished by those arcs; and the arcs are distinguished by their ratio to the periphery. *See* Angle.

It is, however, in many cases, a more simple and more convenient method to estimate angles, not by the arcs subtending them, but by their sines, or the perpendicular falling from one leg to the other. Thus it is usual, among those who are taking the level of the ground, to say that it rises or falls one foot, or one yard, in ten, when the sine of the angle of its inclination to the horizon is one-tenth of the radius. Angles of different magnitudes, are, indeed, proportional to the arcs, and not to the sines; so that in this sense the sine is not a true measure of the comparative magnitude of the angle; but in making calculations, we are more frequently obliged to employ the sine or cosine of an angle than the angle or arc itself. Nevertheless it is easy to pass from one of these elements to the other, by means either of trigonometrical tables, or of the scales engraved on the sector.

Measure of a Figure, or Plane Surface, a square, whose side is one inch, foot, yard, or other determinate length.

Among geometricians it is usually a rod, called a *square rod*, divided into ten square feet, and the square feet into square digits. Hence square measures. See Mensuration.

Measure of Force, *for perforating metal and other substances.* The measure of the force necessary to punch a hole through a plate of metal or other substance, must be an interesting subject to scientific readers. We shall therefore here insert the result of Mr. Bevan's experiments made on that subject. A good cylindrical steel punch was made and fitted to a guide or director, so as to move correctly to a cylindrical hole in a steel plate connected with the guide; with this instrument, the artist was able to force cylinders of metal very uniform, and with little or no bur to the hole, both by simple pressure and percussion. The results of some experiments made on the force of simple pressure, to make a hole through a metal plate of one-eighth of an inch in thickness, and one-fourth of an inch in diameter, are as follows:—Plate iron, 3,900 lbs.; cast brass, 3,200 lbs.; hammered brass, 3,600 lbs.; copper, 2,800 lbs. The following are the results from the same machine, on specimens of wood, in the direction of the grain, of the same thickness and diameter:—Christiana deal, 135 lbs.; mahogany, 170 lbs.; dry boxwood, 356 lbs.; beech, 204 lbs.; ash, 197 lbs.; oak, 156 lbs.; elm, 122 lbs.

Measure of a Line, any right line taken at pleasure, and considered as unity.

Measures, *Line of*, see Line.

Measure of the Mass, or Quantity of Matter, in mechanics, is its weight; it being apparent, that all the matter which coheres and moves with a body, gravitates with it; and it being found by experiment that the gravities of homogeneal bodies are in proportion to their bulks: hence, while the mass continues the same, the absolute weight will be the same, whatever be its figure; but as to its specific weight, it varies as the quantity of surface varies. *See* Weight.

Measure of a Number, in arithmetic, a number which divides another, without leaving any fraction; thus 9 is a measure of 27.

Measure of a Solid, a cube whose side is one inch, foot, yard, or other determined length.

Among geometricians it is sometimes a rod, or perch, called a *cubic perch;* divided into cubic feet, digits, &c. Hence cubic measures, or measures of capacity. *See* Cube and Mensuration.

Measure of Velocity, in mechanics, the space passed over by a moving body in any given time. To measure a velocity, therefore, the space must be divided into as many equal parts as the time is conceived to be divided into. The quantity of space answering to such an interval of time is the measure of the velocity.

Measure, *Universal and Perpetual*, a kind of measure unalterable by time, to which the measures of different nations and ages might be reduced, and by which they might be compared and estimated. Such a measure is very desirable, if it could be attained. Huygens, in his *Horol. Oscill.*, proposes, for this purpose, the length of a pendulum vibrating seconds, taken from the point of suspension to the point of oscillation. The third part of such a pendulum may be called the *horary foot*, and serve as a standard to which the measure of all other feet may be preferred. Thus, *e. g.* the proportion of the Paris foot to the horary foot would be that of 864 to 881; because the length of three Paris feet is 864 half lines, and the length of a pendulum vibrating seconds contains three horary feet, or 3 feet 8½ lines, *i. e.* 881 half lines. But this measure, in order to its being universal, supposes, that the action of gravity is everywhere the same, which is contrary to fact; and, therefore, it would really serve only for places under the same parallel of latitude; and in order to its being perpetual, it supposes that the action of gravity continues always the same in the same place.

Measure, in a legal, commercial, and popular sense, denotes a certain quantity or proportion of anything bought, sold, valued, or the like. It denotes also a vessel of capacity employed in measuring grain and other articles: the fourth part of a peck. The regulation of weights and measures ought certainly to be the same throughout the kingdom, and therefore be reducible to some fixed rule or standard; the prerogative of so fixing it was vested, by our ancient law, in the crown. This standard was originally kept at Winchester; and we find, in the laws of king Edgar, cap. 8, near a century before the Conquest, an injunction, that the one measure, which was kept at Winchester, should be observed throughout the realm. With respect to measures of length, our ancient historians (Wil. Malm. *in Vita. Hen. I.* Spelm. *Hen. I. apud Wilkins*, 299) inform us, that a new standard of longitudinal measure was ascertained by king Henry I., who commanded that the ulna, or ancient ell, which answers to the modern yard, should be made of the exact length of his own arm; and one standard of measures of length once gained, all others are easily derived from hence: those of greater length by multiplying; those of less by subdividing the original standard. Thus, by the statute called "*Compositio ulnarum et perticarum*," 5½ yards make a perch; and the yard is subdivided into 3 feet, and each foot into 12 inches, which inches will be each of the length of 3 grains of barley. The standard of weights was originally taken from corns of wheat, whence the lowest denomination of weights which we have still expressed by a "grain," 32 of which are directed by the statute called "*Compositio mensurarum*," to compose a pennyweight, of which 20 make an ounce, 12 ounces a pound, and so upwards. Upon these principles the standards were first made, which, being originally so fixed by the crown, their subsequent regulations have been generally made by the king in parliament. Thus, under king Richard I., in his parliament holden at Westminster, A. D. 1197, it was ordained that there should be only one weight and one measure throughout the kingdom, and that the custody of the assize, or standard of weights and measures, should be committed to certain persons in every city and borough. In king John's time, this ordinance of king Richard was frequently dispensed with for money (Hoved. A. D. 1201), which occasioned a provision to be made for enforcing it, in the great charters of king John and his son.—*Stat.* 9. *Hen. III. c.* 25.

The statute of Magna Charta, cap. 25, ordains that there shall be but one measure throughout England, according to the standard in the Exchequer, which standard was formerly kept in the king's palace; and in all cities, market-towns, and villages, it was kept in the churches. (4 Inst. 273.) By 16 Car. I. cap. 19, there is to be one weight and measure, and one yard, according to the king's standard; and whoever shall keep any other weight or measure, whereby anything is bought or sold, shall forfeit for every offence five shillings; and by 22 Car. II. cap. 8, water measure (viz., five pecks to the bushel), as to corn, or grain, or salt, is declared to be within the statute 16 Car. I.; and if any sell grain, or salt, &c., by any other bushel or measure than what is agreeable to the standard in the Exchequer, commonly called Winchester measure, he shall forfeit 40s. (22 Car. II. c. 8. 22 and 23 Car. II. c. 12.) Notwithstanding these statutes, in many places and counties there were, till within the last few years, many different measures of corn and grain, and also of length and solidity. Great inconvenience being felt in consequence, the government at length interfered, and introduced a bill into parliament for the establishment of a uniform system throughout the country.

This system, called the Imperial, came into operation on the 1st May, 1825, on which day a total alteration took place in the weights and measures hitherto used in Great Britain. The principles upon which this alteration was founded we shall now proceed briefly to describe.

The Rationale of the Imperial System.—Take a pendulum which will vibrate seconds in London, on a level of the sea, in a vacuum; divide all that part thereof which lies between the axis of suspension and the centre of oscillation into 391·393 equal parts; then will ten thousand of those parts be an imperial inch, twelve whereof make a foot, and thirty-six whereof make a yard.

The *Standard Yard* is "that distance between the centres of the two points in the gold studs in the straight brass rod, now in the custody of the clerk of the House of Commons, whereon the words and figures 'standard yard, 1760,' are engraved, which is declared to be the genuine standard of the measure of length called a yard; and as the expansibility of the metal would cause some variation in the length of the rod in different degrees of temperature, the act determines that the brass rod in question shall be of the temperature of 62 degrees Fahrenheit. The measure is to be denominated the 'imperial standard yard,' and to be *the only standard whereby all other measures of lineal extension shall be computed.* Thus the *foot*, the *inch*, the *pole*, the *furlong*, and the *mile*, shall bear the same proportion to the imperial standard yard as they have hitherto borne to the yard measure in general use." The act also makes provision for the restoration of the standard yard, in case of loss, destruction, or defacement, by reference to an *invariable* natural standard, which is to be that proportion which the yard bears to the length of a pendulum vibrating seconds of time in the latitude of London, in a vacuum at the level of the sea, which is found to be as 36 inches (the yard) to 391·393 (the pendulum); thus a sure means is established to supply the loss which might by possibility occur.

Take a cube of one such inch of distilled water at 62° of temperature by Fahrenheit's thermometer; let this be weighed by any weight, and let such weight be divided into 252·458 equal parts, then will one thousand of such parts be a troy grain; and seven thousand of those grains will be a pound avoirdupois, the operation having been performed in air. Ten pounds such as those mentioned, of distilled water, at 62° of temperature, will be a gallon, which gallon will contain two hundred and seventy-seven cubic inches, and two hundred and seventy-four one-thousandth parts of another cubic inch.

The Standard Pound is determined to be that standard pound *troy* weight made in the year 1758, in the custody of the clerk of the House of Commons: such weight is to be denominated the "imperial standard troy pound;" and after the first of May, 1825, is to be "*the only standard measure of weight, from which all other weights shall be derived, computed, and ascertained*, and that one twelfth part of the said troy pound shall be *an ounce*, and one twentieth part of such ounce shall be *a pennyweight*, and that one twenty-fourth part of such pennyweight shall be *a grain;* so that 5760 such grains shall be *a pound troy*, and 7000 such grains shall be declared to be *a pound avoirdupois*, and one sixteenth part of the said pound avoirdupois shall be *an ounce avoirdupois*, and one sixteenth part of such ounce shall be *a drachm*."

If the standard pound shall be lost, destroyed, or defaced, the act directs that it shall be recovered by reference to the weight of a cubic inch of water: it having been ascertained that a cubic inch of distilled water, weighed in air by brass weights, at the temperature of 62° Fahrenheit, and the barometer at 30 inches, is equal to 252·458 grains; and, as the standard troy pound contains 5760 such grains, it is therefore established that the original standard pound may be at any time recovered by making another weight to bear the proportion just mentioned to a cubic inch of water.

The Standard Gallon is determined by the act to be such measure as shall contain ten pounds avoirdupois of distilled water, weighed in air, at the temperature of 62° Fahrenheit, and the barometer at 30 inches, and such measure is declared to be the "imperial standard gallon, and shall be the unit and *only standard measure of capacity to be used, as well for wine, beer, ale, spirits, and all sorts of liquids, as for dry goods not measured by heaped measure;* and that other measures shall be taken in parts, or multiples, of the said imperial standard gallon—the quart being the fourth part of such gallon, and *the pint* one eighth part—two such gallons making *a peck*, eight such gallons *a bushel*, and eight such bushels *a quarter* of corn, or other dry goods not measured by heaped measure.

The Standard for Heaped Measure, for such things as are commonly sold by heaped measure, such as coal, culm, lime, fish, potatoes, fruit, &c., shall be "*the aforesaid bushel*, containing eighty pounds of water, as aforesaid, the same being made round with a plane and even bottom, and being 19½ inches from outside to outside;" and goods thus sold by heaped measure shall be heaped "in the form of a cone, such cone to be of the height of at least six inches, the outside of the bushel to be the extremity of the base of such cone;" three such bushels shall be a *sack*, and twelve such sacks shall be a *chaldron.*

Stricken Measure.—The last mentioned goods may be sold either by the heaped measure, or by the standard weight as before mentioned; but all other kinds of goods not usually sold by heaped measure, which may be sold or agreed for by measure, the same standard measure shall be used; but it shall not be heaped, but stricken with a round stick or roller, straight, and of the same diameter from end to end.

N.B.—Copies and models of the standard of length, weight, and measure, are to be made and verified under the direction of the Treasury, and every county to be supplied with them for reference whenever required; and after the first of May, 1825, all contracts for sale, &c., by weight or measure, shall relate to the standard, unless the contrary is specified. Existing weights and measures may be used, being marked so as to show the proportion they have to the standard measures and weights. Tables of equalization of the weights to be made by the Treasury; tables, also, for the customs and excise, by which the duties will be altered so as to make them equal to what they are at present, in consequence of the alterations in the weights and measures. *See* WEIGHTS.

The following extracts from the bill for ascertaining and establishing uniformity of weights and measures will explain this subject fully:—"Whereas it is necessary, for the security of commerce, and for the good of the community, that weights and measures should be just and uniform; and whereas, notwithstanding it is provided by the great charter, that there shall be but one measure and one weight throughout the realm; and, by the treaty of union between England and Scotland, that the same weights and measures should be used throughout Great Britain as were then established in England; yet different weights and measures, some larger and some less, are still in use in various places throughout the United Kingdom of Great Britain and Ireland; and the true measure of the present standard is not verily known, which is the cause of great confusion and of manifest frauds; for the remedy and prevention of those evils for the future, and to the end that certain standards of weights and measures should be established throughout the United Kingdom of Great Britain and Ireland, "Be it therefore enacted, by the king's most excellent majesty, by and with the consent of the lords spiritual and temporal, and commons, in this present parliament assembled, and by the authority of the same, that a cubic inch of distilled water in a vacuum, weighed by brass weights, also in a vacuum, at the temperature of 62° of Fahrenheit's thermometer, is equal to two hundred and fifty-two grains and seven hundred and twenty-four thousandth parts of a grain.

"And be it further enacted, that the standard measure of capacity, as well for liquid as for dry goods not measured by heaped measure, shall be the gallon containing ten pounds avoirdupois weight of distilled water, weighed in air, at the temperature of 62° of Fahrenheit's thermometer, the barometer being at thirty inches, to be used as well for wine, beer, ale, spirits, and all sorts of liquids, as for dry goods not measured by heaped measure; and eight such gallons shall be a bushel, and eight such bushels a quarter—of corn, or other dry goods not measured by heaped measure.

"And be it further enacted, that the standard measure of capacity for coals, culm, lime, fish, potatoes, or fruit, and all other goods and things commonly sold by heaped measure, shall be the aforesaid bushel, containing eighty pounds avoirdupois of water as aforesaid, the same being made round with a plane and even bottom, and being nineteen and a half inches from outside to outside of such standard measure as aforesaid.

"And be it further enacted, that all contracts, bargains, sales, and dealings, which shall be made or had within any part of the United Kingdom of Great Britain and Ireland, for any work to be done, or for any goods, wares, merchandise, or other thing to be sold, delivered, done, or agreed for, by weight or measure, where no special agreement shall be made to the contrary, shall be deemed, taken, and construed, to be made and had according to the weights and standard measures ascertained by this act; and in all cases where any special agreement shall be made, with reference to any weight or measure established by any local custom, the ratio or proportion which every such local weight or measure shall bear to any of the said standard weights or measures, shall be expressly declared and specified in such agreement, or otherwise such agreement shall be null and void.

"And whereas it is expedient, that persons should be allowed to use the several weights and measures which they may have in their possession, although such weights and measures may not be in conformity with the standard weights and measures established by this act; be it therefore enacted, that it shall and may be lawful for any person or persons to buy and sell goods and merchandise by any weights or measures, established either by local custom or founded on special agreement; provided always, that in order that the ratio or proportion which all such measures and weights shall bear to the standard weights and measures established by this act, shall be and become a matter of common notoriety, the ratio or proportion which all such customary measures and weights shall bear to the said standard measures, shall be painted or marked upon all such customary weights and measures respectively; and that nothing herein contained shall extend, or be construed to extend, to permit any makers of weights or measures, or any person or persons whomsoever, to make any weight or measure at any time after, except in conformity with the standard weights and measures established under the provisions of this act.

"And be it further enacted, that accurate tables shall be prepared and published, showing the proportions between the weights and measures heretofore in use, as mentioned in such inquisitions, and the weights and measures hereby established; and after the publication of such tables, all future payments to be made shall be regulated according to such tables.

"And whereas the weights and measures by which the rates and duties of the customs and excise, and other his majesty's revenue, have been heretofore collected, are different from the weights and measures of the same denominations directed by this act to be universally used; and whereas the alteration of such weights and measures may, without due care had therein, greatly affect his majesty's revenue, and tend to the diminishing of the same; for the prevention thereof, be it therefore enacted, that, so soon as conveniently may be, accurate tables shall be prepared and published, in order that the several rates and duties of customs and excise, and other his majesty's revenue, may be adjusted and made payable according to the respective quantities of the legal standards directed by this act to be universally used; and that from and after the publication of such tables, the several rates and duties thereafter to be collected by any of the officers of his majesty's customs or excise, or other his majesty's revenue, shall be collected and taken according to the calculations in the tables to be prepared as aforesaid."

Table of the several Standard Measures.—English Long Measure.

Barleycorns.	Inches.	Feet.	Yards.	Poles.	Fur.	Mile.
3 =	1					
36 =	12 =	1				
108 =	36 =	3	1			
594 =	198 =	16½	5½ =	1		
23,768 =	7,920 =	660 =	220 =	40 =	1	
190,080 =	63,360 =	5,280 =	1,760 =	320 =	8 =	1

ALSO:—

4	Inches	= 1	Hand
6	Feet	= 1	Fathom
3	Miles	= 1	League
60	Geographical miles	= 1	Degree
69⅓	English miles	= 1	Degree nearly
360	Degrees, or 25,000 miles, is equal to the circumference of the earth, nearly.		

Cloth Measure.

Inches.	Nails.	Quarters.	
2½ =	1		
9 =	4 =		
36 =	16 =	4 =	1 yard
27 =	12 =	3 =	1 ell Flemish
45 =	20 =	5 =	1 ell English
54 =	24 =	6 =	1 ell French

The French standard was formerly the aune, or ell, containing 3 Paris feet, 7 inches, 3 lines, or 1 yard 2-sevenths English; the Paris foot-royal exceeding the English by 68 thousandth-parts. This ell is divided two ways, viz., into halves, thirds, sixths, and twelfths, and into quarters, half-quarters, and sixteenths.

The standard in Holland, Flanders, Sweden, and a good part of Germany—many of which were formerly called the Hans-towns, as Dantzic and Hamburg, and at Geneva, Frankfort, &c.—is likewise the ell; but the ell in all these places differs from the Paris ell. In Holland, it contains one Paris foot eleven lines, or four-sevenths of the Paris ell. The Flanders ell contains two feet one inch five lines and half a line, or seven-twelfths of the Paris ell. The ell of Germany Brabant, &c. is equal to that of Flanders.

The Italian measure is the branchio, brace, or fathom. This obtains in the states of Modena, Venice, Florence, Lucca, Milan, Mantua, Bologna, &c., but is of different lengths. At Venice, it contains one Paris foot eleven inches three lines, or eight-fifteenths of the Paris ell. At Bologna, Modena, and Mantua, the brace is the same as at Venice. At Lucca, it contains one Paris foot nine inches ten lines, or half a Paris ell. At Florence, it contains one foot nine inches four lines, or forty-nine hundredths of a Paris ell. At Milan, the brace for measuring of silks is one Paris foot seven inches four lines, or four-ninths of a Paris ell; that for woollen cloths is the same with the ell of Holland. Lastly, at Bergamo, the brace is one foot seven inches six lines, or five-ninths of a Paris ell. The usual measure at Naples, however, is the canna, containing six feet ten inches and two lines, or one Paris ell and fifteen-seventeenths.

The Spanish measure is the vara, or yard—in some places called the bara—containing seventeen twenty-fourths of the Paris ell. But measure in Castile and Valencia is the pan, span, or palm, which is used, together with the canna, at Genoa. In Arragon, the vara is equal to a Paris ell and a half, or five feet five inches six lines.

The Portuguese measure is the cavedos, containing two feet eleven lines, or four-sevenths of a Paris ell; and the vara, an hundred and six whereof make an hundred Paris ells.

The Piedmontese measure is the ras, containing one Paris foot nine inches ten lines, or half a Paris ell. In Sicily, their measure, the canna, the same with that of Naples.

The Muscovy measures are the cubic, equal to one Paris foot four inches two lines; and the arcin, two whereof are equal to three cubits.

The Turkish and Levant measures are the picq, containing two feet two inches and two lines, or three-fifths of the Paris ell. The Chinese measure, the cobre, ten whereof are equal to three Paris ells. In Persia, and some parts of the Indies, the gueze, whereof there are two kinds; the royal gueze, called also the *gueze monkelser*, containing two Paris feet ten inches eleven lines, or four-fifths of the Paris ell; and the shorter gueze, called simply *gueze*, only two-thirds of the former. At Goa and Ormuz, the measure is the vara, the same with that of the Portuguese, having been introduced by them. In Pegu, and some other parts of the Indies, the cando, or candi, equal to the ell of Venice. At Goa, and other parts, they use a larger cando, equal to seventeen Dutch ells; exceeding that of Babel and Balsora by $\frac{7}{8}$ per cent., and the vara by $6\frac{1}{2}$. In Siam, they use the ken, short of three Paris feet by one inch. The ken contains two soks, the sok two keubs, the keub twelve nious, or inches, the niou to be equal to eight grains of rice, *i. e.* to about nine lines. At Camboia, they use the haster; in Japan, the tatam; and the span on some of the coasts of Guinea.

Square Measure.

Inches.					
144 =	1 foot				
1,296 =	9 =	1 yard			
39,204 =	$272\frac{1}{4}$ =	$36\frac{1}{4}$ =	1 pole		
1,568,160 =	10,890 =	1,210 =	40 =	1 rood	
6,272,640 =	43,560 =	4,840 =	160 =	4 =	1 acre

Also: $5\frac{1}{2}$ yards . . . . = 1 pole
40 poles . . . . = 1 rood
4 roods . . . . = 1 acre

Square, Superficial, or Land Measure.—English square measures are raised from the yard of 36 inches multiplied into itself, and thus producing 1,296 square inches in the square yard; the divisions of this are square feet and inches; and the multiples, poles, roods, and acres. Because the length of a pole is $5\frac{1}{2}$ yards the square of the same contains $30\frac{1}{4}$ square yards. A square mile contains 640 square acres. In measuring fens and woodlands, 18 feet are generally allowed to the pole, and 21 feet in forest-land. A hide of land, frequently mentioned in the earlier part of the English history, contained about 100 arable acres; and five hides were esteemed a knight's fee. At the time of the Norman conquest, there were 243,600 hides in England.

Scotch square or land measure is regulated by the Scotch ell: 36 square ells = 1 fall; 40 falls = 1 rood; 4 roods = 1 acre. The proportion between the Scotch and English acre, supposing the feet in both measures alike, is as 1,369 to 1,089, or nearly as five to four. If the difference of the feet be regarded, the proportion is as 10,000 to 7,869. The length of the chain for measuring land in Scotland is 23 ells, or 74 feet. A husband-land contains six acres of sock and scythe land—that is, of land that may be tilled with a plough, or mown with a scythe; 13 acres of arable land make one ox-gang; and four ox-gangs make a poundland of old extent.

French square measures are regulated by 12 square lines in the inch square, 12 inches in the foot, 22 feet in the perch, and 100 perches in the arpent or acre.

In the following tables, the reader will find enumerated the various general standing measures—long, square, and cubic, now or heretofore in use, with their proportions and reductions.

TABLES OF DIFFERENT MEASURES, ACCORDING TO VARIOUS AUTHORITIES, REDUCED TO ENGLISH MEASUREMENT.

LONG MEASURES.

Table I.—Scripture Long Measure.

			English Ft.	English In.
1 Digit	. . . .	=	0	0.912
4 Digits	= 1 Palm	=	0	3.648
3 Palms	= 1 Span*	=	0	10.944
2 Spans	= 1 Cubit †	=	1	9.888
4 Cubits	= 1 Fathom	=	7	3.552
$1\frac{1}{2}$ Fathoms	= 1 Reed (Ezekiel's) . .	=	10	11.328
$1\frac{1}{3}$ Reeds	= 1 Pole (Arabian) . . .	=	14	7.104
10 Poles	= 1 Scænus, or measuring line	=	145	1.104

* The Orientals used another span, equal to one-fourth of a cubit.

† See Table II.

Table II.—Jewish Long, or Itinerary Measures.

			English Miles.	English Paces.	English Feet.
1 Cubit*	. . . .	=	0	0	1.824
400 Cubits . . .	= 1 Stadium . . .	=	0	145	4.6
5 Stadii . . .	= 1 Sab. day's journ.	=	0	729	3.0
2 Sab. day's journ.	= 1 Eastern mile .	=	1	403	1.0
3 Eastern miles .	= 1 Parasang . .	=	4	153	3.0
8 Parasangs . .	= 1 Days' journey	=	33	172	4.0

* Dr. Hutton reckons the Hebrew cubit as follow: Eng. feet.
Common Cubit . . . . = 1.817
Sacred cubit . . . . = 2.002
Great cubit = 6 common cubits . . . . . = 10.902
The Hebrew foot, according to Dr. Hutton, was equal to 1.212 English foot.

Table III.—Grecian Long Measures.

				English Pa.	English Ft.	English Inches.
1	Dactylus or Digit		=	0	0	$0.7554\frac{1}{10}$
4	Dactyli . .	= 1 Doron, or Dochme, or Palesta	=	0	0	$3.0218\frac{3}{4}$
$2\frac{1}{2}$	Palestæ, &c.	= 1 Lichas . . .	=	0	0	$7.5546\frac{7}{8}$
$1\frac{1}{10}$	Lichas . .	= 1 Orthodoron .	=	0	0	$8.3101\frac{9}{10}$
$1\frac{1}{11}$	Orthodoron	= 1 Spithame . .	=	0	0	$9.0656\frac{1}{4}$

			Pa.	Ft.	English Inches.
$1\frac{1}{3}$ Spithame	= 1	Pous, or foot*	0	1	0.0875
$1\frac{1}{8}$ Pous	= 1	Pygme, or cubit	0	1	$1.5984\frac{3}{8}$
$1\frac{1}{9}$ Pygme	= 1	Pygon	0	1	$3.109\frac{3}{8}$
$1\frac{1}{5}$ Pygon	= 1	Pecus, or larger cubit	0	1	6.13125
4 Pecus	= 1	Orgya, or pace	0	6	0.525
100 Orgya, or paces	= 1	Stadium, aulus, or furl.	100	4	4.5
8 Stadii, &c.	= 1	Million, or mile	805	5	0

* The Greek foot is variously estimated; thus:

	Eng. foot.
By Dr. Hutton†	= 1.009
By Folkes, who reckons it equal to $1\frac{1}{24}$ Roman foot	= 1.006 / 1.007
By Cavallo	= 1.007

† Dr. Hutton reckons the Phyleterian foot = 1.167; Macedonian foot = 1.160

N. B. Two sorts of long measures were used in Greece, viz., *the Olympic* and *the Pythic*: the former in Peloponnesus, Attica, Sicily, and the Greek cities in Italy; the latter in Thessaly, Illyria, Phocis, Thrace, and at Marseilles in Gaul.

		Eng. In.
The Olympic foot (properly called *Greek*) contains, according to	Dr. Hutton	12.108
	Folkes	12.072
	Cavallo	12.084
The Pythic foot, (called also *natural foot*,) contains, according to	Dr. Hutton	9.768
	Paucton	9.731

Hence it appears, that
The Olympic stadium is $201\frac{1}{2}$ English yards, nearly.
The Pythic or Delphic stadium, $162\frac{1}{2}$ yards, nearly.
And the other measures in proportion.
The Phyleterian foot is the Pythic cubit, or $1\frac{1}{2}$ Pythic foot.
The Macedonian foot was 13.92 English inches.
The Sicilian foot of Archimedes, 8.76 English inches.

Table IV.—Roman Long Measures.

			English Pa.	Ft.	In.
6 Scrupula	= 1	Sicilicum			
8 Scrupula	= 1	Duellum			
$1\frac{1}{2}$ Duellum	= 1	Seminaria			
18 Scrupula	= 1	Digitus transversus	0	0	$0.725\frac{3}{4}$
$1\frac{1}{3}$ Digiti	= 1	Uncia, or inch	0	0	0.967
3 Unciæ	= 1	Palma minor	0	0	2.901
4 Palmæ	= 1	Pes, or foot*	0	0	11.604
$1\frac{1}{4}$ Pes, or foot	= 1	Palmipes	0	1	2.505
$1\frac{1}{5}$ Palmipes	= 1	Cubit	0	1	5.406
$1\frac{2}{3}$ Cubits	= 1	Gradus	0	2	5.01
2 Gradus	= 1	Passus	0	4	10.02
2 Passus	= 1	Decempeda	1	4	8.04
125 Passus	= 1	Stadium	120	4	4.5
8 Stadii	= 1	Milliare, or Mile †	967	0	0

* The length of the Roman foot, in English inches, is stated by various writers as follows:

	Eng In.
By Bernard	11.640
By Picard and Hutton	11.604
By Folkes	11.592
By Raper (before Titus)	11.640
By the same (after Titus)	11.580
By Shuckburgh, from rules	11.6064
By the same, from buildings	11 6172
By the same, from a tomb-stone	11.6352

Hence 11.6 Eng. in. seem to be a medium; and, therefore, the Roman mile = 1611 English yds., being 149 yds. less than the English mile.

Its proportion to the English foot is thus stated:—

By Bernard	.970	By Raper	Before Titus	.970
By Picard and Greaves	.976		After Titus	.965
		By Shuckburgh	From Rules	.9672
			From Build.	.9681
By Folkes	.966 / .967		From a Stone.	9696
		By Dr. Hutton		.967

† The Roman mile of Pliny (according to Cavallo) contained 4840.5 English feet; and that of Strabo 4903.

Table V.—Ancient Long Measures, according to Dr. Hutton.

	Eng. Feet.
Arabian foot	= 1.095
Babylonian foot	= 1.144 / 1.135
Drusian foot	= 1.090
Egyptian foot	= 1.421
——— stadium	= 7.308
Natural foot	= .814
Ptolemaic = the Greek foot (see Table III.)	
Sicilian foot of Archimedes	= .730

Table VI.—Scottish Long Measures.

	Eng. Inches.
An Ell	= 37.2
A Fall	= 223.2
A Furlong	= 8928.
A Mile	= 71424.
A Link	= 8.928
A Chain, or Short Rood	= 89.28
A Long Rood	= 1339.2

Table VII.—French Long Measures, before the First Revolution.

	Eng. Inches.
A Point	= .0148025, or nearly $\frac{2}{135}$.
A Line	= .088815, or nearly $\frac{8}{90}$.
An Inch, or Pouce	= 1.06578, or, $\frac{1}{93828}$, or $\frac{81}{76}$.
A Foot	= 12.78933
An Ell, or Aune*	= 46.8947, or 44 French In.; or, according to Vega, 43.9
A Sonde	= 63.9967, or 5 French feet, about $\frac{8}{9}$ English fathom.
A Toise, or Fathom	= 76.7360, or 6 French feet.†
A Perche	= 230.2080, or 18 French feet.
A Perche, mesure royale	= 22 French feet.
A League	= 2282 toises, or $\frac{1}{25}$ of a degree

* The aune, or ell, of Paris, varies, being for silk stuffs 527.5 lines, or $46\frac{17}{20}$ English inches; for woollens, 526.4 French lines, or $46\frac{3}{4}$ English inches; for linens, 524 French lines, or $46\frac{11}{20}$ English inches; and it varies still more in other parts of France.

† Formerly 76.71, *Phil. Trans.* for 1742.

Table VIII.—French Long Measures, according to the Present System.

	Eng. Inches.
Millimetre	= .03937
Centimetre	= .39371
Decimetre	= 3.93710
Metre	= 39.37100, or 3.281 feet, or 1.09364 yards, or nearly 1 yard $1\frac{1}{2}$ nail, or 443.2959 French lines, or .513074 toise.
Decametre	= 393.71000, or 10 yards, 2 feet, 9.7 inches.
Hecatometre	= 3937.10000, or 100 yards, 1 foot, 1 inch.
Chiliometre	= 39371.00000, or 4 furlongs, 213 yards, 1 foot 10.2 inches: so that 8 chiliometres are nearly 5 miles.
Myriometre	= 393710.0000, or 6 miles, 1 furlong, 136 yards, 0 feet, 6 inches.

N.B. An inch is .0354 metres; 2441 inches 62 metres; 1000 feet nearly 305 metres.

In order to express decimal proportions in this new system, the following terms have been adopted. The term *Deca* prefixed denotes 10 times; *Heca*, 100 times; *Chilio*, 1000 times; and *Myrio*, 10,000 times. On the other hand, *Deci* expresses the tenth part; *Centi*, the hundredth part; and *Milli*, the thousandth part; so that *Decametre* signifies 10 metres; and a *Decimetre*, the 10th part of a metre, &c. &c. The *Metre* is the element of long measures; *Are*, that of square measures; *Stere*, that of solid measures; the *Litre* is the element of all measures of capacity; and the *Gramme*, which is the weight of a cubic centimetre of distilled water, is the element for all weights.

Table IX.—Proportions of several Long Measures to each other, by M. Picard.

	Parts.
The Rhinland, or Leyden foot, (12 whereof make the Rhinland perch) supposed	696
The English foot	675½
The Paris foot	720
The Amsterdam foot, from that of Leyden, by Snellius	629
The Danish foot (two whereof make the Danish ell)	701 8/10
The Swedish foot	658¼
The Brussels foot	609⅗
The Dantzic foot, from Hevelius's Selenographia	636
The Lyons foot, by M. Auzout	757⅔
The Bologna foot, by the same	843
The braccio of Florence, by the same, and father Mersenne	1290
The palm of the architects at Rome, according to the observations of Messrs. Picard and Auzout	494¼
The Roman foot in the Capitol, examined by Messrs. Picard and Auzout	653 or 653½
The same from the Greek foot	652
From the vineyard Mattei	657½
From the palm	658¼
From the pavement of the Pantheon, supposed to contain 10 Roman feet	653
From a slip of marble in the same pavement, supposed to contain 3 Roman feet	650
From the pyramid of Cestius, supposed to contain 95 Roman feet	653½
From the diameters of the columns in the arch of Septimius Severus	653⅓
From a slip of porphyry in the pavement of the Pantheon	653⅓

Table X.—Proportions of the Long Measures of several Nations to the English Foot, taken from Greaves, Auzout, Picard, and Eisenchmid.

The English standard foot being divided into 1000 equal parts, the other measures will have the proportions to it which follow:—

	Parts.	Inches.
English foot	1000	12.
Paris foot	1068	12.816
Venetian foot	1162	13.944
Rhinland foot	1033	12.396
Strasburg foot	952	11.424
Nuremberg foot	1000	12.
Dantzic foot	944	11.328
Danish foot	1042	12.504
Swedish foot	977¾	11.733
Derahor cubit of Cairo	1824	21.888
Persian arish	3197	38.364
Greater Turkish pike	2200	26.4
Lesser Turkish pike	2131	25.572
Braccio at Florence	1913	22.956
Braccio for woollen at Sienna	1242	14.904
Braccio for linen at Sienna	1974	23.688
Canna at Naples	6880	82.56
Vera, at Almeira and Gibraltar	2760	33.12
Palmo di Archtetti at Rome	7320	87.84
Fanna di Archtetti	7320	87.84
Palmo di braccio di mercantia	695½	8.346
Genoa palm	815	9.78
Bolognian foot	1250	15.
Antwerp ell	2283	27.396
Amsterdam ell	2268	27.216
Leyden ell	2260	27.12
Paris draper's ell	3929	47.148
Paris mercer's ell	3937	47.244

Table XI.—Modern Long Measures of several Countries compared with English Feet.

Compiled by Dr. Young, from various Authorities.

	Eng. Ft.	Authorities.
Altdorf, foot	.775	Dr. Hutton
Amsterdam, foot	.927	ditto
	.930	Cavallo
	.931	Howard
Amsterdam, ell	2.233	Cavallo
Ancona, foot	1.282	Dr. Hutton
Antwerp, foot	.940	ditto
Aquileia, foot	1.128	ditto
Arles, foot	.888	ditto
Augsburg, foot	.972	ditto
Avignon = Arles. *See* Arles.		
Barcelona, foot	.992	ditto
Basle, foot	.994	ditto
Bavarian, foot	.968	Beigal. *See* Munich.
Bergamo, foot	1.431	Dr. Hutton
Berlin, foot	.992	ditto
Berne, foot	.962	Howard
Besançon, foot	1.015	Dr. Hutton
Bologna, foot	1.244	ditto
	1.250	Cavallo
Bourg en Bresse, foot	1.030	Dr. Hutton
Brabant, ell, in Germany	2.268	Vega
Bremen, foot	.955	Dr. Hutton
Brescia, foot	1.560	ditto
Brescian, braccio	2.092	Cavallo
Breslau, foot	1.125	Dr. Hutton
Bruges, foot	.749	ditto
Brussels, foot	.902	ditto
	.954	Vega
Brussels, greater ell	2.278	ditto
Brussels, lesser ell	2.245	ditto
Castilian, vara	2.746	Cavallo
Chambery, foot	1.107	Dr. Hutton
China, mathematical foot	1.127	ditto
China, imperial foot	1.051	ditto
	1.050	Cavallo
Chinese, li	606.	ditto
Cologne, foot	.903	Dr. Hutton
Constantinople, foot	2.195	ditto
	1.165	ditto
Copenhagen, foot	1.049	ditto
Cracau, foot	1.169	ditto
Cracau, greater ell	2.024	Vega

	Eng. Ft.	Authorities.
Cracau, smaller ell . .	1.855	Vega
Dantzic, foot	.923	Dr. Hutton
Dauphiné, foot . . .	1.119	ditto
Delft, foot	.547	ditto
Denmark, foot . . .	1.047	ditto
Dijon, foot	1.030	ditto
Dordrecht, foot . . .	.771	ditto
Dresden, foot . . .	.929	Wolfe, Ph. Trans. 1769.
Dresden ell = 2 feet .	1.857	Vega [Vega.
Ferrara, foot . . .	1.317	Dr. Hutton
Florence, foot . . .	.995	ditto
Florence, braccio . .	1.900	Cavallo
	1.910	ditto
Franche Comté, foot .	1.172	Dr. Hutton
Frankfort = Hamburg		ditto
Genoa, palm . . .	.812	ditto
	.800	Cavallo
	.817	ditto
Genoa, canna	7.300	ditto
Geneva, foot . . .	1.919	Dr. Hutton
Grenoble = Dauphiné		ditto
Haarlem, foot . . .	.937	ditto
Halle, foot	.977	ditto
Hamburg, foot . . .	.933	ditto
Heidelberg, foot . .	.903	ditto
Inspruck, foot . . .	1.101	ditto
Leghorn, foot . . .	.992	ditto
Leipzig, foot . . .	1.034	ditto
Leipzig, ell	1.833	Dr. Hutton, Journ. R. I.
Leyden, foot	1.023	ditto
Liege, foot	.944	ditto
Lisbon, foot	.952	ditto
Lucca, braccio . . .	1.958	Cavallo
Lyons = Dauphiné		
Madrid, foot	.915	Dr. Hutton
	.918	Howard
Madrid, vara	3.263	Cavallo
Maestricht, foot . . .	.916	Dr. Hutton
Malta, palm	.915	ditto
Mantua, brasso . . .	1.521	ditto
Mantuan, braccio = Brescian		Cavallo
Marseilles, foot . . .	.814	Dr. Hutton
Mechlin, foot, . . .	.753	ditto
Mentz, foot	.988	ditto
Milan, decimal foot . .	.855	ditto
Milan, aliprand foot .	1.426	ditto
Milanese, braccio . .	1.725	Cavallo
Modena, foot . . .	2.081	Dr. Hutton
Monaco, foot . . .	.771	ditto
Montpelier, pan . . .	.777	ditto
Moravian, foot . . .	.971	Vega
Moravian, ell . . .	2.594	ditto
Moscow, foot . . .	.928	Dr. Hutton
Munich, foot . . .	.947	ditto
Naples, palm	.861	ditto
	.859	Cavallo
Naples, canna . . .	6.908	ditto
Nuremberg, town foot	.996	Hutton
	.997	Vega
Nuremberg, country foot	.907	Dr. Hutton
Nuremberg, artillery foot	.961	Vega
Nuremberg, ell . . .	2.166	ditto
Padua, foot	1.406	Dr. Hutton
Palermo, foot . . .	.747	ditto
Paris, foot	1.066	ditto

	Eng. Ft.	Authorities.
Paris metre	3.281	Dr. Young
Parma, foot	1.869	Dr. Hutton
Parmesan, braccio . .	2.242	Cavallo
Pavia, foot	1.540	Dr. Hutton
Placentia = Parma . .		Cavallo
Prague, foot . . .	.987	Dr. Hutton
	.972	Vega
Prague, ell	1.948	ditto
Provence = Marseilles		Dr. Hutton
Rhinland, foot . . .	1.023	ditto
	1.030	Vega. Eytelwein
Riga = Hamburg . .		
Rome, palm	.733	Dr. Hutton
Rome, foot	.966	Folkes.
Rome, ditto, $\frac{1}{16}$ foot .	.0604	ditto
Rome, oncia, $\frac{1}{12}$ foot .	.0805	ditto
Rome, Palmo	.2515	ditto
Rome, palmo di architettura	.7325	ditto
Rome, canna di architettura	7.325	ditto
Rome, staiolo . . .	4.212	ditto
Rome, canna dei mercanti	6.5365	ditto, 8 palms
Rome, braccio dei mercanti	2.7876	ditto, 4 palms
	2.856	Cavallo
Rome, braccio di tessitor di tela	2.0868	Folkes
Rome, braccio di architettura	2.561	Cavallo
Rouen = Paris . .		Dr. Hutton
Russian, archine . . .	2.3625	Cavallo
Russian, arschin . . .	2.3333	Ph. M. XIX.
Russian, verschock, $\frac{1}{16}$ arschin	.1458	
Savoy = Chambery		Dr. Hutton
Seville = Barcelona		ditto
Seville, vara	2.760	Cavallo
Sienna, foot	1.239	Dr. Hutton
Stettin, foot	1.224	ditto
Stockholm, foot . . .	1.073	ditto
Stockholm, foot . . .	(.974	Celsius Ph. Tr.)
Strasburg, town foot .	.956	Dr. Hutton
Strasburg, country foot	.969	ditto
Toledo = Madrid . .		Dr. Hutton
Trent, foot	1.201	ditto
Trieste, ell for woollens	2.220	ditto
Trieste, ell for silk . .	2.107	ditto
Turin, foot	1.676	ditto
	1.681	Cavallo
Turin, ras	1.958	ditto
Turin, trabuco . . .	10.085	ditto
Tyrol, foot	1.096	Vega
Tyrol, ell	2.639	ditto
Valladolid, foot . . .	.908	Dr. Hutton
Venice, foot	1.137	ditto
	1.140	Bernard. Howard. Vega
	1.167	Cavallo
Venice, braccio of silk	2.108	ditto
Venice, ell	2.089	Vega
Venice, braccio of cloth	2.250	Cavallo
Verona, foot	1.117	Dr. Hutton
Vicenza, foot	1.136	ditto
Vienna, foot	1.036	ditto
	1.037	Howard. Cavallo. Vega
Vienna, ell	2.557	Vega
Vienna, post mile	24888.	ditto

	Eng. Ft.	Authorities.
Vienne in Dauphiné foot	1.058	Dr. Hutton
Ulm, foot	.826	ditto
Urbino, foot	1.162	ditto
Utrecht, foot	.741	ditto
Warsaw, foot	1.169	ditto
Wesel = Dordrecht		ditto
Zurich, foot	.979	ditto
	.984	Ph. M. VIII. 289.

Table XII.—A Comparison of the Foot, and other measures of Length, in different countries.

		Number of each equal to 100 English Feet.	Length of a single Measure of each sort. E. Inches.
Aix la Chapelle	Feet	105.18	11.41
Amsterdam	ditto	107.62	11.15
Anspach	ditto	102.38	11.72
Ancona	Feet	78.02	15.38
Antwerp	ditto	106.76	11.24
Aquileia	ditto	88.69	13.53
Augsburg	ditto	103.	11.65
Basil	ditto	102.22	11.74
Bavaria	ditto	105.08	11.42
Bergamo	ditto	69.89	17.17
Berlin	ditto	98.44	12.19
Berne	ditto	103.98	11.54
Bologna	ditto	80.05	14.99
Bremen	ditto	105.45	11.38
Brescia	Bracci	64.10	18.72
Breslaw	Feet	107.24	11.19
Brunswick	ditto	106.85	11.23
Brussels	ditto	104.80	11.45
Cadiz	(See Spain)		
Cagliari	Palmi	150.52	7.97
Calenberg	Feet	104.34	11.50
Carrara	Palmi	125.	9.60
Castille	(See Spain)		
Chambery	Feet	90.36	13.28
China	Mathematical feet	91.46	13.12
	Builders' ditto	94.41	12.71
	Tradesmen's ditto	90.08	13.32
	Land Surveyor's ditto	95.39	12.58
Cleves	Feet	103.18	11.63
Cologne	ditto	110.80	10.83
Copenhagen	Legal Feet	97.17	12.35
	Fathoms	16.20	74.10
	Ruthes	9.71	123.50
Cracow	Feet	85.53	14.03
Dantzic	ditto	106.28	11.29
	Ruthes	7.08	169.35
Dordrecht	Feet	84.74	14.16
Dresden	ditto	107.62	11.14
Embden	ditto	102.92	11.66
England	ditto	100.	12.
	Yards	33.33	36.
	Poles	6.06	198.
Ferrara	Feet	75.95	15.80
	Pertichi	11.11	108.
Florence	Builders' Bracci	55.55	21.60
France	Pieds du Roi	93.89	12.78
	Toises	15.65	76.68
	Metres	30.48	39.37
Francfort	Feet	106.48	11.27
Geneva	ditto	62.50	19.20
Genoa	Palmi	123.45	9.72
Gottingen	Feet	104.80	11.45
Gotha	ditto	106.	11.32
Groningen	ditto	104.44	11.49
	ditto	106.28	11.29
Hamburg	Rhinland ditto	97.17	12.35
	Clafters	17.71	67.74
	Masch Ruthes	7.59	158.06
	Geest ditto	6.64	180.64
	Rhinland ditto	8.10	148.20
Hanover	Feet	104.80	11.45
	Ruthes	6.50	183.20
Haerlem	Feet	106.67	11.25
Heidelberg	ditto	109.48	10.96
Hildesheim	ditto	108.60	11.05
Holstein	(See Copenhagen)		
Inspruck	Feet	96.	12.50
Konigsburg	ditto	99.09	12.11
Leghorn	(See Florence)		
Leipsic	Common feet	108.01	11.11
	Builders' ditto	107.81	11.13
Leyden	ditto	97.24	12.34
Liege	ditto	106.	11.32
Lindau	Common feet	105.26	11.40
	Long ditto	96.77	12.40
Lisbon	Feet	92.78	12.96
	Palmi	139.17	8.64
Lorraine	Feet	106.20	11.30
Lubec	ditto	104.80	11.45
	Ruthes	6.55	183.20
Luneburg	Feet	104.80	11.45
Madrid	(See Spain)		
Magdeburg	Feet	107.52	11.16
Malta	ditto	107.43	11.17
Manheim	ditto	105.39	11.41
Mantua	Bracci	65.75	18.25
Maestricht	Feet	108.60	11.05
Mecklenberg	(See Hanover)		
Mentz	Feet	101.26	11.85
Middleburg	ditto	101.61	11.81
Milan	ditto	76.82	15.62
	Bracci	62.34	19.25
Monaco	Feet	129.73	9.25
Moscow	ditto	91.12	13.17
Naples	Palmi	115.62	10.38
Neufchatel	Feet	101.61	11.81
Nuremberg	ditto	100.34	11.96
Oldenburg	ditto	103.	11.65
Osnaburg	ditto	109.09	11.
Padua	ditto	86.15	13.93
Palermo	Palmi	125.93	9.53
Paris	(See France)		
Parma	Surveyors' Bracci	56.23	21.34
Pavia	ditto	65.57	18.30
Persia	Arish	31.36	38.27
Pomerania	Feet	104.34	11.50
Portugal	(See Lisbon)		
Prague	Feet	101.	11.88
Ratisbon	(See Bavaria)		
Ratzburgh	Feet	104.80	11.45
Revel	ditto	113.96	10.53
Reggio	Bracci	57.55	20.85
Rhinland	Feet	97.17	12.35
Riga	ditto	111.21	10.79

		Number of each equal to 100 English Feet.	Length of a single Measure of each sort. E. Inches.
Rimini	Bracci	56.10	21.39
Rome	Feet	103.45	11.60
	Builders' Canne	13.65	87.92
	Palmi	136.49	8.79
Rostock	Feet	105.45	11.38
Rotterdam	(See Rhinland)		
Russia	Arsheens	42.86	28.
	Sashes	14.28	84.
	Feet	87.27	13.75
Sardinia	Palmi	122.70	9.78
Savoy	(See Chambery)		
Sienna	Feet	80.75	14.86
Sicily	(See Palermo)		
Silesia	Ruthes	7.06	170.
Spain	Feet	107.91	11.12
	Toesas	17.98	66.72
	Palmos	143.88	8.34
Stade	Feet	104.80	11.45
Stettin	ditto	107.91	11.12
Stockholm	(See Sweden)		
Strasburg	Feet	105.35	11.39
	Land ditto	103.28	11.62
	(See also France)		
Stutgard	(See Wurtemberg)		
Sweden	Feet	102.66	11.69
	Fathoms	17.11	70.14
	Rods	6.43	187.04
Trent	Feet	83.28	14.41
Turin	ditto	94.34	12.72
Ulm	ditto	105.35	11.39
Utrecht	ditto	111.82	10.74
Venice	ditto	87.72	13.40
Verona	ditto	89.55	13.68
Vicenza	ditto	88.04	13.63
Vienna	ditto	96.39	12.45
Warsaw	ditto	85.53	14.03
Wismar	ditto	103.63	11.58
Wurtemberg	ditto	104.80	11.45
Zeil	(See Hanover)		
Ziriczee	Feet	98.28	12.21
Zurich	ditto	101.60	11.81
	Ruthes	10.16	118.10
	Fathoms	16.32	73.50

Table XIII.—A Comparison of the Itinerary Measures of different Countries.

		Number of each equal to 100 English Miles.	Length of a single Measure of each sort. Eng. Yds.
Arabia	Miles	81.93	2148
Bohemia	ditto	17.36	10137
Brabant	ditto	28.93	6082
Burgundy	ditto	28.46	6183
China	Lis	279.80	629
Denmark	Miles	21.35	8244
England	ditto	100.	1760
	ditto Geographical	86.91	2625
Flanders	Miles	25.62	6869
France	Leagues, Astronomical	36.21	4860
	ditto, Marine	28.97	6075
	ditto, legal, 2000 Toises	41.28	4263
Germany	Miles, Geographical	21.72	8101
	ditto, Long	17.38	10126
	ditto, Short	25.66	6859
Hamburg	Miles	21.35	8244
Hanover	ditto	15.23	11559
Hesse	ditto	16.68	10547
Holland	ditto	27.52	6395
Hungary	ditto	19.31	9113
Ireland	ditto	57.93	3038
Italy	ditto	86.91	2025
Lithuania	ditto	18.	9781
Oldenburg	ditto	16.26	10820
Poland	Miles, Short	28.97	6075
	ditto, Long	21.72	8101
Portugal	Legoas	26.03	6760
Prussia	Miles	20.78	8468
Rome	Ancient mile of 8 stadia	109.18	1612
	Modern Miles	86.91	2025
Russia	Versts	150.81	1167
Saxony	Miles	17.76	9905
Scotland	ditto	88.70	1984
Silesia	ditto	27.67	7083
Spain	Leguras, common, of 8,000 Varas	23.73	7416
	ditto, legal, of 5000 Varas	37.97	4635
Swabia	Miles	17.38	10126
Sweden	ditto	15.04	11700
Switzerland	ditto	19.23	9153
Turkey	Berries	96.38	1826
Westphalia	Miles	14.56	12151

SUPERFICIAL, or SQUARE MEASURES.

Table XIV.—Ancient Greek superficial Measures.

Olympic Land Measure.

36	Olympic square feet	= 1	Hexapodon.
6	Hexapoda	= 1	Hemihectos.
2	Hemihecti	= 1	Hectos or Modius.
6	Modii	= 1	Medimnus or Jugerum.

Hence it appears, that the Olympic jugerum was equal to 103 English perches, or nearly five-eighths of an acre.

Pythic Land Measure.

$1666\frac{2}{3}$	Square cubits	= 1	Hemihectos.
2	Hemihecti	= 1	Modius.
6	Modii	= 1	Medimnus or Jugerum.

Hence the Pythic jugerum appears to have been equal to 109 English perches, or nearly $\frac{11}{16}$ths of an acre.

N.B. The plethron, or acre, is said by some to contair 1444, by others 10,000 square feet; and aroura, the half of the plethron. The aroura of the Egyptians was the square of 100 cubits.

Table XV.—Ancient Roman Land Measures.

100	Square Roman feet	= 1	Scrupulum of land.
4	Scrupula	= 1	Sextulus.
$1\frac{1}{5}$	Sextulus	= 1	Actus*
6	Sextuli, or 5 Actus	= 1	Uncia of land.
6	Unciæ	= 1	Square Actus.
2	Square Actus	= 1	Jugerum.†
2	Jugera	= 1	Heredium.
100	Heredia	= 1	Centuria.

* The actus was a slip of ground four Roman feet broad, and 120 long.

† The jugerum, or acre, was considered as integer, and divided, like the libra, or as, in the following manner:

		Unciæ.	Jugerum contained Roman. Sq. Ft.	Scrup.	English. Rds.	Pol.	Sq. Ft.
1	As	= 12	= 28800	288	= 2	18	250.05
$\frac{11}{12}$	Deunx	= 11	= 26400	264	= 2	10	183.85
$\frac{5}{6}$	Dextans	= 10	= 24000	240	= 2	2	117.64
$\frac{3}{4}$	Dodrans	= 9	= 21600	216	= 1	34	51.42
$\frac{2}{3}$	Bes	= 8	= 19200	195	= 1	25	257.46
$\frac{7}{12}$	Septunx	= 7	= 16800	168	= 1	17	191.25
$\frac{1}{2}$	Semis	= 6	= 14400	144	= 1	9	125.03
$\frac{5}{12}$	Quincunx	= 5	= 12000	120	= 1	1	58.82
$\frac{1}{3}$	Triens	= 4	= 9600	96	= 0	32	264.85
$\frac{1}{4}$	Quadrans	= 3	= 7200	72	= 0	24	198.64
$\frac{1}{6}$	Sextans	= 2	= 4800	48	= 0	16	132.43
$\frac{1}{12}$	Uncia	= 1	= 2400	24	= 0	8	66.21

N. B. If we take the Roman foot at 11.6 English inches (*See* Table V.) the Roman jugerum was = 5980 English square yards, or 1 acre 37½ perches.

Table XVI.—English Square Measures.

144	Inches	= 1 Foot.
9	Feet	= 1 Yard.
$2\frac{7}{9}$	Yards	= 1 Pace.
10.89	Paces	= 1 Pole.
40	Poles	= 1 Rood.
4	Roods	= 1 Acre.

N.B. English square or superficial measures are raised from the yard of 36 inches, multiplied into itself; and this producing 1296 square inches in the square yard, the divisions of this are square feet and inches; and the multiples, poles, roods, and acres, as in the Table. The Scottish acre is 55353.6 square feet English, or 1.27 English acres.

Measures used by different Artificers.

144	Square inches	= 1 Square foot.
9	Square feet	= 1 Square yard.
63	Square feet=7 Sq. yards	= 1 Rood.
100	Square feet	= 1 Square of work.
272¼	Square feet=30¼ Sq. yards	= 1 Rod, perch, or square pole.

Table XVII.—French Square Measures before the First Revolution.

A Square Inch . . . . = 1.13582 English sq. inches.
An Arpent . . . . . = 100 Square perches, French, about ⅚ acre English, used near Paris.
An Arpent, mesure royale* = about 1¼ English acre.

* The perch (*See* Table VIII.) which determines the measure of the acre, varies in different parts of the country: but the arpent of woodland is everywhere the same, the perch being 22 feet long; and this arpent contains 48,400 French square feet, or 6108 English square yards, or one acre, one rood, one perch. The arpent for cultivated land, in the vicinity of Paris, contains 900 square toises, or 4088 English yards; so that 43 such arpents are equal to 38 English acres nearly.

Table XVIII.—French Square Measures, according to the present System.

Are, a square decametre . =	3.95 English perches, or 119.6046 Square yards.
Decare . . . . =	1196.0460 Square yards.
Hecatare . . . . . . =	11960.4600 Square yards, or 2 acres, 1 rood, 35.4 perches.

Table XIX.—Contents of a Square Foot of different Countries.

	Eng. Square Inches.
A Square Foot of Amsterdam contains	124.32
Antwerp	126.34
Berlin	148.59
Berne	133.23
Bologna	224.70
Bremen	129.50
Denmark or Rhinland	152.52
Danzic	127.46
Dresden	124.10
England	144.00
France	163.32
Hamburg.	127.40
Hanover	131.10
Konigsberg	146.65
Leipsic	123.43
Lisbon	167.96
Milan	234.98
Nuremberg	134.04
Osnaburg	121.00
Rome	134.56
Spain	123.65
Sweden	136.63
Turin	161.80
Venice	187.13
Vienna	155.00
Zurich	139.45
A French Square Metre	1505.01

Cubical Measures, or Measures of Capacity, for Liquids.—The English measures were originally raised from troy weight: it being enacted by several statutes, that eight pounds troy of wheat, gathered from the middle of the ear, and well dried, should weigh a gallon of wine measure, the divisions and multiples whereof were to form the other measures; at the same time it was also ordered, that there should be but one liquid measure in the kingdom; yet custom has prevailed, and there having been introduced a new weight, viz., the avoirdupois, we have now a second standard gallon adjusted thereto; and therefore exceeding the former in the proportion of the avoirdupois weight to troy weight. From this latter standard are raised two several measures, the one for ale, the other for beer. The sealed gallon at Guildhall, which is the standard for wines, spirits, oils, &c. was supposed to contain 231 cubic inches; but by actual experiment, made in 1688, before the lord mayor and the commissioners of excise, it was found to contain only 224 cubic inches, it was, however, agreed to continue the common supposed contents of 231 cubic inches; so that all computations stood on their own footing. Hence as 12 is to 231, so is $14\frac{12}{20}$ to 281½, the cubic inches in the ale gallon: but in effect the ale quart contained 70½ cubic inches, on which principle the ale and beer gallon will be 282 cubic inches. The barrel of ale in London is 32 gallons, and the barrel of beer 36 gallons. In all other places of England, the barrel, both for ale and beer, was wont to be 34 gallons.

Scotch liquid measure is founded on the pint. The Scotch pint was formerly regulated by a standard jug of cast metal, the custody of which was committed to the borough of Stirling. This jug was supposed to contain 105 cubic inches; and though, after several careful trials, it has been found to contain only about 103½ inches, yet in compliance with established custom, founded on that opinion, the pint stoups are still regulated to contain 105 inches, and the customary ale measures are about $\frac{1}{16}$ above that standard. It was enacted by James I. of Scotland, that the pint should contain 41 ounces trone weight of the clear water of Tay, and by James VI. that it should contain 55 Scots troy ounces of the clear water of Leith. This affords another method of regulating the pint, and also ascertaining the ancient standard of the trone weight. As the water of Tay and Leith is alike, the trone weight must have been to the Scots troy weight, as 55 to 41, and therefore the pound trone must have contained about $21\frac{1}{2}$ ounces Scots, troy.

4 Gills	=	1 Mutchkin.
2 Mutchkins	=	1 Chopin
2 Chopins	=	1 Pint
2 Pints	=	1 Quart
4 Quarts	=	1 Gallon.

The Scotch quart contains 210 inches, and is therefore about $\frac{1}{10}$ less than the English wine gallon, and about $\frac{1}{4}$ less than the ale gallon.

As to the liquid measures of foreign nations, it is to be observed, that their several vessels for wine, vinegar, &c. have also various denominations, according to their different sizes and the places wherein they are used. The woeders of Germany, for holding Rhenish and Moselle wines, are different in their guages; some containing 14 aumes of Amsterdam measure, and others more or less. The aume is reckoned at Amsterdam for 8 steckans, or 20 verges, or for $\frac{1}{5}$ of a tun of 2 pipes, or 4 barrels of French or Bordeaux, which $\frac{1}{6}$ at this latter place is called *tierçon*, because three of them make a pipe, or two barrels, and six the said tun. The steckan is 16 mingles, or 32 pints; and the verge is, in respect of the said Rhenish and Moselle, and some other sorts of wine, 6 mingles, but in measuring brandy it consists of $6\frac{1}{4}$ mingles. The aume is divided into 4 anckers, and the ancker into 2 steckans, or 32 mingles. The ancker is taken sometimes for $\frac{1}{24}$ of a tun, or 4 barrels; on which footing the Bordeaux barrel ought to contain at Amsterdam (when the cask is made according to the just guage,) $12\frac{1}{2}$ steckans, or 200 mingles, wine and lees; or 12 steckans, or 192 mingles, racked wine; so that the Bordeaux tun of wine contains 50 steckans, or 800 mingles, wine and lees; and 48 steckans, or 768 mingles, of pure wine. The barrels, or poinçons, of Nantes, and other places on the river Loire, contain only 12 steckans, Amsterdam measure. The wine tun of Rochelle, Cogniac, Charente, and the Isle of Rhé, differs very little from the tun of Bordeaux, and consequently from the barrels and pipes. A tun of wine of Chalosse, Bayonne, and the neighbouring places, is reckoned 60 steckans, and the barrel 15, Amsterdam measure.

The old muid of Paris contains 150 quarts or 300 pints, wine and lees; or 280 pints clear wine; of which muids three make a tun.

The butts, or pipes, from Cadiz, Malaga, Alicant, Benecarlo, Saloe, and Mataro, and from the Canaries, Lisbon, Oporto, and Fayal, are very different in their guages, though in affreightments they are all reckoned two to the tun.

Vinegar is measured in the same manner as wine, but the measures for brandies are different, these spirits, from France, Spain, Portugal, &c., are generally shipped in large casks, called pipes, butts, and pieces, according to the places from whence they are imported, &c. In France, brandy is shipped in casks called pieces at Bordeaux, and pipes at Rochelle, Cogniac, the Isle of Rhé, and other neighbouring places, which contain some more and some less, even from 60 to 90 Amsterdam verges or veertels, according to the capacity of the vessel, and the places they come from.

Dry Measure.

Pints.							
8 =	1 Gallon						
16 =	2 =	1 Peck					
64 =	8 =	4 =	1 Bushel				
256 =	32 =	16 =	4 =	1 Coomb			
512 =	64 =	32 =	8 =	2 =	1 Quarter		
2560 =	320 =	160 =	40 =	10 =	5 =	1 Wey	
5120 =	640 =	320 =	80 =	20 =	10 =	2 =	1 Last.

$268\frac{4}{5}$ Cubic Inches = 1 Gallon
36 Bushels = 1 Chaldron of Coals.

Measure of Capacity for things Dry, was the Winchester gallon heretofore; as for corn, salt, coal, and other dry goods, in England. The gallon contains $272\frac{1}{4}$ cubic inches. The bushel 8 gallons, or 2178 inches. A cylindrical vessel, $18\frac{1}{2}$ inches diameter, and 8 inches deep, is appointed to be used as a bushel in levying the malt tax. A vessel of these dimensions is rather less than the Winchester bushel of 8 gallons, for it contains only 2150 inches, though probably there was no difference intended. The denominations of dry measure commonly used, are given in the first of the subjoined tables. Four quarters of corn make a chaldron, five quarters make a wey or load, and ten quarters make a tun. In measuring seacoal, five pecks make a bushel, nine bushels make a quarter or vatt, four quarters make a chaldron, and twenty-one chaldrons make a score.

40 feet hewn timber make a load.
50 feet unhewn timber make a load.
32 gallons make a herring barrel.
42 gallons make a salmon barrel.
1 cwt. gunpowder makes a barrel.
256 lbs. soap make a barrel.
10 doz. candles make a barrel.
12 barrels make a last.

Scotch dry measure. There was formerly only one measure of capacity in Scotland; and some commodities were heaped, others straiked, or measured exactly to the capacity of the standard. The method of heaping was afterwards forbidden as unequal, and a larger measure appointed for such commodities as that custom had been extended to. The wheat firlot, used also for rye, pease, beans, salt, and grass seeds, contains 21 pints 1 mutchkin, measured by the Stirling jug. The barley firlot, used also for oats, fruit, and potatoes, contains 31 pints. A different method of regulating the firlot was appointed from a cylindrical vessel. The diameter for both measures was fixed at $19\frac{1}{4}$ inches, the depth $7\frac{1}{2}$ inches for the wheat firlot, and $13\frac{1}{2}$ for the barley firlot. A standard constructed by these measures is rather less than when regulated by the pint; and as it is difficult to make vessels exactly cylindrical the regulation by the pint has prevailed, and the other method gone into disuse.

If the Stirling jug contains $103\frac{1}{2}$ inches, the wheat firlot will contain 2109 inches, which is more than two per cent. larger than the legal malt bushel of England, and about one per cent. larger than the Winchester bushel; and the barley firlot will contain 3208 inches. The barley boll is nearly equal to six legal malt bushels. In Stirlingshire, 17 pecks are reckoned to the boll; in Inverness-shire, 18 pecks; in Ayrshire, the boll is the same as the English quarter. And the firlots in many places are larger than the Linlithgow standard.

French dry measure, are the litron, bushel, minot, mine, septier, muid, and tun. The litron is divided into two demilitrons, and four quarter litrons, and contains 36 cubic inches of Paris. By ordonnance, the litron is to be three inches and a half high, and three inches ten lines broad. The litron for salt is larger, and is divided into two halves, four quarters, eight demi-quarters, and 16 measurettes. The French bushel is different in different jurisdictions. At Paris it is divided into demi-bushels, each demi-bushel into two quarters, the quart into two half-quarts, and the half-quart into two litrons, so that the bushel contains 16 litrons. By ordonnance the Paris bushel is to be 8 inches 2½ lines high, and 10 inches broad, or in diameter within side. The minot consists of 3 bushels, the mine of 2 minots or 6 bushels, the septier of 2 mines or 12 bushels, and the muid of 12 septiers, or 144 bushels. The bushel of oats is estimated double that of any other grain; so that there go 24 bushels to make the septier, and 288 to make the muid. It is divided into 4 picotins, the picotin containing 2 quarts, or 4 litrons. The bushel for salt is divided into 2 half-bushels, 4 quarters, 8 half-quarters, and 16 litrons; 4 bushels make a minot, 16 a septier, and 192 a muid. The bushel for wood is divided into halves, quarters, and half-quarters. 8 bushels make the minot, 19 a mine; 20 mines, or 320 bushels, the muid. For plaster, 12 bushels make a sack, and 36 sacks a muid. For lime, 3 bushels make a minot. and 48 minots a muid. The minot is by ordonnance to be 11 inches 9 lines high, and 14 inches 8 lines in diameter. The minot is composed of 3 bushels, or 16 litrons; 4 minots make a septier, and 48 a muid. The French mine is no real vessel, but an estimation of several others. At Paris, the mine contains 6 bushels, and 24 make the muid; at Rouen, the mine is 4 bushels; and at Dieppe, 18 mines make a Paris muid. The septier differs in different places: at Paris, it contains 2 mines, or 8 bushels, and 12 septiers the muid; at Rouen the septier contains 2 mines or 12 bushels. Twelve septiers make a muid at Rouen as well as Paris; but 12 of the latter are equal to 14 of the former. At Toulon, the septier contains a mine and a half; three of which mines make the septier of Paris. The muid, or muy of Paris, consists of 12 septiers, and is divided into mines, minots, bushels, &c. That for oats is double that for other grain, *i. e.*, contains twice the number of bushels. At Orleans, the muid is divided into mines, but those mines only contain two Paris septiers and a half. In some places they use the tun instead of the muid, particularly at Nantes, where it contains 10 septiers of 16 bushels each, and weighs between 2,200 and 2,250 pounds. Three of these tuns make 28 Paris septiers. At Rochelle, &c., the tun contains 42 bushels, and weighs two per cent. less than that of Nantes. At Brest, it contains 20 bushels, is equal to 10 Paris septiers, and weighs about 2,240 pounds.

Dutch, Swedish, Polish, Prussian, and Muscovite. In these places, they estimate their dry things on the foot of the *last*, *lest*, *leth*, *lecht*; so called according to the various pronunciations of the people who use it. In Holland, the last is equal to 19 Paris septiers, or 38 Bordeaux bushels, and weighs about 4,560 pounds; the last they divide into 27 muids, and the muid into 4 scheples. In Poland, the last is 40 Bordeaux bushels, and weighs about 4,800 Paris pounds. In Prussia, the last is 133 Paris septiers. In Sweden and Muscovy, they measure by the great and little last, the first containing 12 barrels, and the second half as many. In Muscovy, they likewise use the chefford, which is different in various places; that of Archangel is equal to three Rouen bushels.

Italian. At Venice, Leghorn, and Lucca, they estimate their dry things on the foot of the staro or staio. The staro of Leghorn weighs 54 pounds; 112⅞ are equal to the Amsterdam last. At Lucca, 119 staros make the last of Amsterdam. The Venetian staro weighs 128 Paris pounds; the staro is divided into four quarters. Thirty-five staros and one-fifth, or 140 quarters and four-fifths, make the last of Amsterdam. At Naples, and other parts, they use the tomolo, or tomalo, equal to one-third of the Paris septier. Thirty-six tomoli and a half make the carro, and a carro and a half, or 54 tomoli, make the last of Amsterdam. At Palermo, 16 tomoli make the salma, and 4 mondili the tomolo. Ten salmas and three-sevenths, or 171 tomoli and three-sevenths, make the last of Amsterdam.

Flemish. At Antwerp, &c., they measure by the viertel, 32½ whereof make 19 Paris septiers. At Hamburg, the schepel; 90 whereof make 19 Paris septiers.

Spanish and Portuguese. At Cadiz, Bilboa, and St Sebastian, they use the fanega; 23 whereof make the Nantes or Rochelle tun, or 9½ Paris septiers, though the Bilboa fanega is somewhat larger, insomuch that 21 fanegas make a Nantes tun. At Seville, &c., they use the anagoras, containing little more than the Paris mine; 36 anagoras make 19 Paris septiers. At Bayonne, &c., the concha; 30 whereof are equal to 9½ Paris septiers. At Lisbon, the alquiver, a very small measure; 240 whereof make 90 Paris septiers, 60 the Lisbon muids.

MEASURING, or MENSURATION, defined geometrically, is the assuming any certain quantity, and expressing the proportion of other similar quantities to the same.

MEASURING, defined popularly, is the using of a certain known measure, and determining thereby the precise extent, quantity, or capacity, of anything. In general, it constitutes the practical part of geometry. *See* MENSURATION.

MEASURING OF LINES, or quantities of one dimension, is called *longimetry*; and when those lines are not extended parallel to the horizon, *altimetry*. When the different altitudes of the two extremes of the lines are alone regarded, it is termed *levelling*.

MEASURING OF SUPERFICIES, or quantities of two dimensions, is variously denominated according to its subjects: when lands are the subject, it is called *geodesy*, or *surveying*; in other cases, simply *measuring*. The instruments used are the ten-foot rod, chain, compass, circumferentor, &c.

MEASURING OF SOLIDS, or quantities of three dimensions, is called *stereometry*; but where it relates to the capacities of vessels, or the liquors they contain particularly, *gauging*. The instruments for this art are the gauging-rod, sliding-rule, &c.

From the definition of measuring, where the measure is expressed to be similar or homogeneous to, *i. e.* of the same kind with, the thing measured, it is evident that, in the first case, or in quantities of one dimension, the measure must be a line; in the second, a superficies; and in the third, a solid. For example, a line cannot measure a surface; the art of measuring being no more than the application of a known quantity to the unknown, till the two become equal. Now, a surface has breadth, and a line has none; and if one line have no breadth, two or a hundred have none. A line, therefore, can never be applied so often to a surface as to be equal to it, *i. e.* to measure it. And from the like reasoning it is evident, a superficies, which has no depth, cannot become equal to, *i. e.* cannot measure, a solid which has.

While a line continues such, it may be measured by any part of itself; but when the line begins to flow, and to generate a new dimension, the measure must keep pace, and flow too; *i. e.* as the one commences superficies, the other must do so too. Thus we come to have square measures, and cubic measures.

Hence we see why the measure of a circle is an arc or part of the circle, for a right line can only touch a circle in one point, but the periphery of a circle consists of infinite points. The right line, therefore, to measure the circle must be applied infinite times, which is impossible. Again the right line only touches the circle in a mathematical point, which has no parts nor dimensions, and has consequently no magnitude; but a thing that has neither magnitude nor dimensions bears no proportion to another that has, and cannot therefore measure it. Hence we see the reason of the division of circles into 360 parts or arcs, called *degrees*. *See* ARC, CIRCLE, and MENSURATION.

MECHANICS (from the Greek *μηχανη*, *art*) that branch of practical mathematics which treats of motion and moving powers, their nature, laws, effects, &c. This term, in a popular sense, is applied equally to the doctrine of the equilibrium of powers, more properly called *statics*, and to that science which treats of the generation and communication of motion, which constitutes *dynamics*, or mechanics strictly so called. *See* FORCE, MOTION, POWER, and STATICS.

This science is divided by Newton into *practical* and *rational* mechanics, the former of which relates to the mechanical powers, viz., the lever, balance, wheel and axis, pulley, wedge, screw, and inclined plane; and the latter, or rational mechanics, to the theory of motion; showing, when the forces or powers are given, how to determine the motion that will result from them; and, conversely, when the circumstances of the motion are given, how to trace the forces or powers from which they arise.

Mechanics, according to the ancient sense of the word, considers only the energy of organs, or machines. The authors who have treated the subject of mechanics systematically have observed, that all machines derive their efficacy from a few simple forms and dispositions, which may be given to organs interposed between the agent and the resistance to be overcome; and to those simple forms they have given the name of *mechanical powers*, *simple powers*, or *simple machines*.

The practical uses of the several mechanical powers were undoubtedly known to the ancients, but they were almost wholly unacquainted with the theoretical principles of this science till a very late period; and it is therefore not a little surprising that the construction of machines, or the instruments of mechanics, should have been pursued with such industry, and carried by them to such perfection. Vitruvius, in his 10th book, enumerates several ingenious machines, which had then been in use from time immemorial. We find, that for raising or transporting heavy bodies, they employed most of the means which are at present commonly used for that purpose, such as the crane, the inclined plane, the pulley, &c.; but with the theory or true principles of equilibrium, they seem to have been unacquainted till the time of Archimedes. This celebrated mathematician, in his book of *Equiponderants*, considers a balance supported on a fulcrum, and having a weight in each scale; and taking as a fundamental principle, that when the two arms of the balance are equal, the two weights supposed to be in equilibrio are also of necessity equal, he shows, that if one of the arms be increased, the weight applied to it must be proportionally diminished. Hence he deduces the general conclusion, that two weights suspended to the arms of a balance of unequal length, and remaining in equilibrio, must be reciprocally proportional to the arms of the balance; and this is the first trace anywhere to be met with of any theoretical investigation of mechanical science. Archimedes also further observed, that the two weights exert the same pressure on the fulcrum of the balance, as if they were directly applied to it; and he afterwards extended the same idea to two other weights suspended from other points of the balance, then to two others, and so on; and hence, step by step, advanced towards the general idea of the centre of gravity, a point which he proved to belong to every assemblage of small bodies, and consequently to every large body, which might be considered as formed of such an assemblage. This theory he applied to particular cases, and determined the situation of the centre of gravity in the parallelogram, triangle, trapezium, parabola, parabolic trapezium, &c. &c. To him we are also indebted for the theory of the inclined plane, the pulley, and the screw, besides the invention of a multitude of compound machines; of these. however, he has left us no description, and therefore little more than their names remain.

We may judge of the very imperfect state in which the theory of mechanics was at that time, by the astonishment expressed by King Hiero, when Archimedes exclaimed, "Give me a place to stand on, and I will move the earth!" a proposition which could have excited no surprise in any person possessing a knowledge of the simple property of the lever. Of the theory of motion, however, it does not appear that even Archimedes possessed any adequate idea; the properties of uniform motion seem only to have engaged the attention of the ancients, and with those of accelerated and variable motion they were totally unacquainted: these were subjects to which their geometry could not be applied, the modern analysis being necessary to bring this branch of the science to perfection.

From the time of Archimedes till the commencement of the sixteenth century, the theory of mechanics appears to have remained in the same state in which it was left by this prince of Grecian science, little or no additions having been made to it during so many ages; but about this time, Stevinus, a Flemish mathematician, made known directly, without the introduction of the lever, the laws of equilibrium of a body placed on an inclined plane: he also investigated with the same success, many other questions on statics, and determined the conditions of equilibrium between several forces concurring in a common point, which comes, in fact, to the celebrated proposition relating to the parallelogram of forces; but it does not appear that he was at all aware of its consequences and application. In 1592, Galileo composed a treatise on statics, which he reduced to this single principle, viz:—It requires an equal power to raise two different bodies to heights having the inverse ratio of their weights: that is, whatever power will raise a body of two pounds to the height of one foot, will raise a body of one pound to the height of two feet. On this simple principle he investigated the theory of the inclined plane, the screw, and all the mechanical powers: and Descartes afterwards employed it in considering the statical equilibriums of machines in general, but without quoting Galileo, to whom he had been indebted or the first idea. After Stevinus and Galileo, Torricelli, Descartes, Huygens, Wallis, Wren, Newton, Liebnitz, Dechales, Oughtred, Keil, Delahire, Lagrange, Atwood, Prony, Emerson, Watt, Gregory, Young, &c., have in succession, since the period to which we have alluded, explained and applied the principles of this civilizing science in a wonderful manner.

MECHANICAL CARPENTRY, that part of the art of construction in timber which treats of the proper disposition of framing, so as to enable it to resist its own weight, or any additional load or pressure that may be casually laid upon it.

MECHANICAL CARPENTRY is so called from the principles of mechanics being employed in the construction of truss-framing, or other parts of the art; while CONSTRUCTIVE CARPENTRY shows the rules for cutting and framing the timbers according to the proposed design. *See* that article.

The mechanical principles of a piece of carpentry are therefore first to be considered; because they must, in some measure, regulate the disposition and size of the timbers in the design, after which they are to be prepared or formed according to the rules of constructive carpentry.

We shall here state a few of the elementary propositions, with the principles of trussing, and offer some observations on the best forms of bodies constructed of timber work, to be used under various circumstances. And as it is impossible, in complex parts, to give all the minutiæ with mathematical precision, this deficiency will, in a great measure, be compensated by general information.

The application of mechanical principles to carpentry was first introduced in this country by Professor Robinson, of Edinburgh, in the *Encyclopædia Britannica*, whose elaborate papers on this subject prepared the way for that investigation which has since been so ably followed out by others. In 1814, Mr. P. Nicholson drew up a complete article in every department of carpentry, for Rees's *Encyclopædia*, where this branch of the art, as depending upon the principles of mechanics, was particularly inculcated; and though several of the plates have been engraved and published some years ago, the manuscript relative to this particular branch has been retained for the article Roof, in this work, to which, indeed, it chiefly pertains.

In this application of mechanical science, Alex. Nimmo, Esq., F. R. S. E., the celebrated engineer, also published a very neat and well-connected theory of mechanical carpentry, under the article Carpentry, in the *Edinburgh Encyclopædia*; but perhaps the best work extant on this subject is Tredgold's Elementary Principles of carpentry, which contains a mass of the most valuable information, in the most convenient and available form.

Under the article Curb Roof, of the present Work, the reader will find an investigation of the best forms for a roof, restricted to certain data. The observations on the strength of timber are reserved for that article; but the practical rules derived therefrom will be here introduced preparatory to the general design of mechanical carpentry; and as these will be chiefly applicable to practice, we shall show the rules under their most simple form; discarding such as, though accurate, would be too complex for common use.

To find the comparative strength of timber.

Definition.—The depth of a piece of timber is its dimension in the direction of the pressure.

Proposition I.—*To find the comparative strength of different timbers.*

Rule.—Multiply the square of the depth of each piece into its thickness; and each product being divided by its respective lengths, will give the proportional strength of each.

Example.—Suppose three pieces of timber of the following dimensions:

The first 6 inches deep, 3 inches thick, and 12 feet long.
The second 5 inches deep, 4 inches thick, and 8 feet long.
The third 9 inches deep, 8 inches thick, and 15 feet long.
The comparative weight that will break each piece is required.

OPERATIONS.

First.	Second.
6 deep	5 deep
6	5
36	25
3 thick	4 thick
Length 12) 108	Length 8) 100
9	12 and a half.

Third.
9 deep
9
81
8 thick
Length 15) 648 (43 and a fifth.
60
48
45
3

Therefore, the weights that will break each are nearly in proportion to the numbers 9, 12, and 43, leaving out the fractions; in which it is to be observed, that the number 43 is almost five times the number 9; therefore the third piece of timber will bear almost five times as much weight as the first; and the second piece nearly once and a third the weight of the first piece; because the number 12 is one and a third greater than the number 9.

The timber is supposed to be everywhere of the same texture, otherwise these calculations cannot hold true.

Proposition II.—*Given the length, breadth, and depth of a piece of timber; to find the depth of another piece, whose length and breadth are given, so that it shall bear the same weight as the first piece, or any number of times more.*

Rule.—Multiply the square of the depth of the first piece into its breadth, and divide that product by its length: multiply the quotient by the number of times you would have the other piece to carry more weight than the first: and multiply the product by the length of the last piece, and divide the product by its width; out of this last quotient extract the square root, which is the depth required.

Example 1.—Suppose a piece of timber 12 feet long, 6 inches deep, 4 inches thick; another piece 20 feet long, 5 inches thick; required its depth, so that it shall bear twice the weight of the first piece.

	Proof.
6 deep	9.7
6	9.7
36	67.9
4	873
12) 144	94.09
	1.91 remainder added
12	96.00
2 times	5
24	20) 480
20 length	24
5) 480	

96 (9.7, or 9.8 nearly, for the depth.
81
187) 1500
1309
191

Example 2.—Suppose a piece of timber 14 feet long, 8 inches deep, 3 inches thick; required the depth of another piece 18 feet long, 4 inches thick, so that the last piece shall bear five times as much weight as the first.

As the lengths of both pieces of timber are divisible by the number 2, therefore half the length of each is used instead of the whole; the answer will be the same.

```
        8
        8
       ---
       64
        3
      ----
Half 7) 192
      ----
      27.4, &c.
       5 times
      ----
      137
        9 half the length
      ----
   4) 1233
      ------
      308.25 ( 17.5 the depth nearly.
      1
      ----
  27) 208 (
      189
      ----
 345) 1925, &c.
```

Proposition III.—*Given the length, breadth, and depth of a piece of timber; to find the breadth of another piece whose length and depth are given, so that the last piece shall bear the same weight as the first piece, or any number of times more.*

Rule.—Multiply the square of the depth of the first piece into its thickness; the product divide by its length; multiply the quotient by the number of times it is required to have the last piece support more than the first; that product multiplied by the length of the last piece, and divided by the square of its depth, gives the breadth required.

Example 1.—Given a piece of timber 12 feet long, 6 inches deep, 4 inches thick; and another piece 16 feet long, 8 inches deep; required the thickness, so that it shall bear twice as much weight as the first.

```
    6
    6
   ---
   36
    4
   ---
3) 144
   ---
   48
    2
   ---
   96
    4
   ---
8) 384
   ---
8)  48
   ---
    6 thickness.
```

Or thus, at full length.

```
             6 depth of the first piece.
             6
            ---
            36
             4 thickness of the first piece
            ----
Length 12) 144
            ----
            12
             2 the number of times stronger
            ---
            24
            16 length of the last piece
            ----
           144
            24
           ----
        8) 384
           ----
        8) 48
           ---
            6 thickness.
```

Example 2.—Given a piece of timber 12 feet long, 5 inches deep, 3 inches thick; and another piece 14 feet long, 6 inches deep; required the thickness, so that the last piece may bear four times as much weight as the first piece.

```
        5
        5
       ---
       25
        3
       ---
  12) 75
      ------
        6.25
           4
      ------
       25.00
       14
      ------
      100
       25
      ----
   6) 350
      ------
   6) 58.333
       9.722
```

Proposition IV.—*If a piece of timber sustain a force placed unequally between the extremes on which it is supported, the strength in the middle will be to the strength in that part of the timber so divided, as one divided by the square of half the length is to one divided by the rectangle of the two unequal segments; that is, in the reciprocal ratio of their products.*

Example 1.—Suppose a piece of timber 20 feet long, the depth and width immaterial; suppose the stress or weight to lie five feet distant from one of its ends, consequently from the other end 15 feet, then the above proportion will be

$\frac{1}{10 \times 10} = \frac{1}{100} : \frac{1}{5 \times 15} = \frac{1}{75}$ as the strength at five feet from the end is to the strength at the middle, or 10 feet, or as $5 \times 15 : 10 \times 10 : \frac{100}{75} = 1\frac{1}{3}$.

Hence it appears, that a piece of timber 20 feet long is one-third stronger at 5 feet distance from the bearing than it is in the middle, which is 10 feet, when cut in the above proportion.

Example 2.—Suppose a piece of timber 30 feet long; let the weight be applied 4 feet distant from one end, or more properly from the place where it takes its bearing, then from the other end it will be 26 feet, and the middle is 15 feet; then $\frac{1}{15 \times 15} = \frac{1}{225} : \frac{1}{4 \times 26} = \frac{1}{104}$;

or as $4 \times 26 : 15 \times 15 = 2\frac{17}{104}$, or nearly $2\frac{1}{6}$.

Hence it appears, that a piece of timber 30 feet long will bear double the weight, and one-sixth more, at 4 feet distance from one end, than it will do in the middle, which is 15 feet distant.

Example 3.—Allowing that 266 pounds will break a beam 26 inches long, required the weight that will break the same beam when it lies at 5 inches from either end; then the distance to the other end is 21 inches; $21 \times 5 = 105$, the half of 26 inches is 13; therefore $13 \times 13 = 169$; consequently the strength at the middle of the piece is to the strength at 5 inches from the end, as $\frac{169}{169} : : \frac{169}{105}$; or as $1 : \frac{169}{105}$

The proportion is stated thus:

$$1 : \frac{169}{105} : : 266 \text{ to the weight required.}$$

```
          lb.
          169
      105  169
         ----
         2394
        1596
        266
        -----
105 ) 44954 ( 428
        420
        ---
         295
         210
         ---
          854
          840
          ---
           14
```

From this calculation, it appears that rather more than 428 pounds will break the beam at 5 inches' distance from one of its ends, if 266 pounds will break the same beam in the middle.

By similar propositions, the scantlings of any timber may be computed, so that they shall sustain any given weight; for if the weight that one piece will sustain be known, with its dimensions, the weight that another piece will sustain, of any given dimensions, may also be computed. The reader must observe, that although the foregoing rules are mathematically true, yet it is impossible to account for knots, cross-grained wood, &c., such pieces being not so strong as those which have straight fibres; and if care be not taken in choosing the timber for a building, so that the fibres be disposed in parallel straight lines, all rules which can be laid down will be useless. It will be impossible, however, to estimate the strength of timber fit for any building, or to have any true knowledge of its proportions, without some rule; as otherwise everything must be done by mere conjecture.

Timber is much weakened by its own weight, except it stand perpendicular to the horizon.

The bending of timber will be nearly in proportion to the weight laid on it. No beam ought to be trusted for any long time with above one-third or one-fourth part of the weight it will absolutely carry; for experiment proves, that a far less weight will break a piece of timber when hung to it for any considerable time, than what is sufficient to break it when first applied.

Problem I.—*Having the length and weight of a beam that can just support a given weight in the middle, to find the length of another beam of the same scantling, that shall just break with its own weight.*

Let l = the length of the first beam;
L = the length of the second;
a = the weight of the first beam;
w = the additional weight that will break it.

Then $w + \frac{a}{2} = \frac{2w + a}{2}$ is the weight that will break the lesser beam.

Again, let W be the weight of the beam that breaks with its own weight; and because the weights that will break beams of the same scantling are reciprocally as their lengths:

$$L : l : : \frac{2w + a}{2} : l\frac{2w + a}{2L} = W.$$

But the weights of beams of the same scantlings are to each other as their lengths;

$l : L : : \frac{a}{2} : \frac{aL}{2l} = \frac{W}{2}$, half the weight of the greater beam.

Now, a beam supported at both ends cannot break with its own weight, unless half the weight of the beam be equal to the weight that will break it;

$$\text{therefore; } \frac{aL}{2l} = l\frac{2w + a}{2L};$$

$$\text{consequently, } aL^2 = l^2(2w + a)$$

$$\text{and, } L = l\left(\frac{2w + a}{a}\right).$$

Problem II.—*Having the weight of a beam that can just support a given weight in the middle; to find the depth of another beam similar to the former, so that it shall just support its own weight.*

Let d = the depth of the first beam;
x = the depth of the second beam;
a = the weight of the first beam;
w = the additional weight that will break the first beam.

Then will $w + \frac{a}{2}$, or $\frac{2w + a}{2}$ = the whole weight that will break the lesser beam.

And because the weights that will break similar beams are as the squares of their lengths,

$$d^2 : x^2 : : \frac{2w + a}{2} : \frac{2x^2 w + x^2 a}{2d^2} = W.$$

Then because the weights of similar beams are as the cubes of their corresponding sides:

$$d^3 : x^3 : : \frac{a}{2} : \frac{a x^3}{2d^3} = W;$$

$$\text{therefore } \frac{a x^3}{2d^3} = \frac{2x^2 w + a x^2}{2d^2};$$

$$a x^3 = (2w + a) \times d;$$

consequently $a : a + 2w : : d : x^3$ = the depth required.

As the weight of the lesser beam is to that of the greater beam, together with the additional weight; so is the depth of the lesser beam to the cube of the depth of the greater.

Note.—Any other corresponding sides will answer the same purpose, being all proportional to each other.

Example.—Suppose a beam, whose weight is one pound, and its length 10 feet, to carry a weight of 399.5 pounds; required the length of a beam similar to the former, of the same matter, so that it shall break with its own weight:

then $a = 1$
$w = 39.5$
and $a + 2w = 800 = 1 + 2 \times 399.5$
$d = 10$

Then, by the last problem, it will be
$1 : 800 : : 10$
10

$8000 = x$, for the length of a beam that will break by its own weight.

Problem III.—*The weight and length of a piece of timber being given, and the additional weight that will break it; to find the length of a piece of timber similar to the former, so that this last piece of timber shall be the strongest possible.*

Put l = the length of the piece given;
w = half its weight;
w = the weight that will break it;
x = the length required.

Then, because the weights that will break similar pieces of timber are in proportion to the squares of their lengths,

$l^2 : x^2 : : \mathrm{w} + w : \frac{\mathrm{w}\,x^2 + w\,x^2}{l^2}$ = the whole weight that will break the beam.

And because the weights of similar beams are as the cubes of their lengths, or any other corresponding sides,

$l^3 : x^3 : : w : \frac{w\,x^3}{l^3}$ the weight of the beam;

consequently, $\frac{\mathrm{w}\,x^2 + w\,x^2}{l^2} - \frac{w\,x^3}{l^3}$ is the weight that breaks the beam = *a* maximum; therefore its fluxion is nothing: that is,

$$2\,\mathrm{w}\,x\dot{x} + 2\,w\,x\dot{x} - \frac{3\,w\,x^2\,\dot{x}}{l} = 0.$$

$$2\,\mathrm{w} + 2\,w = \frac{3\,w\,x}{l};$$

$$\text{hence, } x = l \times \frac{2\,\mathrm{w} + 2\,w}{3\,w}.$$

Hence it appears from the foregoing problems, that large timber is weakened in a much greater proportion than small timber, even in similar pieces, therefore a proper allowance must be made for the weight of the pieces, as in the following example.

Suppose a beam, 12 *feet long, and a foot square, whose weight is three hundred-weight, to be capable of supporting* 20 *hundred-weight; what weight will a beam* 20 *feet long,* 15 *inches deep, and* 12 *thick, be able to support?*

```
12 inches square          15
12                        15
----                      ---
144                       75
12                        15
----                      ---
12 ) 1728                 225
----                      12
144                       ----
                    2,0 ) 270,0
                          -----
                          135
```

	Inches.
Now the solid contents of the first beam is . . .	20736
and that of the second	43200

But the weights of beams are as their solid contents; therefore,

```
20736 : 43200 : : 3
                  3
        --------    cwt. lb.
20736 ) 129600 ( 6 28 = the weight of the second beam.
        124416
        ------
          5184
           112
        ------
         10368
         5184
        5184
        ------
20736 ) 580608 ( 28
        41472
        ------
        165888
        165888
        ------
        . . .

144 : 135 : : 21.5 by Proposition I.
      215
      ---
      675
      135
     270
    ------
12 ) 2902.5
    ------
12 )  241.875
      --------
      20.15625
           112
      --------
        31250
       15625
      15625
      --------
      17.50000
      16
      --
      30
      5
      --
      8.0
```

21 cwt. 56 lb. is the weight that will break the first beam, and 20 cwt. 17 lb. 8 oz. the weight that will break the second beam. Deduct out of these half their own weight:

cwt.	lb.	oz.
20	17	8
3	14	0 half
17	3	8

Now 20 cwt. is the additional weight that will break the first beam; and 17 cwt. 3 lb. 8 oz. the weight that will break the second; in which the reader will observe, that 17 cwt. 3 lb. 8 oz. bears a much less proportion to 20 cwt. than 20 cwt. 17 lb. 8 oz. bears to 21 cwt. 56 lb. From these examples, it is evident that a proper allowance ought to be made for all horizontal beams: that is, half the weights of beams ought to be deducted out of the whole weight they will carry, and the remainder is the weight which each piece will bear.

If several pieces of timber of the same scantling and length be applied one above another, and supported by props at each end, they will be no stronger than if they were laid side by side ; or, which is the same thing, the pieces that are applied one above another are no stronger than one single piece whose width is the width of the several pieces collected into one, and its depth that of one of the pieces; it is therefore useless to cut a piece of timber lengthwise, and apply the pieces so cut one above each other, for these pieces are not so strong as before, even though assisted by bolting.

Example.—Suppose a girder 16 inches deep, 12 inches thick, the length immaterial, and let the depth be cut lengthwise into two equal pieces; then will each piece be 8 inches deep, and 12 inches thick. Now, according to the rule of proportioning timber, the square of 16 inches, that is the depth before it was cut, is 256, and the square of 8 inches is 64; but twice 64 is only 128, therefore it appears that the two pieces applied one above another, is but half the strength of the solid piece, because 256 is double 128.

If a girder be cut lengthwise in a perpendicular direction, the ends turned contrary, and then bolted together, it will be but very little stronger than before it was cut; for although the ends, being turned, give to the girder an equal strength throughout, yet wherever a bolt is, there the girder will be weaker; and it is doubtful whether it will be any stronger for this process of sawing and bolting.

Figure 1.—If there be two pieces of timber of an equal scantling, the one lying horizontally and the other inclined, the horizontal piece being supported at the points *e* and *f*, and the inclined piece at *c* and *d*, perpendicularly over *e* and *f*; according to the principles of mechanics, these pieces will be equally strong. But to reason a little on this matter, let it be considered, that though the inclined piece, D, is longer, yet the weight has less effect upon it when placed in the middle, than the weight at *h* has upon the horizontal piece, C, the weights being the same; it is therefore reasonable to conclude, that in these positions the one will bear equal to the other.

From different experiments, it has been found that the law of resistance in a piece of timber does not exactly obey the foregoing rules. The labour and expense attending such experiments, on a scale likely to be at all useful, far exceed the abilities of individuals, who might otherwise be disposed to investigate this useful branch of mechanical knowledge. This grand objection, no doubt, has been the cause why so little has been done to determine the law of resistance by experiments; yet, as we are not absolutely without some lights, we shall proceed to lay them before our readers, in as concise a manner as the nature of the subject will admit.

The first authority to our purpose is what Belidor has given on the subject, in his *Science des Ingenieurs.*

Belidor's Experiments.

In the subjoined table, the column B contains the breadth of the pieces in inches; D contains their depths; the column L contains their lengths; P the weight (in pounds) which broke them, when hung on their middles.

In order to obtain the best idea of the strengths of pieces of different dimensions with more certainty, three pieces of each dimension were tried; a medium among them being more accurate than a single experiment.

The column M contains those mediums.

The experiments were made on oak, of equal quality, and tolerably well seasoned.

	B	D	L	P	M
Experiment 1, ends loose.....	1	1	18	400 415 405	406
Experiment 2, ends firmly fixed	1	1	18	600 600 624	608
Experiment 3, ends loose.....	2	1	18	810 795 812	805
Experiment 4, ends loose.....	1	2	18	1570 1580 1590	1580
Experiment 5, ends loose.....	1	1	36	185 195 180	187
Experiment 6, ends fixed.....	1	1	36	285 280 285	283
Experiment 7, ends loose.....	2	2	36	1550 1620 1585	1585
Experiment 8, ends loose.....	$1\frac{5}{8}$	$2\frac{1}{8}$	33	1665 1675 1640	1660

By comparing the 1st experiment with the 3d, the strength appears proportional to the breadth; the length and depth of each piece being the same.

By comparing the 1st and 4th experiments, the strength appears as the square of the depth, nearly; the breadth and length being always the same.

By comparing the 1st and 5th experiments, the strength is seen to be nearly as the lengths, inversely; the breadth and depth of each piece being the same.

By comparing experiments 5 and 7, the strengths will appear to be nearly in proportion to the breadth, multiplied by the square of the depth; the length being the same in both.

The 1st and 7th experiments show the strengths to be as the square of the depth, multiplied by the breadth, and divided by the length.

Experiments 1 and 2, and 5 and 6, show the increase of the strength by fastening the ends, to be in the proportion of 2 to 3.

From the foregoing experiments, it appears that the rule founded upon the Galilean hypothesis, for finding the comparative strength of timber, is nearly true. But as it would be wrong to draw conclusions from timbers of so small scantlings as in the above experiments, we shall, after making the following observation, give an abstract of the experiments of M. de Buffon, as well as of those of M. du Hamel, men of acknowledged abilities, who were directed by the French government to make experiments on this subject; and who were supplied with ample funds and apparatus for the purpose, and had the choice of the best subjects in all the forests of France. The reports of M. de Buffon may be found in the *Memoirs of the French Academy*, for the years 1740, 1741, 1742, 1768; and those of M. du Hamel, in his work, *Sur l'Exploitation des Arbres, et sur la Conservation et le Transportation de Bois.* But we observe, the chief cause of the irregularity in such experiments, is the fibrous, or rather plated texture of timber, which consists of annual additions, whose cohesion with each other is vastly weaker than that of their own fibres. Let *Figure* 2, represent the section of a tree, and A B C D, and *a b c d*, the sections of two quarterings, to be cut out of it, for experiment; let A D, and *a d*, be the depths; and D C, *d c*, the breadths; the quartering A B C D will be the strongest for the same reason that an assemblage of planks set edgewise, will be stronger than the same number of planks laid above each other.

M. de Buffon found that the strength of A B C D, was to that of *a b c d*, in oak, nearly as 8 to 7.

The authors of the different experiments, we have reason to fear, were not very careful that their bars had their plates all disposed the same way.

As great beams occupy much, if not the whole section of the tree, it has happened that their strength is less than in proportion to that of a small lath quartering or scantling; for which reason a set of experiments ought to be carefully made on each, as all large buildings require a great number of both kinds: as girders and other beams for supporting large weights, so small bars are employed in making joists, rafters, purlins, &c., all of which are for the purpose of carrying or discharging weights.

M. de Buffon's Experiments.

The following table exhibits a number of experiments on bars of sound oak, clear of knots, each bar being four inches square.

The column No. 1, contains the length of the bar in feet, between the two props.

The column No. 2, contains the weight of the bar, the second day after it was felled, in pounds.

The column No. 3, contains the number of pounds necessary for breaking the bar in a few minutes.

The column No. 4, contains the number of inches it bent down before breaking.

The column No. 5, contains the number of minutes that each respective piece was in breaking.

In this table two bars were tried of each length: each of the first three pairs consisted of two cuts of the same tree; the one next to the root was always found to be the heaviest, stiffest, and strongest; from which M. de Buffon recommends a certain and sure rule for estimating the goodness of timber by its weight: he finds that this is always the case when the timber has grown vigorously, forming thick annual layers. But he also observes, that this is only during the advances of the tree to maturity, for the strength of the different circles approaches gradually to an equality during a healthy growth.

1	2	3	4	5
7	60 56	5350 5275	3.5 4.5	29 22
8	68 63	4600 4500	3.75 4.7	15 13
9	77 71	4100 3950	4.85 5.5	14 12
10	84 82	3625 3600	5.83 6.5	15 15
12	100 98	3050 2925	7. 8.	

Experiments on other sizes were made in the same manner: a pair, at least, of each length and scantling was taken; the mean result is contained in the following table. The beams were all square, and their sizes, in inches, are placed at the head of the columns; and their length, in feet, in the first column. The column A exhibits the strength which each of the five-inch bars ought to have, by the theory.

M. de Buffon found, by numerous experiments, that oak timber lost much of its strength by drying or seasoning; and therefore, in order to secure uniformity, his trees were all felled in the same season of the year, were squared the day after, and tried on the third day. Trying them in this green state, gave him an opportunity of observing a very curious phenomenon.

When the weights were laid briskly on, nearly sufficient to break the log, a smoke was observed to issue from each end, accompanied with a hissing noise, which continued while the tree was bending and cracking; owing to the strain excited by bending: in which state it must be both compressed and extended.

	4	5	6	7	8	A
7	5312	11525	18950	32200	47649	11525
8	4550	9787	15525	26050	39750	10085
9	4025	8308	13150	22350	32800	8964
10	3612	7125	11250	19475	27750	8068
12	2987	6075	9100	16175	23450	6723
14		5300	7475	13225	19775	5763
16		4350	6362	11000	16375	5042
18		3700	5562	9245	13200	4482
20		3225	4950	8375	11487	4034
22		2975				3667
24		2162				3362
28		1775				2881

From the above experiments, some conclusions respecting the law of the strength of oak timber may be deduced, from which it will be seen whether the theory already established be sufficiently accurate; or, if not, they will show in what manner it ought to be corrected.

M. de Buffon considers the experiments upon the five-inch bars as the standard of comparison, having both extended these to a greater length, and having tried more pieces of each length.

The theory determines the relative strengths of bars of the same section, to be inversely as their lengths; but, if the five experiments in the first column be excepted, there will be found a very great deviation from this rule: thus the five-inch bar of 28 feet long should have half the strength of that of 14 feet, or 2650, whereas it is but 1775; the bar of 14 feet should have half the strength of the 7 feet, or 5762; whereas it is but 5300; and in like manner the fourth of 11,525 is 2881; but the real strength of the 28-inch bar is but 1775. The column A exhibits the strength that each of the five-inch bars ought to have by the theory, which decreases much slower than those shown by the experiment; and therefore it appears, that the strength of different pieces of timber decreases much quicker than that of the inverse ratio of their lengths; but in what ratio precisely the strength decreases, it would be almost impossible to know, as there is not a sufficient number of experiments for the purpose; the few that have been tried are so very anomalous, as will appear by taking the differences between those in the third column, found by the experiments, from their respective numbers under A in the seventh column, as found by the rule, which are respectively 298, 656, 943, 648, 463, 692, 782, 809, 692, 1200, 1106: by comparing these numbers together, it is easy to see the impossibility of discovering any progression, or regular increase; for example, the third difference is greater than any of the preceding, and less than any of the succeeding, except the two last; and therefore it appears, that no rule can be founded on these experiments for finding the relative strength of timber, but what will in many cases differ very considerably from that which ought to correspond to it; in the table, however, the rule given in our former calculations may, if somewhat corrected, correspond nearly with the five-inch bars, as follows:—from the length of the required piece, take the 7 feet length, and multiply the difference by the number 1474, divide that product by the length, subtract the quotient from the number of pounds found by the former rule, and the remainder will be the answer.

M. de Buffon uniformly found that two-thirds of the weight which was sufficient to break a beam at first, sensibly impaired its strength, and frequently broke it, at the end of two or three months; and one-half of this weight brought it to a certain curvature, which did not increase after the first minute or two, and may be borne by the beam for any length of time.

One-third seemed to have no permanent effect on the beam; but it recovered its rectilinear shape completely, even after it had been loaded several months, provided the timber was seasoned when first loaded: that is to say, one-third of the weight which would quickly break a seasoned beam, or one-fourth of what would break one just felled, may lie on it for ever, without giving the beam a set.

The agreement of the numbers, found by the rule of the breadth being multiplied by the square of the depth, appears to deviate less from the experiments of Buffon, than that of the inverse ratio of the length; but even this rule, applied to softer woods, will differ greatly from the truth, which must be evident when we consider a beam just breaking, that it will be strongly compressed on the side nearest to the axis of fracture, and the opposite side will be greatly extended; consequently, there must be some point between the fulcrum and the opposite side, which will neither be extended nor compressed; and all the fibres lying between this point and the fulcrum, being in a state of compression, can offer little resistance against the fracture; the fibres on the other side only being exerted.

This is fully verified by some curious

Experiments by M. du Hamel.

He took 16 bars of willow, two feet long and half an inch square, and supported them by props under the ends: he broke them with weights hung on their middle. He broke four of them by weights of 40, 41, 47, and 52 pounds; the mean is 45.

He then cut four of them one-third through, on the upper side, and filled up the cut with a thin piece of harder wood, stuck in very tight: these were broken by 48, 54, 50, and 52, the mean of which is 51.

He cut other four half through; they were broken by 47, 49, 50, and 45, the mean of which is 48.

The remaining four were cut two-thirds, and their mean strength was 42.

Another set of Experiments, still more remarkable.

Six battens of willow, 36 inches long, and 1½ square, were broken by 525 pounds, at a medium.

Six bars were cut one-third through, and the cut filled with a wedge of hard wood, struck in with little force; these broke with 551 pounds.

Six bars were cut half through, and the cut was filled up in the same manner: they broke with 542 pounds.

Six bars were cut three-fourths through, and after being loaded till nearly broken, were unloaded, the wedge was taken out of the cut, and a thicker wedge was put in tight, so as to make the batten straight again, by filling up the space left by the compression of the wood: and it then broke with 577 pounds.

Of the Absolute Strength of Timber.

The strain occasioned by pulling timber in the direction of its length is called *tension;* it frequently occurs in roofs, and is therefore worthy of consideration.

The absolute strength of a fibre, or small thread of timber, is the force by which every part of it is held together, which is equal to the force that would be required to pull it asunder; and the force which would be required to tear any number of threads asunder is proportional to that of their sum; but the areas of the sections of two pieces of timber composed of fibres of the same kinds are as the number of fibres in each; and therefore the strength of the timber is as the area of the sections.

Hence all prismatic bodies are equally strong; that is, they will not break in one part rather than in another.

Bodies which have unequal sections will break at their smallest part; and therefore, if the absolute strength which would be required to tear a square inch of each kind of timber be known, we shall be able to determine the strength of any other quantity whatever.

The following table is taken from Muschenbroëk's experiments; he has described his method of trial minutely; the woods were all formed into slips fit for his apparatus, and part of the slip was cut away to a parallelopiped one-fifth of an inch square, and therefore the twenty-fifth part of a square inch in section; the absolute strengths of a square inch were as follow:—

	lb		lb
Locust tree	20,100	Pomegranate	9,750
Jujeb	18,500	Lemon	2,950
Beech oak	17,300	Tamarind	8,750
Orange	15,500	Fir	8.330
Alder	13 900	Walnut	8,130
Elm	13,200	Pitch pine	7,650
Mulberry	12,500	Quince	6.750
Willow	12.500	Cypress	6,000
Ash	12,000	Poplar	5,500
Plum	11,800	Cedar	4,880
Elder	10,000		

M. Muschenbroëk has given a very minute detail of the experiments on the ash and walnut, stating the weight requisite to tear asunder slips taken from the four sides of the tree, and on each side in a regular progression, from the centre to the circumference. The numbers of this table corresponding to the two timbers, may therefore be considered as the average of more than fifty trials made on each; and he says that all the others were made with the same care, and therefore there is no reason for not confiding in the results.

Practical Observations.

The following observations on wood will be of great use to the practical carpenter, in making a proper choice of timber, according to the purposes for which he may want to employ it.

1. The wood immediately surrounding the pith, or heart, is the weakest; and its inferiority is so much the more remarkable as the tree is older. Muschenbroëk's detail of experiments is decidedly in the affirmative. M. de Buffon, on the other hand, says that his experience has taught him that the heart of a sound tree is the strongest, but he gives no instances. It is certain, from other experiments, on large oaks and firs, that the heart is much weaker than the exterior parts.

2. The wood next to the bark commonly called *white*, or *blea*, is also weaker than the rest; and the wood gradually increases in strength as we recede from the centre to the blea.

Fig. 1.

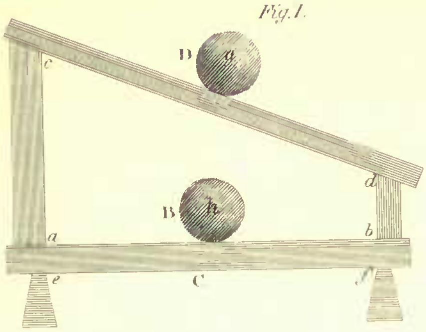


Fig. 2.

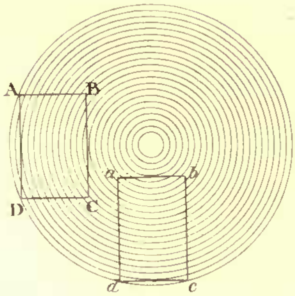


Fig. 3.

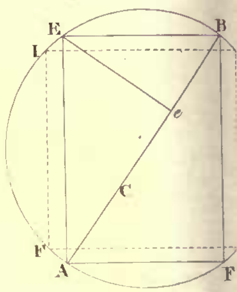


Fig. 4.

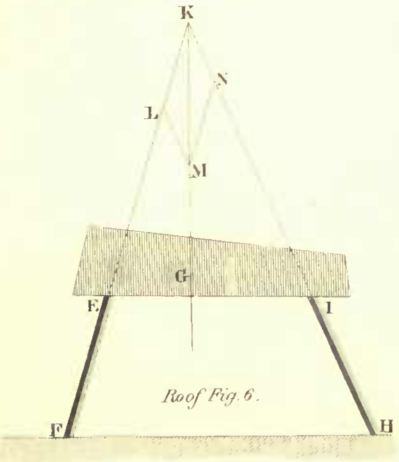


Fig. 5.

Fig. 6.

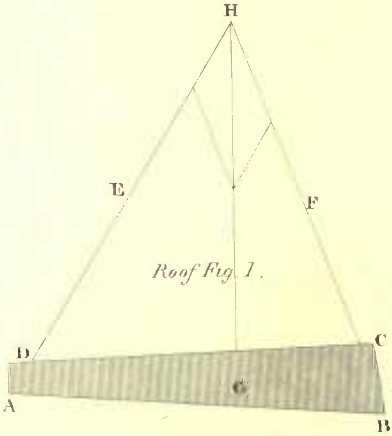


Fig. 7.

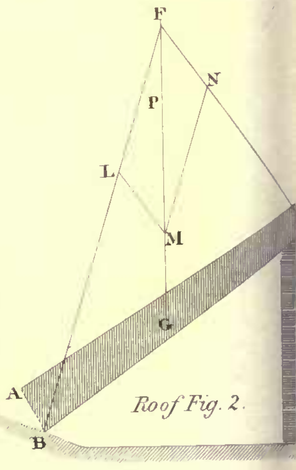


Fig. 8

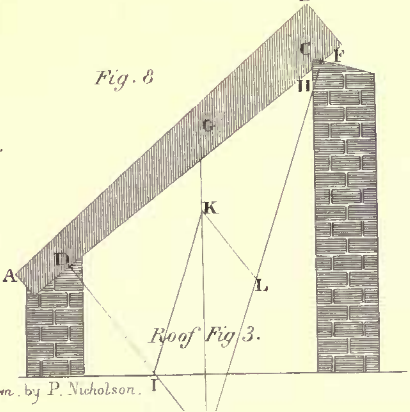


Fig. 9.

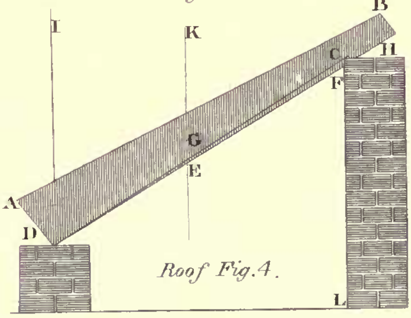
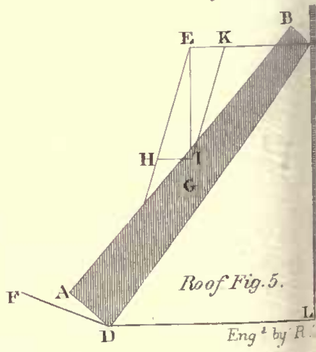


Fig. 10.



3. The wood is stronger in the middle of the trunk than at the springing of the branches, or at the root; and the wood of the branches is weaker than that of the trunk.

4. The wood on the north side of all trees, which grow in the European climates, is the weakest, and that of the south side the strongest; and the difference is most remarkable in hedge-row trees, and such as grow singly.

The heart of a tree is never in its centre, but always nearer to the north side, and the annual coats of wood are thinner on that side. In conformity to this, it is a general opinion of carpenters, that the timber is stronger whose annual plates are thicker. The tracheæ, or air-vessels, are weaker than the simple ligneous fibres. These air-vessels are the same in diameter and number of rows in all trees of the same species, and they make the visible separation between the annual plates. Therefore, when these are thicker, they contain a greater proportion of the simple ligneous fibres.

5. All woods are more tenacious while green, and lose very considerably by drying after the tree is felled.

We shall conclude these observations with the following useful problem.

To cut the strongest beam possible out of a round tree, whose section is a given circle.

Figure 3.—Let A E B F be the section; draw the diameter A B, and divide it into three equal parts at c and *e*: from either of these points, as *e*, draw *e* E perpendicular to A B, cutting the circumference at E; draw A E and E B; through the points A and B draw A F and B F respectively parallel to E B and E A, cutting each other at F; and A E B F will be a section of the strongest beam that can possibly be cut out of the tree, A E B F; for the square of the depth, A E, or F B, multiplied into the breadth, E B, or F A, is then the greatest that can be produced.

From this it is plain, that the strongest beam which can be cut out of a round tree does not contain the most timber; for the greatest rectangle that can be inscribed in a circle is a square, and therefore the square F G H I is greater than the rectangle A F B E, and yet is not the strongest.

To support a piece of timber by means of two props resting on the ground, so that it shall have no tendency to go to either side.

Figure 4.—Let E I be a piece of timber, and G its centre of gravity; then the position, E I, of the timber being given, with the direction of one of the props, H I, and the point, E, where the other is to be placed; to find its length and position, draw G K perpendicular to the horizon; produce H I to K, and draw K E to meet the ground in F, then E F is the length and direction of the post.

To ascertain the proportions between the weight of the piece of timber and the compression of the props.

On the plumb-line G K, take any distance, K M; draw M N parallel to E K, cutting I K in N; and draw M L parallel to I K, cutting E K in L; then, if K M represent the weight of the piece of timber, K N will represent its pressure on the prop I H, and K L its pressure on the prop E F.

The *compression of timber* is another consideration worthy of attention.

In considering strains of this kind, it is absolutely impossible to conceive how a piece of timber that is perfectly straight can be bent, crippled, or broken, by any force whatever acting at the extremes. But suppose the smallest force whatever, acting in the middle, on a direction perpendicular to the length, this force will be sufficient to give it a small degree of curvature; and if a strong force be supposed to act at the ends at the same time, each pressing the timber in the direction of its length, these forces may instantly contribute towards breaking it.

It is easy, therefore, to conceive, that if a piece of timber be the least bent whatever, or if the fibres of that timber be not quite straight, there is a certain force which, if acting at the ends, will break it. Thus, suppose the column, A C B, *Figure* 5, resting on the ground at B, and loaded at the top with a weight, A, acting in a vertical direction A B; and if the fibres, or the piece A C B, is in the smallest degree crooked, the degree of curvature, by the pressure of the two ends, will be increased, until the fibres are bent to their utmost extent, and the smallest addition at the ends will break it.

The first writer who considered the compression of columns with attention, was the celebrated Euler, who published, in the *Berlin Memoirs* for 1757, his Theory on the Strength of Columns. The general proposition established by this theory is, that the strength of prismatic columns is in the direct quadruplicate ratio of their diameters, and the inverse ratio of their lengths; he prosecuted this subject in the *Petersburg Commentaries* for 1778, confirming his former theory. Muschenbroëk has compared the theory with experiment, but the comparison has been very unsatisfactory; the difference from the theory being so enormous as to afford no argument for its justness; neither do they contradict it, for they are so very anomalous as to afford no conclusion or general rule whatever.

PROPOSITION V. *Figure* 6.—*If a heavy body,* A B C D, *be supported by two oblique strings,* D E *and* C F, *in a vertical plane, a straight line drawn through the intersection will pass through the centre of gravity of the body.*

It is shown under the article LEVER, that if any three forces act upon a point, or body, their directions will tend to the same point, or be parallel to each other: now every body acts with its full force in one point only, viz., in the centre of gravity of that body, and in a direction perpendicular to the horizon: that is to say, if the weight of the body be supposed to be collected into the centre of gravity, the effect would be the same, provided the directions of the other two sustaining forces remained the same: therefore, if a body be sustained at E and F, it will revolve round these points till the line, G H, passing through the intersection, H, of the two strings, D E and C E, and the centre of gravity, G, become perpendicular to the horizon.

COROLLARY 1.—Hence, if any body be supported by two strings, it may also be supported by two planes perpendicular to these strings; provided the two points of the body supported be in the direction of the strings; for every body acting upon a plane, acts in a line perpendicular to that plane.

COROLLARY 2.—Hence also a body may be supported by two props in any two directions in which it may be supported by strings; provided the surface of the body at the points of contact, at the ends of the props, be planes at right angles to the strings.

COROLLARY 3.—Hence all the properties that have been demonstrated of three forces acting upon a body supposed void of weight, will equally flow from a heavy body supported by two strings, by substituting the weight of the body for the middle force; and hence, if the direction of any force supporting a heavy body be given, the other may easily be found.

PROPOSITION VI.—*Given the position in which a body should be placed, and the position of a plane supporting the body at one end; to find the position of another plane, to support it at another given point; and to find the pressure on the planes, the weight of the body being given.*

Through the centre of gravity of the body draw a vertical line, and through the point on which the body rests on the given plane draw a line perpendicular to that plane, meeting the vertical line; from their intersection draw a line to the other point to be supported; from that point draw a plane at right angles to this line, which will be the direction of the plane required.

To find the intensity of the forces, take any distance on the vertical line to represent the weight of the beam from the intersection; on that line, as a diagonal, complete a parallelogram, whose sides are in the directions of the lines perpendicular to the supporting planes; and the side of the parallelogram perpendicular to either plane will represent the force on that plane.

Example 1. *Figure* 7.—Let the body A B C D lie upon the top of the wall, K C, at C, so as to touch the lower edge, B C, of the body at that point, B; it is required to find the direction of a plane that will support the lower end at B; and to find the pressure of the body on the wall and on the plane.

Through the centre of gravity, G, of the body, draw the vertical line G F; draw C F perpendicular to C B; join F B; and draw B I perpendicular to F B; and B I is the direction of the plane required. On the vertical line, F, make F M to represent the weight of the body, and complete the parallelogram L M N F; then F N represents the force on the wall-head in the direction C F, and F L the force acting perpendicular to the plane in the direction B F. But if the vertical and horizontal thrusts on the wall at C be required, draw N P perpendicular to F G, meeting it in P; then the force F N is resolved into two forces, F P and P N; P N representing the horizontal part of the force, viz., that which pushes the wall in a direction parallel to the horizon, and F P the other part which tends to press it downwards in a direction perpendicular to the horizon.

Example 2.—*Figure* 8.—Let the sloping body, A B C D, be supported by a wall at its lower end, D, which coincides with the surface of the body; and let G be the centre of gravity; it is required to cut a notch out of the body at the upper end, C, so that it may rest upon the top of a wall which is made to fit the notch, and to find the pressure on the walls. Draw the vertical line G E; from D draw D E perpendicular to D C; join E C, and draw C F at right angles to it; then the notch, H C F, being cut, the body, A B C D, will be at rest.

To find the pressure on the walls, complete the parallelogram E I K L, having a given angle, D E C, and its diagonal on the given line E G: now if K E represent the weight of the body, I E will represent the pressure in the direction, D E, upon the wall at D, and L E the pressure in the direction C E.

The horizontal and perpendicular pressures upon each wall may be found, as in the first example, by resolving each of the forces, I E and L E, into two, one of which is perpendicular to the horizon, and the other parallel to it.

SCHOLIUM.—It must be observed in this example, that the notch cut out at C will remove the centre of gravity nearer the lower end, D, and consequently alter the slope, C F; but as this can only be in a small degree, the equilibrium will hardly be affected by it when the notch is minute.

Example 3. *Figure* 9.—Let one of the corners of a sloping body, A B C D, rest upon the level top of a wall at D; it is required to find the position of a notch cut out of the upper end, C, so that the body may rest upon a wall made to fit the notch.

Let the small part, F C H, be so cut that C H may be parallel to the horizon, then the body will be supported by the two walls, at C and D. For if D I, G K, and C L, be drawn perpendicular to the horizon, these lines, being produced, may be supposed to meet at an infinite distance.

To find the pressure on the walls, join L C, and produce the vertical line K G to meet it in L; then, if G be supposed to be the weight of the body, the pressure on D will be $\frac{EC \times G}{DC}$, and the pressure on C will be $\frac{DL \times G}{DC}$.

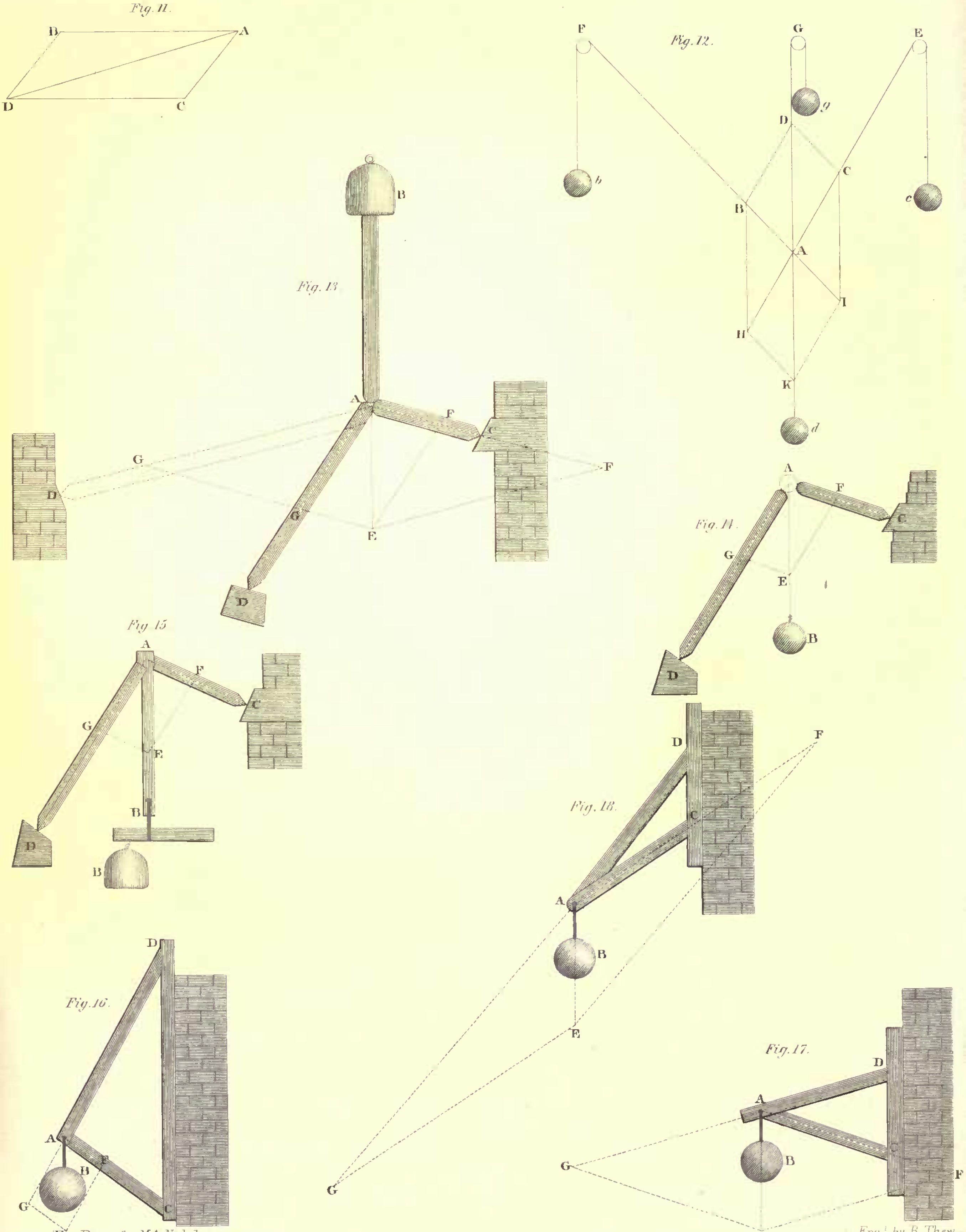
Example 4. *Figure* 10.—Let the body, A B C D, be with its upper end against the vertical face of a wall at C, it is required to find the position of a plane supporting the lower end, D, so that the body may be at rest. Draw the vertical line G E, and draw C E perpendicular to the face of the wall, C L; join E D, and draw D F perpendicular to E D; then D F is the position of the plane required. Complete the parallelogram E H I K: then the pressure on D and C, and the weight of the body, are to each other as E H, E K, E I.

The following, from Professor Robinson, will also be found interesting:

Figure 11.—If a body, or any part of a body, be at once pressed in the two directions A B, A C, and if the intensity or force of those pressures be in the proportion of these two lines, the body is affected in the same manner as if it were pressed by a single force acting in the direction A D, which is the diagonal of the parallelogram A B D C formed by the two lines, and whose intensity has the same proportion to the intensity of each of the other two that A D has to A B or A C.

This proposition has been already treated at some length under the article LEVER. And D. Bernouilli has demonstrated it in the first volume of the *Comment. Petropol.* to which, as well as to D'Alembert's improvement, in his *Opuscles*, and in the *Comment. Taurinens.* the reader is referred for a very accurate view of the subject. But nothing can possibly conduce so fully to the practitioner's advantage as to verify the theoretical demonstrations by actual experiments.

Figure 12.—Let the threads A *d*, A F *b*, and A E *c*, have the weights *d*, *b*, and *c*, appended to them, and let two of the threads be laid over the pulleys F and E. By this apparatus, the knot A will be drawn in the directions A B, A C, and A K. If the sum of the weights *b* and *c* be greater than that of the single weight *d*, the assemblage will of itself settle in a certain determined form; if the knot A be pulled out of its place, it will always return to it again, and will rest in no other position. For example, if the three weights be equal, the threads will always make equal angles, of 120 degrees each, round the knot. If one of the weights be three pounds, another four, and the third five, the angle opposite to the thread stretched by five pounds will be always square, &c. When the knot A is thus in equilibrio, we must infer, that the action of the weight *d*, in the direction A *d*, is in direct opposition to the combined action of *b*, in the direction A B, and of *c*, in the direction A C. Therefore, if *d* A be produced to any point, D, and A D be taken to represent the magnitude of the force, or pressure exerted by the weight *d*, the pressures exerted on A, by the weights *b* and *c*, in the directions A B, A C, will in fact be equivalent to a pressure acting in the direction A D, whose intensity is represented by A D. If we now measure off by a scale on A F and A E the lines A B and A C, having the same proportions to A D that the weights *b* and *c* have to the weight *d*, and if we draw D B and D C, we shall find D C to be equal and parallel to A B, and D B equal and parallel to A C; so that A D is the diagonal of a parallelogram A B D C. This will always be the case, whatever weights be made use of; only care must be taken that the weight acting without the intervention of a pulley be less than the sum of the other two: for if any one of the weights exceed



Drawn by M.A.Nicholson. Eng.d by R. Thew.

the sum of the other two, it will prevail, and drag them along with it.

Now, since we know that the weight *d* would just balance an equal weight, *g*, pulling directly upwards by the intervention of the pulley O; and that it just balances the weights *b* and *c*, acting in the directions A B, A C, we must infer, that the knot A is affected in the same manner by those two weights, or by the single weight *g*; and therefore, that two pressures, acting in the directions, and with the intensities, A B, A C, are equivalent to a single pressure having the direction and proportion of A D. In like manner, the pressures A B, A K, are equivalent to A H, which is equal and opposite to A C. Also A K and A C are equivalent to A I, which is equal and opposite to A B.

We shall consider this combination of pressures a little more particularly.

Figure 13.—Suppose an upright beam, pushed in the direction of its length by a load, B, and abutting on the ends of two beams, A C, A D, which are firmly resisted at their extreme points, C and D, which rest on two blocks, but are nowise joined to them: these two beams can only resist in the directions C A, D A; and therefore the pressures which they sustain from the beam, B A, are in the directions A C, A D. To know how much each sustains, produce B A to E, taking A E from a scale of equal parts, to represent the number of tons, or pounds, by which B A is pressed. Draw E F and E G parallel to A D and A C; then A F, measured on the same scale, will give the number of pounds by which A C is strained or crushed, and A G will give the strain on A D.

Here it deserves particular remark, that the length of A C or A D has no influence on the strain arising from the thrust of B A, while the directions remain the same. The effects, however, of this strain are modified by the length of the piece on which it is exerted. This strain compresses the beam, and will therefore compress a beam of double the length twice as much; though it may change the form of the assemblage. If A C, for example, be very much shorter than A D, it will be much less compressed: the line C A will turn about the centre, while D A will hardly change its position; and the angle C A D will grow more open, the point A sinking down. By thus changing shape, strains are often produced in places where there were none before, and frequently of the very worst kind, tending to break the beams across. The dotted lines of this figure show another position of the beam, A D′, which makes a material change, not only in the strain on A D′, but also in that on A C: both are much increased; A G being almost doubled, and A F four times greater than before. This addition was made to the figure to show what enormous strains may be produced by a very moderate force, A E, when it is exerted on a very obtuse angle.

Figures 14, 15, will assist the most uninstructed reader in conceiving how the very same strains, A F, A G, are laid on these beams, by a weight simply hanging from a billet resting on A, pressing hard on A D, and also leaning a little on A C; or by an upright piece, A E, joggled on two beams, A C, A D, and performing the office of an ordinary king-post.

Figure 15.—The proportion of these strains will be precisely the same, if everything be inverted, and each beam be drawn or pulled in the opposite direction. In the same way that we have substituted a rope and weight in *Figure* 14, or a king-post in *Figure* 15, for the loaded beam, B A, of *Figure* 13, the framing of *Figure* 16 might have been substituted, which is a very usual practice. In this framing, the batten, D A, is stretched by a force, A G, and the piece A C is compressed by a force, A F. It is evident that if a rope, or an iron rod, be fastened on at D, in place of the batten D A, the strains will be the same as before.

Figure 17.—By changing the form of this framing, the same strains are produced as in the disposition represented by the dotted lines in *Figure* 13. The strains on both the battens A D, A C, are now greatly increased.

Figure 18.—The same consequences result from an improper change of the position A C, where the strains on both are vastly increased. In short, the rule is general, that the more open we make the angle against which the push is exerted, the greater will be the strains on the struts or ties forming the sides of the angle.

The reader may not readily conceive the piece A C, of *Figure* 18, as sustaining a compression; for the weight B appears to hang from A C as much as from A D. But his doubts will be removed by considering whether he could employ a rope in place of A C; which he cannot; but A D may be exchanged for a rope. A C is therefore a strut, and not a tie.

Figure 19.—A D is again a strut, butting on the block D; A C is a tie; and the batten A C may be replaced by a rope. While A D is compressed by the force A G, A C is stretched by the force A F. Give A C the position represented by the dotted lines, the compression of A D will be A G′; while the force stretching A C′ will be A F′; both much greater than before. This disposition is analogous to *Figure* 18, and to the dotted lines in *Figure* 13. Nor will the young artist have any doubt of A C′ being on the stretch, if he consider whether A D can be replaced by a rope, which it cannot, but A C, may; and it is therefore not compressed, but stretched.

Figure 20.—All the three pieces, A C, A D, and A B, are ties on the stretch. This is the complete inversion of *Figure* 13; and the dotted position of A C′ induces the same changes in the forces A F′, A G′, as in that figure.

All calculations about the strength of carpentry are reducible to this case; for when more ties, or braces, meet in a point (a thing that rarely happens), they are to be reduced to three, by substituting for any two the force resulting from their combination, and combining this with another; and so on.

The young artist must be particularly careful not to mistake the kind of strain exerted on any piece of the framing, and suppose a piece to be a brace which is really a tie. It is very easy to avoid all mistakes in this matter by the following rule, which has no exception.

Take notice of the direction wherein the piece acts that produces the strain. Draw a line in that direction from the point on which the strain is exerted; and let its length (measured on some scale of equal parts) express the magnitude of this action in pounds, hundreds, or tons. From its remote extremity, draw lines parallel to the pieces on which the strain is exerted. The line parallel to one piece will necessarily cut the other, or its direction produced; if it cut the piece itself, that piece is compressed by the strain, and it is performing the office of a strut, or brace: if it cut its direction produced, the piece is stretched, and it is a tie. In short, the strains on the pieces A C, A D, are to be estimated in the direction of the points F and G from the strained point A. Thus, in *Figure* 13, the upright piece, B A, loaded with the weight B, presses the point A in the direction A E; so does the rope, A B, in the other figures, or the batten A B, in *Figure* 15.

In general, if the straining piece be within the angle formed by the pieces which are strained, the strains sustained by them are of the opposite kind to that which it exerts. If it be pushing, they are drawing; but if it be within the angle formed by their directions produced, the strains sustained by them are of the same kind. All the three are either drawing or pressing. If the straining piece lie within for the same reason, C B is also in a state of compression: for either A or B may be considered as the point that is impelled or withheld. Therefore D A and D B are stretched, and are resisting with attractive forces. D C and C B are compressed, and are resisting with repulsive forces. D B is also acting with repulsive forces, being compressed in like manner: and thus the support of the prop, combined with the firmness of D C, puts the frame A D B C into the condition of the two frames in *Figure* 18 and *Figure* 19. Therefore the external force at A is really in equilibrio with an attracting force acting in the direction A D, and a repulsive force acting in the direction A K. And since all the connecting forces are mutual and equal, the point D is pulled or drawn in the direction D A. The condition of the point B is similar to that of A, and D is also drawn in the direction D B. Thus the point D, being urged by the forces in the directions D A and D B, presses the beam D C on the prop, and the prop resists in the opposite direction. Therefore the line D C is the diagonal of the parallelogram, whose sides have the proportion of the forces which connect D with A and B. This is the principle on which the rest of our investigation proceeds. We may take D C as the representation and measure of their joint effect. Therefore draw C H, C G, parallel to D A, D B. Draw H L, G O, parallel to C A C B, cutting A E, B F, in L and O, and cutting D A, D B, in I and M. Complete the parallelograms I L K A, M O N B; then D G and A I are the equal and opposite forces which connect A and D; for G D = C H, = A I. In like manner D H and B M are the forces which connect D and B.

The external force at A is in immediate equilibrio with the combined forces connecting A with D and with C. A I is one of them; therefore A K is the other; and A L is the compound force with which the external force at A is in immediate equilibrium. This external force is therefore equal and opposite to A L. In like manner, the external force at B is equal and opposite to B O; and A L is to B O as the external force at A to the external force at B. The prop C resists with forces equal to those which are propagated to it from the points D, A, and C. Therefore it resists with forces C H, C G, equal and opposite to D G, D H; and it resists the compressions K A, N B, with equal and opposite forces C *p*, C *n*. Draw *p b*, *n o*, parallel to A D, B D, and draw C *b* Q, C O P: it is plain that *p* C H *b* is a parallelogram equal to K A I L, and that C *b* is equal to A L. In like manner, C *o* is equal to B O. Now the forces C *p*, C H, exerted by the prop, compose the force C *b* and C *n*, C G compose the force C *o*. These two forces C *b*, C *o*, are equal and parallel to A L and B O; and therefore they are equal and opposite to the external forces acting at A and B. But they are (primitively) equal and opposite to the pressures (or at least the compounds of the pressures) exerted on the prop, by the forces propagated to C from A D, and B. Therefore the pressures exerted on the prop are the same as if the external forces were applied there in the same directions as they are applied to A and B. Now if we make C *v*, C *z*, equal to C *b* and C *o*, and complete the parallelogram C *v* Y *z*; it is plain that the force Y C is in equilibrio with *b* C and *o* C. Therefore the pressures at A, C, and B, are such as would balance if applied to one point.

Lastly, in order to determine their proportions, draw C S and C R perpendicular to D A and D B. Also draw A *d*, B *f* pependicular to C Q and C P; and draw C *g*, G *i* perpendicular to A E, B F.

The triangles C P R and B P *f* are similar, having a common angle, P, and a right angle at R and *f*. In like manner the triangles C Q S and A Q *d* are similar. Also the triangles C H R, C G S, are similar by reason of the equal angles at H and G, and the right angles at R and S. Hence we obtain the following analogies:

C *o* : C P = *on* : P B = C G : P B
C P : C R = P B : *f* B
C R : C S = C H : C G
C S : C Q = A *d* : A Q
C Q : C *b* = A Q : *p b* : L K = A Q : C H

Therefore, by equality,

C *o* : C *b* = A *d* : *f* B
or, B O : A L = C *g* : C *i*

That is, the external forces are reciprocally proportional to the perpendiculars drawn from the prop on the lines of their direction.

This proposition is fertile in consequences, and furnishes many useful instructions to the artist. The strains L A, O B, C Y, that are excited, occur in many, if not in all framings of carpentry, whether for edifices or engines, and are the sources of their efficacy. It is also evident, that the doctrine of the transverse strength of timber is contained in this proposition; for every piece of timber may be considered as an assemblage of parts, connected by forces acting in the direction of the lines which join the strained points on the matter lying between those points, and also act on the rest of the matter, exciting those lateral forces which produce the inflexibility of the whole. Thus it appears that this proposition contains the principles which direct the artist to frame the most powerful levers; to secure uprights by shores or braces, or by ties and ropes; to secure scaffoldings for the erection of spires, and many other most delicate problems of his art. He also learns, from this proposition, how to ascertain the strains that are produced, without his intention, by pieces which he intended for other offices, and which, by their transverse action, put his work in hazard. In short, this proposition is the key to the science of his art.

There is a proposition which has been called in question by several very intelligent persons; and they say that Belidor has demonstrated, in his *Science des Ingeneurs*, that a beam firmly fixed at both ends is not twice as strong as when simply lying on the props, and that its strength is increased only in the proportion of 2 to 3; and they support this determination by a list of experiments recited by Belidor, which agree precisely with it. Belidor also says, that Pitot had the same results in his experiments. These are respectable authorities: but Belidor's reasoning is anything but demonstration; and his experiments are described in such an imperfect manner, that we cannot build much on them. It is not said in what manner the battens were secured at the ends, any farther than that it was by *chevalets*. If by this word is meant a *trestle*, we cannot conceive how they were employed; but we see this term sometimes used for a *wedge*, or *key*. If the battens were wedged in the holes, their resistance to fracture may be made what we please: they may be loose, and therefore resist little more than when simply laid on the props. They may be (and probably were) wedged very fast, and bruised or crippled.

Figure 24.—Let L M be a long beam divided into six equal parts, in the points D, B, A, C, E, and firmly supported at L, B, C, M; let it be cut through at A, and have compass joints at B and C; let F B, G C, be two equal uprights, resting on B and C, but without any connection; let A H be a similar and equal piece, to be occasionally applied at the seam A; then extend a thread, or wire, A G E, over the piece G C, and made fast at A, G, and E; do the same on the other side of A. Now, if a weight be laid on at A, the wires A F D, A G E, will be strained, and may be broken. In the instant of fracture, we may suppose their strains to be represented by A *f* and A *g*. Complete the parallelogram, and A *a* is the magnitude of the

Fig. 19.

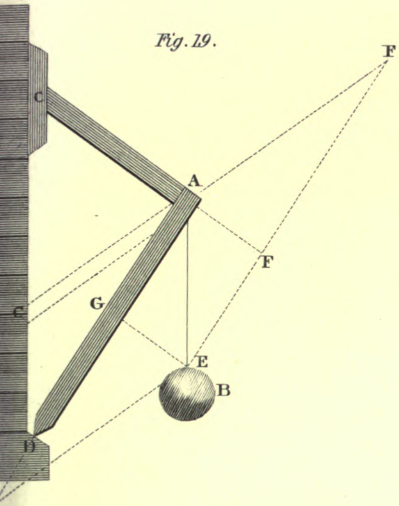


Fig. 20.

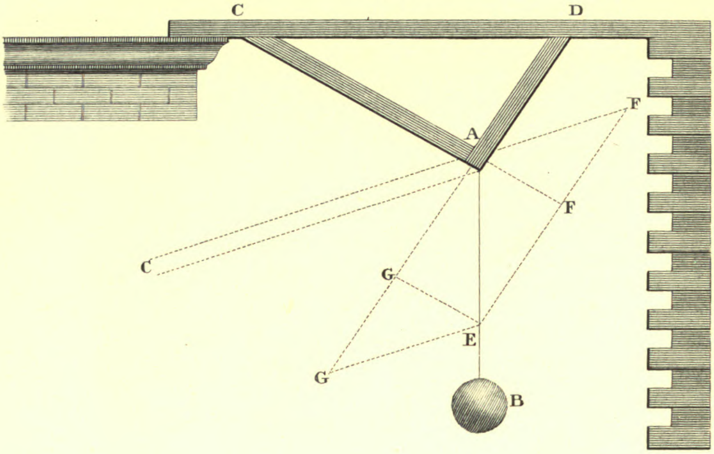


Fig. 21.

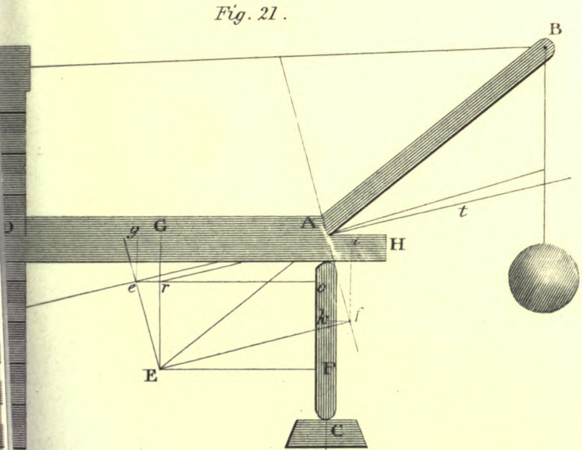


Fig. 22.

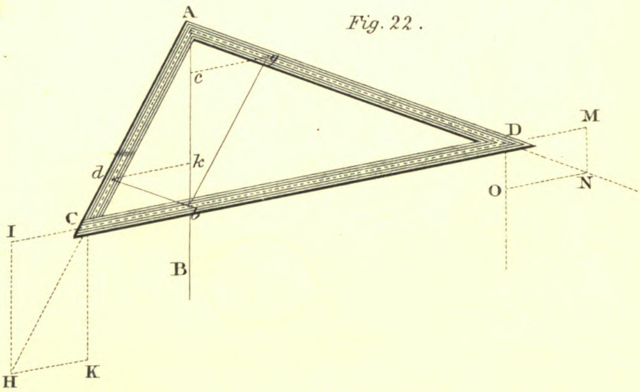


Fig. 23.

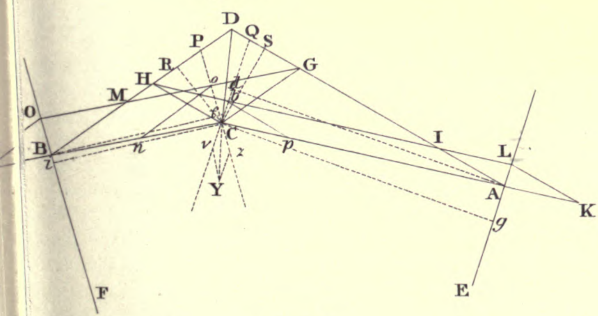


Fig. 24.

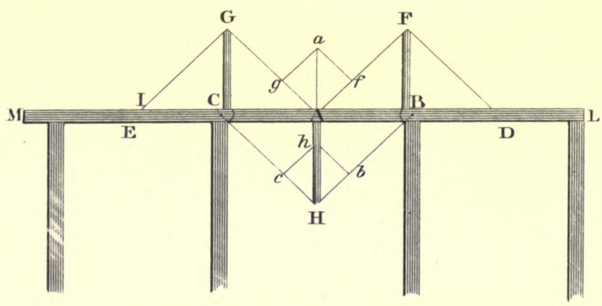


Fig. 25.

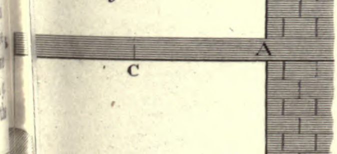


Fig. 26.

weight. It is plain that nothing is concerned here but the cohesion of the wires; for the beam is sawn through at A, and its parts are perfectly moveable round B and C.

Instead of this process, apply the piece A H below A, and keep it there by straining the same wire, B H C, over it: lay on a weight, which must press down the ends of B A and C A, and cause the piece A H to strain the wire B H C. In the instant of fracture of the same wire, its resistances, H b and H c must be equal to A f and A g, and the weight h H, which breaks them, must be equal to A a.

Lastly, employ all the three pieces, F B, A H, G C, with the same wire attached as before. There can be no doubt but that the weight which breaks all the four wires must be = a A + h H, or twice A a.

The reader cannot but see that the wires perform the very same office with the fibres of an entire beam, L M, held fast in the four holes, D B C, and E, of some upright posts.

In the experiments for verifying this, by breaking slender bars of fine deal, we get complete demonstration, by measuring the curvatures produced in the parts of the beam thus held down, and comparing them with the curvature of a beam simply laid on the props B and C; and there are many curious inferences to be made from these observations.

We may observe, by the way, that we learn from this case, that purlins are able to carry twice the load when notched into the rafters, that they carry when mortised into them, which is the most usual manner of framing them. So would the binding joists of floors; but this would double the thickness of the flooring. But this method should be followed in every possible case, such as bres-summers, lintels over several pillars, &c. These should never be cut off and mortised into the sides of every upright; numberless cases will occur which show the importance of the maxim.

We here remark, that the proportion of the spaces B C and C M, or B C and L B, has a very sensible effect on the strength of the beam B C; but we have not yet satisfied our minds as to the *rationale* of this effect. It is undoubtedly connected with the serpentine form of the curve, of the beam before fracture. This should be attended to in the construction of the springs of carriages. These are frequently supported at a middle point (and it is an excellent practice), and there is a certain proportion which will give the easiest motion to the body of the carriage. We also think that it is connected with that deviation from the best theory observable in Buffon's experiments on various lengths of the same scantling. The force of the beams diminished much more than in the inverse proportion of their lengths.

We have seen that it depends entirely on the position of the pieces in respect of their points of ultimate support, and of the direction of the external force which produces the strains, whether any particular piece is in a state of extension or of compression. The knowledge of this circumstance may greatly influence us in the choice of the construction. In many cases we may substitute slender iron rods for massive beams, when the piece is to act the part of a tie. But we must not invert this disposition; for when a piece of timber acts as a strut, and is in a state of compression, it is next to certain that it is not equally compressible in its opposite sides through the whole length of the piece, and that the compressing force on the abutting joint is not acting in the most equable manner all over the joint. A very trifling inequality in either of these circumstances (especially in the first) will compress the beam more on one side than on the other. This cannot be without the beam's bending, and becoming concave on that side on which it is most compressed. When this happens, the frame is in danger of being crushed, and soon going to ruin. It is therefore indispensably necessary to make use of beams in all cases where struts are required of considerable length, rather than of metal rods of slender dimensions, unless in situations where we can effectually prevent their bending, as in trussing a girder internally, where a cast-iron strut may be firmly cased in it, so as not to bend in the smallest degree. In cases where the pressures are enormous, as in the very oblique struts of a centre, or arch frame, we must be particularly cautious to do nothing which can facilitate the compression of either side. No mortises should be cut near to one side; no lateral pressures, even the slightest, should be allowed to touch it. We have seen a pillar of fir, 12 inches long and 1 in section, when loaded with three tons, snap in an instant when pressed on one side by 16 pounds, while another bore $4\frac{1}{2}$ tons without hurt, because it was enclosed (loosely) in a stout pipe of iron.

In such cases of enormous compression, it is of great importance that the compressing force bear equally on the whole abutting surface. The German carpenters are accustomed to put a plate of lead over the joint. This prevents, in some measure, the penetration of the end fibres. M. Perronet, the celebrated French architect, formed his abutments into arches of circles, the centre of which was the remote end of the strut. By this contrivance the unavoidable change of form of the triangle made no partial bearing upon either angle of the abutment. This always has a tendency to splinter off the heel of the beam where it presses strongest. It is a very judicious practice.

When circumstances allow it, we should rather employ ties than struts, for securing a beam against lateral strains. When an upright pillar, such as a flag-staff, a mast, or the uprights of a very tall scaffolding, are to be shored up, the dependence is more certain on those braces that are stretched by the strain than on those which are compressed. The scaffolding of the iron bridge near Sunderland had some ties very judiciously disposed, and others with less judgment.

Figure 25.—1. When a beam, A B, is firmly fixed at the end, A, and a straining force acts perpendicularly to its length at any point, B, the strain occasioned at any section, C, between B and A, is proportional to C B, and may therefore be represented by the product W × C B; that is, by the product of the number of tons, pounds, &c. which measure the straining force, and the number of feet, inches, &c. contained in C B. As the loads on a beam are easily conceived, we shall substitute this for any other straining force.

2. If the strain or load be uniformly distributed along any part of the beam lying beyond C (that is, farther from A), the strain at C is the same as if the load were all collected at the middle point of that part; for that point is the centre of gravity of the load.

Figure 26.—3. The strain on any section, D, of a beam A B, resting freely on two props, A and B, is $w \times \frac{AD \times DB}{AB}$.

4. The strain on the middle point, by a force applied there, is one-fourth of the strain which the same force would produce, if applied to one end of a beam of the same length, having the other end fixed.

5. The strain of any section, C, of a beam resting on two props, A and B, occasioned by a force applied perpendicularly to another point, D, is proportional to the rectangle of the exterior segments, or is equal to $w \times \frac{AC \times DB}{AC}$. Therefore the strain at C, occasioned by the pressure on D, is the same with the strain at D, occasioned by the same pressure on C.

6. The strain on any section, D, occasioned by a load uni-

formly diffused over any part, E F, is the same as if the two parts, E D, D F, of the load were collected at the middle points, *e* and *f*. Therefore the strain on any part, D, occasioned by a load uniformly distributed over the whole beam, is one-half of the strain that is produced when the same load is laid on at D; and the strain on the middle point, C, occasioned by a load uniformly distributed over the whole beam, is the same which half that load would produce if laid on at C.

Figure 24.—7. A beam supported at both ends on two props, B and C, will carry twice as much when the ends beyond the props are kept from rising, as it will carry when it rests loosely on the props.

8. Lastly, the transverse strain on any section, occasioned by a force applied obliquely, is diminished in the proportion of the sine of the angle which the direction of the force makes with the beam. Thus, if it be inclined to it in an angle of thirty degrees, the strain is one-half of the strain occasioned by the same force acting perpendicularly.

On the other hand, the *relative strength* of a beam, or its power in any particular section to resist any transverse strain, is proportional to the absolute cohesion of the section directly to the distance of its centre of effort from the axis of fracture directly, and to the distance from the strained point inversely.

Thus, in a rectangular section of the beam, of which b is the breadth, d the depth (that is, the dimension in the direction of the straining force), measured in inches, and f the number of pounds which one square inch will just support without being torn asunder, we must have $f \times b \times d^2$, proportional to $w \times$ C B. Or, $f \times b \times d^2$, multiplied by some number, m, depending on the nature of the timber, must be equal to $w \times$ C B. Or, in the case of the section, C, of *Figure* 46, that is strained by the force, w, applied at D, we must have $m \times f\, b\, d^2 = w \times \frac{\text{A C} \times \text{D B}}{\text{A B}}$. Thus, if the beam is of sound oak, m is very nearly $= \frac{1}{9}$. Therefore we have $\frac{f\, b\, d^2}{9} = w \times \frac{\text{A C} \times \text{C B}}{\text{A B}}$. Hence we can tell the precise force, w, which any section, C, can just resist when that force is applied in any way whatever. For the above-mentioned formula gives $w = \frac{f\, b\, d^2}{9 \text{ C B}}$, for the case represented by *Figure* 25. But the case represented in *Figure* 26 having the straining force applied at D, gives the strain at C $(= w)$ $= f \times \frac{b\, d^2 \times \text{A B}}{9 \text{ A C} \times \text{C B}}$.

Example.—Let an oak beam, four inches square, rest freely on the props A and B, seven feet apart, or 84 inches. What weight will it just support at its middle point, C, on the supposition that a square inch rod will just carry 16,000 pounds, pulling it asunder?

The formula becomes $w = \frac{16000 \times 4 \times 16 \times 84}{9 \times 42 \times 42}$ or $w = \frac{86016000}{15876} = 5418$ pounds. This is very near what was employed in Buffon's experiment, which was 5312.

Had the straining force acted on a point, D, half way between C and B, the force sufficient to break the beam at C would be equal to $\frac{16000 \times 4 \times 16 \times 84}{9 \times 42 \times 21} = 10836$ lbs.

Had the beam been sound red fir, we must have taken $f =$ 10,000 nearly, and m nearly 8; for although fir be less cohesive than oak in the proportion of 5 to 8 nearly, it is less compressible, and its axis of fracture is therefore nearer to the concave side.

Having considered at sufficient length the strains of different kinds which arise from the form of the parts of a frame of carpentry, and the direction of the external forces which act on it, whether considered as impelling or as supporting its different parts, we must now proceed to consider the means by which this form is to be secured, and the connections by which those strains are excited and communicated.

The joinings practised in carpentry are almost infinitely various, and each has advantages which make it preferable in some circumstances. Many varieties are employed merely to please the eye. We do not concern ourselves with these, nor shall we consider those which are only employed in connecting small works, and can never appear on a great scale; yet, even in some of these, the skill of the carpenter may be discovered by his choice; for, in all cases, it is wise to make every part of his work, even in the smallest details, as strong as the materials will admit. He will be particularly attentive to the changes which will necessarily happen by the shrinking of timber as it dries, and will consider what dimensions of his framings will be affected by this, and what will not; and will then dispose the pieces which are less essential to the strength of the whole, in such a manner that their tendency to shrink shall be in the same direction with the shrinking of the whole framing. If he do otherwise, the seams will widen, and parts will be split asunder. He will dispose his boardings in such a manner as to contribute to the stiffness of the whole, avoiding at the same time the giving them positions which will produce lateral strains on truss-beams which bear great pressures: recollecting, that although a single board has little force, yet many united have a great deal, and may frequently perform the office of very powerful struts.

Our limits confine us to the joinings which are most essential for connecting the parts of a single piece of a frame when it cannot be formed of one beam, either for want of the necessary thickness or length; and the joints for connecting the different sides of a trussed frame.

Much ingenuity and contrivance has been bestowed on the manner of building up a great beam of many thicknesses, and many singular methods are practised, as great nostrums, by different artists; but when we consider the manner in which the cohesion of the fibres performs its office, we shall clearly see that the simplest are equally effectual with the most refined, and that they are less apt to lead us into false notions of the strength of the assemblage.

Thus, were it required to build up a beam for a great lever or a girder, so that it may act nearly as a beam of the same size of one log; it may either be done by plain joggling, as in *Figure* 27, A, or by scarfing, as at B or C. If it is to act as a lever, having the gudgeon on the lower side, we believe that most artists will prefer the form B and C: at least this has been the case with nine-tenths of those to whom we have proposed the question. The best informed only hesitated; but the ordinary artists were all confident in its superiority: and we found their views of the matter very coincident. They considered the upper piece as grasping the lower in its hooks; and several imagined that, by driving the one very tight on the other, the beam would be stronger than an entire log: but if we attend carefully to the internal procedure in the loaded lever, we shall find the upper one clearly the strongest. If they are formed of equal logs, the upper one is thicker than the other by the depth of the joggling or scarfing, which we suppose to be the same in both; consequently, if the cohesion

Fig. 34.

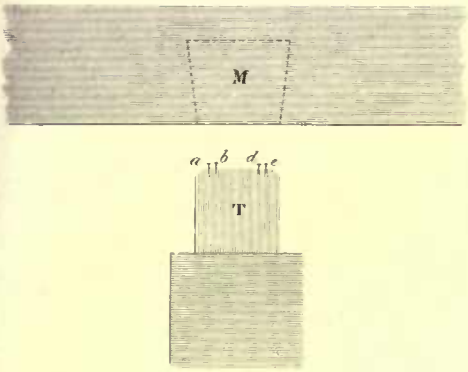


Fig. 35.

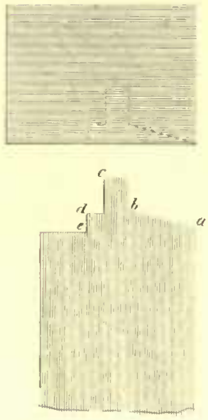


Fig. 36.

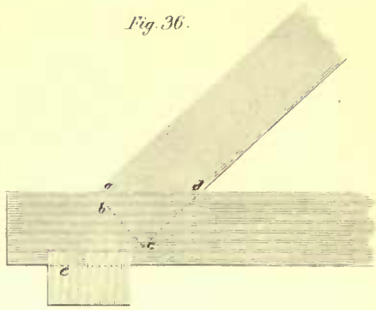


Fig. 37.

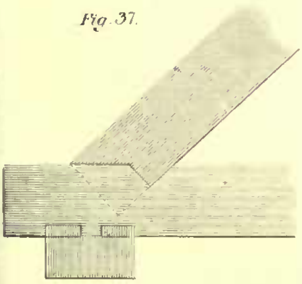


Fig. 38.

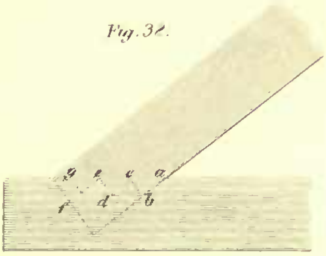


Fig. 39. Nº 1.

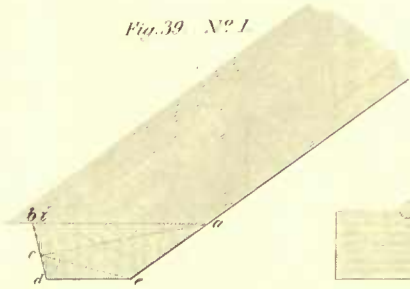


Fig. 39. Nº 2.

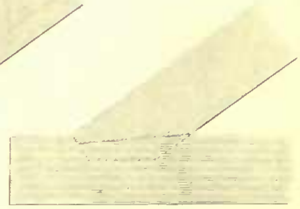
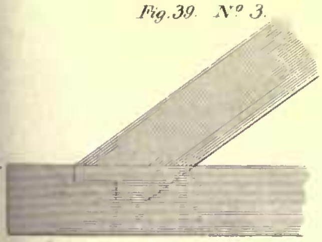


Fig. 40.

Fig. 39. Nº 3.



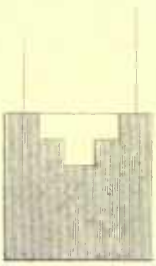


Fig. 41. Nº 1.

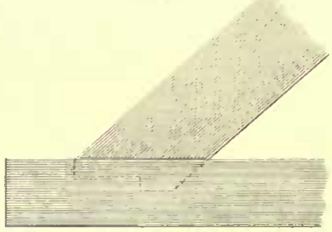


Fig. 41. Nº 2.

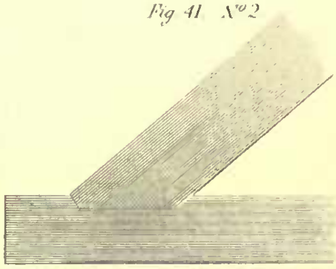


Fig. 42. Nº 1.

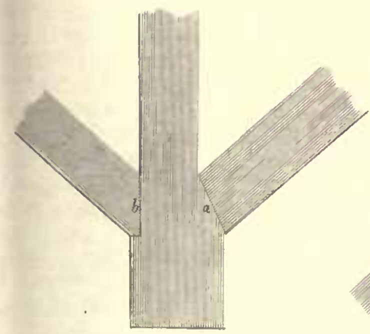


Fig. 42. Nº 2.

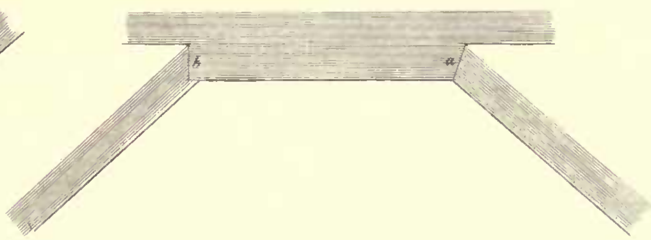
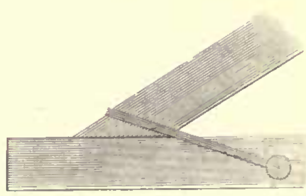


Fig. 43.



of the fibres in the intervals is able to bring the uppermost filaments into full action, the form A is stronger than B, in the proportion of the greater distance of the upper filaments from the axis of the fracture: this may be greater than the difference of the thickness, if the wood is very compressible. If the gudgeon be in the middle, the effect, both of the joggles and the scarfings, is considerably diminished; and if it is on the upper side, the scarfings act in a very different way. In this situation, if the loads on the arms are also applied to the upper side, the joggled beam is still more superior to the scarfed one. This will be best understood by resolving it in imagination into a trussed frame. But when a gudgeon is thus put on that side of the lever which grows convex by the strain, it is usual to connect it with the rest by a powerful strap, which embraces the beam, and causes the opposite point to become the resisting point. This greatly changes the internal actions of the filaments, and, in some measure, brings it into the same state as the first, with the gudgeon below. Were it possible to have the gudgeon on the upper side, and to bring the whole into action without a strap, it would be the strongest of all; because, in general, the resistance to compression is greater than to extension. In every situation the joggled beam has the advantage; and it is the easiest executed. We may frequently gain a considerable accession of strength by this building up of a beam; especially if the part which is stretched by the strain be of oak, and the other part of fir. Fir being so much superior to oak as a pillar (if Musschenbroek's experiments may be confided in), and oak so much preferable as a tie, this construction seems to unite both advantages. But we shall see much better methods of making powerful levers, girders, &c. by trussing.

Observe, that the efficacy of both methods depends entirely on the difficulty of causing the piece between the cross joints to slide along the timber to which it adheres. Therefore, if this be moderate, it is wrong to make the notches deep; for as soon as they are so deep that their ends have a force sufficient to push the slice along the line of junction, nothing is gained by making them deeper; and this requires a greater expenditure of timber.

Scarfings are frequently made oblique, as in *Figure* 28, but we imagine that this is a bad practice. It begins to yield at the point, where the wood is *crippled* and *splintered* off, or at least bruised out a little: as the pressure increases, this part, by squeezing broader, causes the solid parts to rise a little upwards, and gives them some tendency, not only to push their antagonists along the base, but even to tear them up a little. For similar reasons, we disapprove of the favourite practice of many artists, to make the angles of their scarfings acute, as in *Figure* 29. This often causes the two pieces to tear each other up. The abutments should always be perpendicular to the directions of the pressures. Lest it should be forgotten in its proper place, we may extend this injunction also to the abutments of different pieces of a frame, and recommend it to the artist even to attend to the shrinking of the timbers by drying. When two timbers abut obliquely, the joint should be most full at the obtuse angle of the end; because, by drying, that angle grows more obtuse, and the beam would then be in danger of splintering off at the acute angle.

It is evident, that the nicest work is indispensably necessary in building up a beam. The parts must abut on each other completely, and the smallest play, or void, takes away the whole efficacy. It is usual to give the butting joints a small taper to one side of the beam, so that they may require moderate blows of a maul to force them in, and the joints may be perfectly close when the external surfaces are even on each side of the beam. But we must not exceed in the least degree; for a very taper wedge has great force; and if we have driven the pieces together by very heavy blows, we leave the whole in a state of violent strain, and the abutments are perhaps ready to splinter off by a small addition of pressure.

The most general reason for piecing a beam is to increase its length. This is frequently necessary, in order to procure tie-beams for very wide roofs. Two pieces must be scarfed together. Numberless are the modes of doing this; and almost every master carpenter has his favourite nostrum. Some of them are very ingenious: but here, as in other cases, the most simple are commonly the strongest. We do not imagine that any, the most ingenious, is equally strong with a tie consisting of two pieces of the same scantling laid over each other for a certain length, and firmly bolted together. We acknowledge that this will appear an artless and clumsy tie-beam; but we only say that it will be stronger than any that is more artificially made up of the same thickness of timber. This, we imagine, will appear sufficiently certain. The simplest and most obvious scarfing (after the one now mentioned) is that represented in *Figure* 30, No. 1 and 2. If considered merely as two pieces of wood joined, it is plain that, as a tie, it has but half the strength of an entire piece, supposing that the bolts (which are the only connections) are fast in their holes. No. 2 requires a bolt in the middle of the scarf, to give it that strength; and, in every other part, is weaker on one side or the other.

But the bolts are very apt to bend by the violent strain, and require to be strengthened by uniting their ends by iron plates; in which case it is no longer a wooden tie. The form of No. 1 is better adapted to the office of a pillar than No. 2; especially if its ends be formed in the manner shown in the elevation, No. 3. By the sally given to the ends, the scarf resists an effort to bend it in that direction. Besides, the form of No. 2 is unsuitable for a post; because the pieces, by sliding on each other by the pressure, are apt to splinter off the tongue which confines their extremity.

Figures 31 and 32, exhibit the most approved form of a scarf, whether for a tie or a post. The key represented in the middle is not essentially necessary: the two pieces might simply meet square there. This form, without a key, needs no bolts (although they strengthen it greatly); but if worked very true and close, and with square abutments, will hold together, and will resist bending in any direction. But the key is an ingenious and a very great improvement, and will force the parts together with perfect tightness. The same precaution must be observed that we mentioned on another occasion, not to produce a constant internal strain on the parts by over-driving the key. The form of *Figure* 31 is by far the best; because the triangle of 32 is much easier splintered off by the strain, or by the key, than the square wood of 31. It is far preferable for a post, for the reason given when speaking of *Figure* 30, No. 1 and 2. Both may be formed with a sally at the ends equal to the breadth of the key. In this shape, *Figure* 31 is vastly well suited for joining the parts of the long corner posts of spires and other wooden towers. *Figure* 31, No. 2, differs from No. 1 only by having three keys. The principle and longitudinal strength are the same. The long scarf of No. 2, tightened by the three keys, enables it to resist a bending much better.

None of these scarfed tie-beams can have more than one-third of the strength of an entire piece, unless with the assistance of iron plates; for if the key be made thinner than one-third, it has less than one-third of the fibres to pull by.

We are confident, therefore, that when the heads of the bolts are connected by plates, the simple form of *Figure* 30, No. 1, is stronger than those more ingenious scarfings. It may be strengthened against lateral bendings by a little tongue, or by a sally; but it cannot have both.

The strongest of all methods of piecing a tie-beam would be to set the parts end to end, and grasp them between other pieces on each side, as in *Figure* 33. This is what the ship-carpenter calls *fishing* a beam; and is a frequent practice for occasional repairs. M. Perronet used it for the tie-beams, or stretchers, by which he connected the opposite feet of a centre, which was yielding to its load, and had pushed aside one of the piers above four inches. Six of these not only withstood a strain of 1,800 tons, but, by wedging behind them, he brought the feet of the truss 2½ inches nearer. The stretchers were 14 inches by 11, of sound oak, and could have withstood three times that strain. M. Perronet, fearing that the great length of the bolts employed to connect the beams of these stretchers would expose them to the risk of bending, scarfed the two side pieces into the middle piece. The scarfing was of the triangular kind (*trait de Jupiter*), and only an inch deep, each face being two feet long, and the bolt passed through close to the angle.

In piecing the pump rods, and other wooden stretchers of great engines, no dependence is had on scarfing; and the engineer connects everything by iron straps. But we doubt the propriety of this, at least in cases where the bulk of the wooden connection is not inconvenient.

These observations must suffice for the methods employed for connecting the parts of a beam; and we now proceed to consider what are more usually called *the joints* of a piece of carpentry.

Where the beams stand square with each other, and the strains are also square with the beams, and in the plane of the frame, the common mortise and tenon is the most perfect junction. A pin is generally put through both, in order to keep the pieces united, in opposition to any force which tends to part them. Every carpenter knows how to bore the hole for this pin, so that it shall draw the tenon tight into the mortise, and cause the shoulder to butt close, and make neat work; and he knows the risk of tearing out the bit of the tenon beyond the pin, if he draw it too much. We may just observe, that square holes and pins are much preferable to round ones for this purpose, bringing more of the wood into action, with less tendency to split it. The ship-carpenters have an ingenious method of making long wooden bolts, which do not pass completely through, take a very fast hold, though not nicely fitted to their holes, which they must not be, lest they should be crippled in driving. They call it *fox-tail wedging.* They stick into the point of the bolt a very thin wedge of hard wood, so as to project a proper distance: when this reaches the bottom of the hole by driving the bolt, it splits the end of it, and squeezes it hard to the side. This may be practised with advantage in carpentry. If the ends of the mortise are widened inwards, and a thin wedge be put into the head of the tenon, it will have the same effect, and make the joint equal to a dovetail. But this risks the splitting of the piece beyond the shoulder of the tenon, which would be unsightly. This may be avoided as follows:—Let the tenon, T, *Figure* 34, have two very thin wedges, *a* and *c*, stuck in near its angles, projecting equally: at a very small distance within these, put in two shorter wedges, *b*, *d*, and more within these, if necessary. In driving this tenon, the wedges *a* and *c* will take first, and split off a thin slice, which will easily bend without breaking. The wedges *b*, *d*, will act next, and have a similar effect, and the others in succession. The thickness of all the wedges taken together must be equal to the enlargement of the mortise toward the bottom.

The mortise in a girder for receiving the tenon of a binding joist of a floor should be as near the upper side as possible, because the girder becomes concave on that side by the strain. But as this exposes the tenon of the binding-joist to the risk of being torn off, we are obliged to mortise farther down. The form (*Figure* 35) generally given to this joint is extremely judicious. The sloping part *a b*, gives a very firm support to the additional bearing *c d*, without much weakening of the girder. This form should be copied in every case where the strain has a similar direction.

The joint that most of all demands the careful attention of the artist, is that which connects the ends of beams, one of which pushes the other very obliquely, putting it into a state of extension. The most familiar instance of this is the foot of a rafter pressing on the tie-beam, and thereby drawing it away from the other wall. When the direction is very oblique (in which case the extending strain is the greatest), it is difficult to give the foot of the rafter such a hold of the tie-beam as to bring many of its fibres into the proper action. There would be little difficulty if we could allow the end of the tie-beam to project to a small distance beyond the foot of the rafter; but, indeed, the dimensions which are given to tie-beams, for other reasons, are always sufficient to give enough of abutment when judiciously employed. Unfortunately, this joint is much exposed to failure by the effects of the weather. It is much exposed, and frequently perishes by rot, or becomes so soft and friable, that a very small force is sufficient, either for pulling the filaments out of the tie-beam, or for crushing them together. We are therefore obliged to secure it with particular attention, and to avail ourselves of every circumstance of construction.

One is naturally disposed to give the rafter a deep hold by a long tenon; but it has been frequently observed, in old roofs, that such tenons break off. Frequently they are observed to tear up the wood that is above them, and push their way through the end of the tie-beam. This, in all probability, arises from the first sagging of the roof, by the compression of the rafters and of the head of the king-post. The head of the rafter descends; the angle, with the tie-beam, is diminished by the rafter revolving round its step in the tie-beam. By this motion the heel, or inner angle of the rafter, becomes a fulcrum to a very long and powerful lever much loaded. The tenon is the other arm, very short, and being still fresh, it is therefore very powerful. It therefore forces up the wood that is above it, tearing it out from between the cheeks of the mortise, and then pushes it along. Carpenters have therefore given up long tenons, and give to the toe of the tenon a shape which abuts firmly, in the direction of the thrust, on the solid bottom of the mortise, which is well supported on the under side by the wall-plate. This form has the farther advantage of having no tendency to tear up the end of the mortise; and is represented in *Figure* 36. The tenon has a small portion, *a b*, cut perpendicular to the surface of the tie-beam, and the rest, *b c*, is perpendicular to the rafter.

But if the tenon be not sufficiently strong (and it is not so strong as the rafter, which is thought not to be stronger than is necessary), it will be crushed, and then the rafter will slide out along the surface of the beam. It is therefore necessary to call in the assistance of the whole rafter. It is in this distribution of the strain among the various abutting parts, that the varieties of joints and their merits chiefly consist. It would be endless to describe every nostrum, and we shall only mention a few that are most generally approved of.

The aim, in *Figure* 37, is to make the abutments exactly perpendicular to the thrusts. It does this very precisely; and the share which the tenon and the shoulder have of the whole

MECHANICAL CARPENTRY.

Fig. 27.

A.

Fig. 27.

B

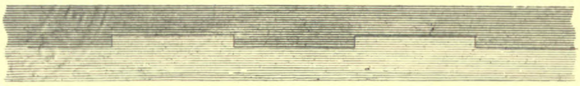


Fig. 27.

C

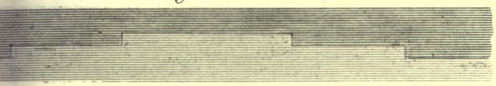


Fig. 28.

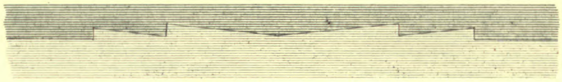


Fig. 29.

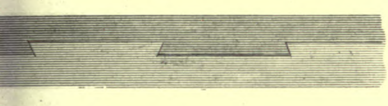


Fig. 30. No. 1.

Fig. 30. No. 2.

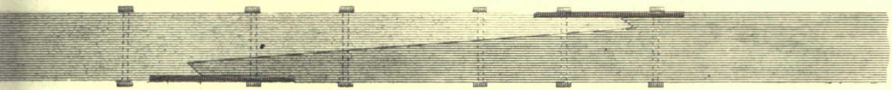


Fig. 30. No. 3.

Fig. 31 No. 1.

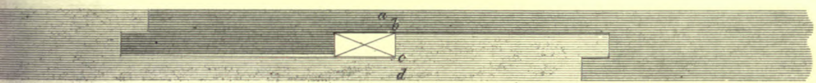


Fig. 31 No. 2

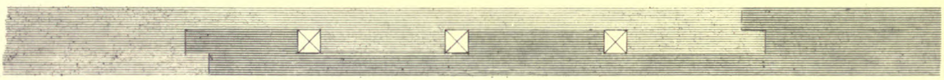


Fig. 32.

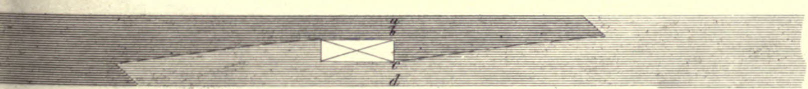
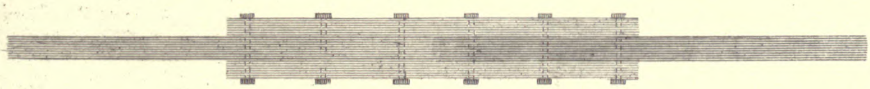


Fig. 33.



...n by M. A. Nicholson

Engraved by J. C. Buttre

may be what we please, by the portion of the beam that we notch down. If the wall plate lie duly before the heel of the rafter, there is no risk of straining the tie across, or breaking it, because the thrust is made direct to that point where the beam is supported. The action is the same as against the joggle on the head or foot of a king-post. We have no doubt but that this is a very effectual joint. It is not, however, much practised. It is said that the sloping seam at the shoulder lodges water; but the great reason seems to be a secret notion that it weakens the tie-beam. If we consider the direction in which it acts as a tie, we must acknowledge that this form takes the best method for bringing the whole of it into action.

Figure 38 exhibits a form that is more general, but certainly worse. The part of the thrust that is not borne by the tenon acts obliquely on the joint of the shoulder, and gives the whole a tendency to rise up and slide outward.

The shoulder joint is sometimes formed like the dotted line, *a b c d e f g*, of *Figure* 38. This is much more agreeable to the true principle, and would be a very perfect method, were it not that the intervals, *b d* and *d f*, are so short that the little wooden triangles, *b c d*, *d e f*, will be easily pushed off their bases, *b d*, *d f*.

Figure 39 seems to have the most general approbation. It is the joint recommended by Price, (p. 7), and copied into all books of carpentry, as the true joint for a rafter foot. The visible shoulder-joint is flush with the upper surface of the tie-beam. The angle of the tenon at the tie nearly bisects the obtuse angle formed by the rafter and the beam, and is therefore somewhat oblique to the thrust. The inner shoulder, *a c*, is nearly perpendicular to *b d*. The lower angle of the tenon is cut off horizontally, as at *e d*.

Figure 40 is a section of the beam and rafter foot, showing the different shoulders.

We do not perceive the peculiar merit of this joint. The effect of the three oblique abutments *a b*, *a c*, *e d*, is undoubtedly to make the whole bear on the outer end of the mortise, and there is no other part of the tie-beam that makes immediate resistance. Its only advantage over a tenon extending in the direction of the thrust, is, that it will not tear up the wood above it. Had the inner shoulder had the form *e c i*, having its face, *i c*, perpendicular, it certainly would have acted more powerfully in stretching many filaments of the tie-beam, and would have had much less tendency to force out the end of the mortise. The little bit, *c i*, would have prevented the sliding upwards along *e c*. At any rate, the joint, *a b*, being flush with the beam, prevents any sensible abutment on the shoulder, *a c*.

Figure 39, No 2. is a simpler, and in our opinion a preferable, joint. We observe it practised by the most eminent carpenters, for all oblique thrusts; but it surely employs less of the cohesion of the tie-beam than might be used without weakening it, at least when it is supported on the other side by the wall-plate.

Figure 39, No. 3, is also much practised by the first carpenters.

Figure 41 is proposed by Mr. Nicholson, as preferable to *Figure* 39, No. 3, because the abutment of the inner part is better supported. This is certainly the case; but it supposes the whole rather to go to the bottom of the socket, and the beam to be thicker than the rafter. Some may think that this will weaken the beam too much, when it is no broader than the rafter is thick: in which case they think that it requires a deeper socket than Nicholson has given it. Perhaps the advantages of Nicholson's oonstruction may be had by a joint like *Figure* 41, No. 2.

Whatever be the form of these butting joints, great care should be taken that all parts bear alike, and the artist will attend to the magnitude of the different surfaces. In the general compression, the greater surfaces will be less compressed, and the smaller will therefore change most. When all has settled, every part should be equally close. Because great logs are moved with difficulty, it is very troublesome to try the joint frequently, to see how the parts fit; therefore we must expect less accuracy in the interior parts. This should make us prefer those joints whose efficacy depends chiefly on the visible joint.

It appears from all that we have said on this subject, that a very small part of the cohesion of the tie-beams is sufficient for withstanding the horizontal thrust of a roof, even though very low pitched. If therefore no other use be made of the tie-beam, one much slenderer may be used, and blocks may be firmly fixed to the ends, on which the rafters might abut, as they do on the joggles on the head and foot of a king-post. Although a tie-beam has commonly floors or ceilings to carry, and sometimes the workshops and store-rooms of a theatre, and therefore requires a great scantling, yet there frequently occur in machines and engines very oblique stretches, which have no other office, and are generally made of dimensions quite inadequate to their situation, often containing ten times the necessary quantity of timber. It is therefore of importance to ascertain the most perfect manner of executing such a joint. We have directed the attention to the principles that are really concerned in the effect. In all hazardous cases, the carpenter calls in the assistance of iron straps; and they are frequently necessary, even in roofs, notwithstanding this superabundant strength of the tie-beams. But this is generally owing to the bad construction of the wooden joint, or to the failure of it by time. Straps will be considered in their place.

There need but little to be said of the joints at a joggle worked out of solid timber; they are not near so difficult as the last. When the size of a log will allow the joggle to receive the whole breadth of the abutting brace, it ought certainly to be made with a square shoulder; or, which is still better, an arch of a circle, having the other end of the brace for its centre. Indeed, this in general will not sensibly differ from a straight line perpendicular to the brace. By this circular form, the setting of the roof makes no change in the abutment; but when there is not sufficient stuff for this, we must avoid bevel joists at the shoulders, because these always tend to make the brace slide off. The brace, in *Figure* 42, must not be joined as at *a*, but as at *b*, or some equivalent manner.

When the very oblique action of one side of a frame of carpentry does not extend, but compress the piece on which it abuts, as in *Figure* 21, there is no difficulty in the joint. Indeed, a joining is unnecessary, and it is enough that the pieces abut on each other; and we have only to take care that the mutual pressure be equally borne by all the parts, and that it do not produce lateral pressures, which may cause one of the pieces to slide on the butting joint. A very slight mortise and tenon is sufficient at the joggle of a king-post, with a rafter or straining beam. It is best, in general, to make the butting plain, bisecting the angle formed by the sides, or else perpendicular to one of the pieces. In *Figure* 42, No. 2, where the straining beam, *a b*, cannot slip away from the pressure, the joint *a* is preferable to *b*, or indeed to any uneven joint, which never fails to produce very unequal pressures on the different parts, by which some are crippled, others are splintered off, &c.

When it is necessary to employ iron steps for strengthening a joint, a considerable attention is necessary, that we may place them properly. The first thing to be determined is the direction of the strain. We must then resolve this strain into a strain parallel to each piece, and another perpendicular to it. Then the strap, which is to be made fast to any of the pieces, must be so fixed, that it shall resist in the direction parallel to the piece. Frequently this cannot be done; but we must come as near to it as we can. In such cases, we must suppose that the assemblage yields a little to the pressures which act on it. We must examine what change of shape a small yielding will produce. We must now see how this will affect the iron strap, which we have already supposed attached to the joint in some manner that we thought suitable. This settling will perhaps draw the pieces away from it, leaving it loose and unserviceable; (this frequently happens to the plates which are put to secure the obtuse angles of butting timbers, when their bolts are at some distance from the angles, especially when these plates are laid on the inside of the angles); or it may cause it to compress the pieces harder than before; in which case it is answering our intention. But it may be producing cross strains, which may break them; or it may be crippling them. We can hardly give any general rules; he will see the nature of the strap or stirrup by which the king-post carries the tie-beam. The strap that we observe most generally ill-placed is that which connects the foot of the rafter with the beam. It only binds down the rafter, but does not act against its horizontal thrust. It should be placed farther back on the beam, with a bolt through it, which will allow it to turn round. It should embrace the rafter almost horizontally near the foot, and should be notched square with the back of the rafter. Such a construction is represented in *Figure* 43. By moving round the eye-bolt it follows the rafter, and cannot pinch and cripple it, which it always does in its ordinary form. We are of opinion that straps which have eye-bolts in the very angles, and allow all motion round them, are, of all, the most perfect. A branched strap, such as may at once bind the king-post and the two braces which butt on its foot, will be more serviceable if it have a joint. When a roof warps, those branched steps frequently break the tenons, by affording a fulcrum in one of their bolts. An attentive and judicious artist will consider how the beams will act on such occasions, and will avoid giving rise to these great strains by levers. A skilful carpenter never employs many straps, considering them as auxiliaries foreign to his art, and subject to imperfections in workmanship, which he cannot discern nor amend.—*Supplement to the article Carpentry of the Encyclopædia Britannica, by Professor Robinson.*

The following part was written by Mr. Nicholson for the *Edinburgh Cyclopædia*, and is here inserted by permission of the editor.

A circular roof may be executed with timbers disposed in vertical planes, whether the ribs or rafters are convex, concave, or straight, without any tie between the rafters or ribs, even though the wall were ever so thin; provided that it be only sufficient to sustain the weight of the roof pressing vertically, by joining the wall-plate so as to form a complete ring, and by strutting the rafters in one or more horizontal courses, without danger of lateral pressure, or of the timbers being bent by the weight of the covering. The same cannot be done with the roof of a rectangular building, for single parallel rafters would not only obtain a concave curvature, but would thrust the walls outwards: hence the means of executing circular roofs with safety are simple; but those for straight-sided buildings are complex, and require much skill in contriving, according to the use that is to be made of the space between the rafters, which may be found necessary in rendering more lofty, or more elegant apartments, as in concave, or coved ceilings.

A polygonal roof, with a great number of sides, approaching very nearly to a circle, is stronger than one of fewer sides; the less the number of sides, the weaker will the roof be, and more liable to get out of order. A roof executed upon an equilateral and equiangular polygonal plan, is much stronger than one that is elongated. All circular roofs, for the same reason, are stronger than elliptical ones; the pressure in the former case being equally distributed round the wall-plate, which is therefore kept in an equal state of tension.

Trusses are strong frames of carpentry, resolved into two or a series of triangles, so as to make the truss act as a solid body, and thereby support certain weights, each at a given immoveable point, the truss itself being suspended from two such immoveable points. The trusses of roofs are constructed generally of a triangular form, and disposed equidistantly on the wall-plates, in parallel vertical planes, at right angles to the walls; the top of the opposite walls are the two points of suspension, and the weights supported by the truss at the immoveable points are horizontal pieces of timber, running transversely to the planes of the trusses: these horizontal pieces of timber support other equidistant pieces parallel to the upper sides of the trusses, and these last timbers support the covering, or the covering and timber-work, to which the covering is fixed. In a truss, some pieces of timber are in a state of tension, and some are in a state of compression; but a piece of timber which is neither extended nor compressed, is useless. A quadrilateral frame, so constructed that each two adjoining timbers, made moveable round a point at their intersection, may be put into an infinite number of forms, because the whole frame will be revolvable about the angles: but if any one of the angles be immoveable, the whole frame will also be so. Two pieces of timber forming an angle, and revolving round a point at their intersection, may be made immoveable by fastening each end of a bar to each leg, or by taking any two points in the bar, and fastening each point to each leg. Now, if a force be applied at any of the three angular points, the frame will be immoveable, but of the two legs which form the angle, the one will be in a state of tension, and the other in a state of compression, provided that the direction of the force applied does not fall within the angle if produced; but if the line of direction of the force applied fall within the angle of the triangle, then both legs are either in a state of tension or in a state of compression, according as the force applied is pulling or pressing; if one of the sides of the triangle be lengthened without the boundary, and a force be applied transversely to the part so lengthened, this force will bend the side of the figure which is in the straight line with the side to which the force is applied: therefore, suppose again a quadrangle, or quadrilateral, revolvable about the angles, and a bar be fixed to any two sides forming an angle, viz., a point in the bar to a point in one of the legs, and another point in the bar to a point in the other leg, and suppose the two points not to be in two of the angles, or one of the points to be in the side, at some distance from either end, the figure will be divided into two parts, one will always be a triangle; then, if it be supported at two of its angles, and a force be applied to the angle opposite, the angle which has the bar fixed to its legs, so that the direction of the force thus applied does not tend to the fixed point, which is the farther extremity of the one leg, where the force is applied to the angular point at the other extremity, all the sides of this figure will be bent, and the bar thus fixed will occasion transverse strains to the sides. But if the bar be fixed to two opposite angles, and if the frame be held immoveable at one of the angular points where the bar is fixed, and also at one of the other angles at the extremity of one of the legs of the said angle, and a force in any direction in the plane of the figure be applied to the angle where the frame is unsupported, and where the bar is not fixed, the frame will be by this means rendered immoveable, and the force by this disposition will not occasion any transverse strain on the sides of the frame. Suppose the frame to be pentagonal, and a bar fixed in like manner to two angles, at the ends of two adjoining sides, these two adjoining sides and the bar will form a triangular compartment in the figure; if the frame be suspended by two of the angles of the triangle, the three remaining sides will be moveable at the extremities of the bar, and at the remaining angles; but if another bar be fixed to any one of the three angles of the triangle at one end, to one of the angles of the other three sides, to form another triangle, three of the sides of the pentagonal frame will be made immoveable, and the two remaining sides will be so likewise. In like manner, in whatever number of sides the frame consists, by first forming a triangle of two of the sides, and fixing a second bar from any angle of the triangle to one of the other angles of the figure, at the remote ends of two adjoining sides of this frame, will form another immoveable side, and give another immoveable point at the next angle of the frame; if, from this fixed point, or any of the other three points, which are the angles of the triangle, the end of a third bar be fixed, and the other end of the bar to one of the remaining angles of the frame, so as to form a triangle with the second bar and one of the adjoining moveable sides of the frame, or a triangle with one of the fixed sides of the frame and the adjoining moveable side; and by proceeding in this manner successively, until all the sides are fixed, the frame will be made immoveable; so that if any two angles of this frame be supported, and a force or forces be applied at one or each of the angles in the plane of the figure, the whole figure will be immoveable.

Frames of a triangular form, which have to resist only a single force, or support one weight, are most simply and best constructed of three sides; the frame being suspended from two angles, and the force or weight from the other. A triangular frame, supporting only one weight, has no occasion for any subdivision to compart the internal space, provided the compressed timber or timbers were inflexible, so as to support their own weight without bending, and the tensile timbers incapable of extension. Though a frame should have to support several weights, the external figure may be of any form whatever, provided that the points from which the weights are hung, and the two points from which the frame is suspended, be all immoveably supported by comparting the figure with timber divisions, and thereby forming a succession of adjoining triangles, of which each two contiguous have a common side; that is, when two of the angles of each of the adjacent triangles are coincident. It may be proper to observe here, that though it may not be at all times eligible to divide a frame, so that all the compartments will be triangles, yet the succession must not by any means be discontinued by the intervention of quadrilateral or polygonal figures, for these compartments may adjoin without injury to the truss. The triangle is the most simple of all rectilinear figures; it is also easier constructed, and better adapted to the discharge of rain or moisture in a roof, than any other figure; but, in its adoption to large buildings, as several weights must be supported, and as there is only one point from which this weight can be suspended, it becomes necessary to take other equidistant points in the sides, in order to support the covering equally: these points may be made stationary, by the former means of dividing the interior space into a succession of triangular compartments. But if the two upper sides of the frame be of equal lengths, and equally inclined to the horizon, the opposite points may be made to counteract each other without a concatenation of triangles, by introducing timbers from point to point, parallel to the horizon; in this the compartments will all be trapezoids, except the upper one, which will be a triangle. These beams may be supported by vertical bolts passing transversely through them from the points where the weights are supported, and the bolts may be nutted below the beams. This mode of securing the points of support depends entirely upon the doctrine of equilibrium, and thus a very little difference from the equality of forces might easily occasion a change of figure, to which the other method by a series of triangles is not liable. The securing of the points of support by beams is not confined to triangular frames, but may be applied to roofs having two or several rafters upon each side, so that their lengths and inclinations are equal, and their junctions on the same level. The beauty of every truss is to dispose the timbers in positions as direct to each other as possible: oblique directions require timbers of large scantlings, and exert prodigious thrusts on the abutments, so as to compress the joggle-pieces, and render the truss in danger of sagging. Trusses are variously constructed, according to the width of the building, and contour of the roof, and the circumstances of walling below.

The general principle of construction is a series of triangles, of which every two are connected by a common side.

Let A B C D E F G (see Plate I., Centering, *Figure* 1,) be the curve of the arch which requires a centre. Let the points A B C, &c., be connected, so as to form the equilateral polygon A B C D E F G, and join A C, C E, and E G; the timbers thus disposed will form three triangles, which may be looked upon as so many solids revolvable about the angular points, A, C, E, G; suppose now these to be in equilibrium, the smallest force on either side would throw it down; and therefore, without other connecting timbers, it would be unfit for the purpose of a centre.

Let A B C D E F G (Plate I., Centering, *Figure* 2,) be the curve of an arch which requires a centre. First, from the equilateral polygon, A B C D E F G, with the timbers, A B, C D, G D, &c., and fix the timbers A C, C E, E G, as before, which will form three triangles, moveable round A C E G; let the timbers B D and D F be fastened, and thus the whole will be immutable, so that if supported at the points A and G, and a force be applied at any other of the angles, B, C, D, or F, the timbers will be all in a state of tension, or in a state of compression, and the whole may be looked upon as a solid body. For since the sides and angular points of a triangle are fixed, when the triangle is supported at two of the angles, and a force applied to the other, let us suppose the triangle, A B C, to be supported at the points A and B, and the point C, and the other two sides, B C, C A, will be fixed; and, because B C D is a triangle, and the points B and C are fixed, the point D, and consequently the sides C D and D B, are fixed. In like manner, since C D E is a triangle, and the points C and D fixed, the point E will also be fixed, and also the sides D E and E C. The same may be shown in like manner for the points F and G. Suppose, then, two equal and opposite forces applied at the points A and G, in the plane of the figure, the figure can neither be extended out nor compressed together. The pieces A H, H B, and G I, I F, are of no other use than to make the centre stand firmly on its base. This disposition of the timbers will cause them to occupy the least possible space.

If the timbers are fixed at the points *k*, *l*, *m*, *n*, *o*, *p*, the same immutability of figure may be demonstrated; for suppose the points A and H to be fixed, the point *k* will also be fixed; the points A and k being fixed, the point B, of the triangle A k B, will likewise be fixed. Again, the points B and k being fixed, the point l will also be fixed: in the same manner, all the remaining points, C, m, D, n, o, F, p, G, L, may be proved to be stationary in respect of the points A, H; and the whole figure being kept in equilibrio by any three forces, acting in the plane of the figure at any three angles, the action of the forces will only tend to compress or extend the timbers in the direction of their length.

In the construction of this truss, the triangular parts may be constructed all in the same plane, and the pieces, B D and D F, may be halved upon the pieces C A and E G; but the utmost care must be taken to secure the several pieces concurring at each of the angles, by bolting, or iron straps, as no dependence can be put in any such joint without iron; but perhaps the best method of any is to halve the thicknesses of the pieces A C, C E, E G, at the points C and E, and also the pieces A B, B C, C D, D E, E F, F G, at the points B, D, F: then bolting the ends, A and C, of the pieces B A, D C, the end C and E, of the pieces D C and D E, and the ends E and G of the pieces F E and F G, and then fixing double braces, B D, D F; that is, fixing B D upon one side of the truss, and another upon the other side of the truss, opposite to it; also fixing D F upon one side, and another opposite to it.

Figure 6, of the same plate, represents the manner of constructing a centre according to the principles of Perronet, the celebrated French engineer; but the disposition of the timbers, forming only a series of quadrilaterals, gives nothing but immutability of figure; and can, therefore, only derive its stiffness from the resistance of the joints.

Having thus given a general account of the principles of centering, as connected with the article Carpentry, we must refer our readers to the article STONE BRIDGE for its application, and other practical remarks in the construction.

MECHANICAL POWERS, such machines as are used for raising greater weights, or overcoming greater resistances, than could be effected by the natural strength without them; the power or strength being applied to one part of the machine, and another part of the machine applied to the weight or resistance. In treating of each of which, two principal problems ought to be resolved.

The first is, to determine the proportion which the power and weight ought to have to each other, that they may just sustain one another, or be in equilibrio.

The second is, to determine what ought to be the proportion of the power and weight to each other in a given machine, that it may produce the greatest effect possible, in a given time.

As to the first problem, this general rule holds in all powers: suppose the engine to move, and reduce the velocities of the power and weight to the respective directions in which they act; find the proportions of these velocities; then, if the power be to the weight as the velocity of the weight is to the velocity of the power,—or, which amounts to the same thing, if the power multiplied by its velocity, gives the same product as the weight multiplied by its velocity,—this is the case wherein the power and weight sustain each other, and are in equilibrio; so that in this case the one would not prevail over the other, if the engine were at rest; and if in motion, it would continue to proceed uniformly, were it not for the friction of its parts, and other resistances.

The second general problem in mechanics is, to determine the proportion which the power and weight ought to bear to each other, that when the power prevails, and the machine is in motion, the greatest effect possible may be produced by it in a given time. It is manifest, that this is an inquiry of the greatest importance, though few have treated of it. When the power is only a little greater than that which is sufficient to sustain the weight, the motion is too slow; and though a greater weight is raised in this case, it is not sufficient to compensate the loss of time. When the weight is much less than that which the power is able to sustain, it is raised in less time; and this may happen not to be sufficient to compensate the loss arising from the smallness of the load. It ought, therefore, to be determined when the product of the weight, multiplied by its velocity, is the greatest possible; for this product measures the effect of the engine in a given time, which is always the greater in proportion as the weight which is raised is greater, and as the velocity with which it is raised is greater.

The simple machines by which power is gained are six in number, viz., the *lever*, the *wheel and axle*, or *axis in peritrochio*, the *pulley* (or rather system of pulleys), the *inclined plane*, the *wedge*, and the *screw*. Of these, all sorts of mechanical engines consist; and in treating of them, so as to settle their theory, we must consider them as mechanically exact, and moving without friction. For the properties and applications of the mechanical powers, see LEVER, PLANE (INCLINED), PULLEY, WEDGE, and WHEEL.

MEDALLION (from the French), in architecture, a circular tablet, on which are embossed figures, bustos, or other ornaments.

MEDIÆVAL ARCHITECTURE, comprises all those styles which were prevalent during what are commonly, though unfairly, styled the dark ages, viz., from the fall of the Roman empire to the revival of classic art. It includes those styles which may be peculiarly termed Christian, amongst which may be enumerated the Romanesque, the Byzantine, and Lombardic, and more especially the Gothic style. These are treated of under their distinctive titles.

MEDIANÆ, in Vitruvius, the columns in the middle of the portico, where the intercolumniation is enlarged.

MEMBER (from the French) any part of an edifice; or any moulding in a collection.

MENSURATION (from the Latin *mensura*, measurement) that branch of mathematics which is employed in ascertaining the extension, solidities, and capacities of bodies; and in consequence of its very extensive application to the various purposes of life, it may be considered as one of the most useful and important of all the mathematical sciences: in fact, mensuration, or geometry, which were anciently nearly synonymous terms, seem to have been the root whence all the other exact sciences, with the exception of arithmetic, have derived their origin.

As soon as men began to form themselves into society, and direct their attention towards the cultivation of the earth, it became as necessary to have some means of distinguishing one person's allotment from another, both as to position and quantity, as it did to enumerate the number of their flocks and herds; and hence, in all probability, the former gave rise to the science of mensuration, as the latter did to that of arithmetic; and though we may easily imagine that each of them remained for ages in a rude uncultivated state, yet it is from this period that we must date their commencement; and therefore, to state the precise time when they were discovered, or by whom they were first introduced, would be to trace out the origin of society itself: on this head, therefore, we shall barely observe, that in all probability they first arose from the humblest efforts of unassisted genius, called forth by the great mother of invention, necessity; and that they have since grown up by slow and imperceptible degrees, till they have at length acquired the dignity of the most perfect sciences; as the acorn which is first accidentally sown in a field, is in due course of time converted into the majestic oak

But notwithstanding we cannot attribute the invention of the science of mensuration to any particular person or nation, yet we may discover it in an infant state, rising, as it were, into a scientific form, amongst the ancient Egyptians; and hence the honour of the discovery has frequently been given to this people, and to the circumstance of the overflowing of the Nile, which takes place about the middle of June, and ends in September. It is, however, to the Greeks that we must consider ourselves indebted for having first embodied the leading principles of this art into a regular system. Euclid's *Elements of Geometry* were probably first wholly directed to this subject; and many of those beautiful and elegant geometrical properties, which are so much and so justly admired, it is not unlikely, arose out of simple investigations directed solely to the theory and practical application of mensuration. These collateral properties, when once discovered, soon gave rise to others of a similar kind; and thus geometry, which was first instituted for a particular and limited purpose, became itself an independent and important science, which has perhaps done more towards harmonizing and expanding the human faculties, than all the other sciences united.

But notwithstanding the perfection which Euclid attained in geometry, the theory of mensuration was not in his time advanced beyond what related to right-lined figures; and this, so far as regards surfaces, might all be reduced to that of measuring a triangle; for as all right-lined figures may be reduced to a number of trilaterals, it was only necessary to know how to measure these, in order to find the surface of any other figure whatever bounded only by right lines. The mensuration of solid bodies, however, was of a more varied and complex nature, and gave this celebrated geometrician a greater scope for the exercise of his superior talents, and, still confining himself to bodies bounded by the right-lined plane superficies, he was able to perform all that can be done even at this day. With regard to curvilinear figures, he attempted only the circle and the sphere, and if he did not succeed in those, he failed only where there was no possibility of success; but the ratio that such surfaces and solids have to each other he accurately determined.

After Euclid, Archimedes took up the theory of mensuration, and carried it to a much greater extent. He first found the area of a curvilinear space, unless, indeed, we except the lunules of Hippocrates, which required no other aid than that of the geometrical elements. Archimedes found the area of the parabola to be two-thirds of its circumscribing rectangle, which, with the exception above stated, was the first instance of the quadrature of a curvilinear space. The conic sections were at this time but lately introduced into geometry, and they did not fail to attract the particular attention of this celebrated mathematician, who discovered many of their very curious properties and analogies. He likewise determined the ratio of spheres, spheroids, and conoids, to their circumscribing cylinders, and has left us his attempt at the quadrature of the circle. He demonstrated that the area of a circle is equal to the area of a right-angled triangle, of which one of its sides about the right angle is equal to the radius, and the other equal to the circumference, and thus reduced the quadrature of the circle to that of determining the ratio of the circumference to the diameter, a problem which has engaged the particular attention of the most celebrated mathematicians of all ages, but which remains at present, and in all probability ever will remain, the desideratum of geometricians, and, at the same time, a convincing and humiliating proof of the limited powers of the human mind.

But, notwithstanding Archimedes failed in establishing the real quadrature of the circle, it is to him we are indebted for the first approximation towards it. He found the ratio between the diameter of a circle, and the periphery of a circumscribed polygon of 96 sides, to be less than 7 to 22, or less than 1 to $3\frac{10}{70}$; but the ratio between the diameter, and periphery of an inscribed polygon of the same number of sides, he found to be greater than 1 to $3\frac{10}{71}$; whence *à fortiori*, the diameter of a circle is to its circumference in a less ratio than 1 to $3\frac{1}{7}$, or less than 7 to 22. Having thus established this approximate ratio between the circumference and diameter, that of the area of the circle to its circumscribed square, is found to be nearly as 11 to 14. Archimedes, however, makes the latter the leading proposition. These, it is true, are but rude approximations, compared with those that have been since discovered; but, considering the state of science at this period, particularly of arithmetic, we cannot but admire the genius and perseverance of the man, who, notwithstanding the difficulties that were opposed to him, succeeded in deducing this result, which may be considered as having led the way to the other more accurate approximations which followed, most of which, till the invention of fluxions, were obtained upon similar principles to those employed by this eminent geometrician. Archimedes also determined the relation between the circle and ellipsis, as well as that of their similar parts; besides which figures, he has left us a treatise on the spiral, a description of which will be given under that article. See SPIRAL.

Some advances were successively made in geometry and mensuration, though but little novelty was introduced into the mode of investigation till the time of Cavalerius. Till his time, the regular figures circumscribed about the circle, as well as those inscribed, were always considered as being limited, both as to the number of their sides, and the length of each. He first introduced the idea of a circle being a polygon of an infinite number of sides, each of which was, of course, indefinitely small; solids were supposed to be made up of an indefinite number of sections indefinitely thin, &c. This was called *the doctrine of indivisibles*, which was very general in its application to a variety of difficult problems, and by means of it many new and interesting properties were discovered: but it unfortunately wanted that distinguishing characteristic which places geometry so pre-eminent amongst the other exact sciences. In pure elementary geometry, we proceed from step to step, with such order and logical precision, that not the slightest doubt can rest upon the mind with regard to any result deduced from those principles; but in the new method of considering the subject, the greatest possible care was necessary in order to avoid error, and frequently this was not sufficient to guard against erroneous conclusions. But the facility and generality which it possessed, when compared with any other method then discovered, led many eminent mathematicians to adopt its principles, and of these, Huygens, Dr. Wallis, and James Gregory, were the most conspicuous, being all very fortunate in their application of the theory of indivisibles. Huygens, in particular, must always be admired for his solid, accurate, and masterly performances in this branch of geometry. The theory of indivisibles was, however, disapproved of by many mathematicians, and particularly by Newton, who, amongst his numerous and brilliant discoveries, has given us that of the method of fluxions, the excellency and generality of which immediately superseded that of indivisibles, and revived some hopes of squaring the circle, and accordingly its quadrature was again attempted with the greatest eagerness. The quadrature of a space, and the rectification of a curve, was now reduced to that of finding the fluent of a given fluxion; but still the problem was found to be incapable of a general solution in finite terms. The fluxion of every fluent was found to be always assignable, but the converse proposition, viz., of finding the fluent of a given fluxion, could only be effected in particular cases, and amongst these exceptions, to the great disappointment and regret of geometricians, was included the case of the circle, with regard to all the forms of fluxions under which it could be obtained.

At length, all hopes of accurately squaring the circle and some other curves being abandoned, mathematicians began to apply themselves to finding the most convenient series for approximating towards their true length and quadrature; and the theory of mensuration now began to make rapid progress towards perfection. Many of the rules, however, were given in the transactions of learned societies, or in separate and detached works, till at length Dr. Hutton formed them into a complete treatise, intitled, *A Treatise on Mensuration*, in which the several rules are all demonstrated, and some new ones introduced. Mr. Bonnycastle also published a very neat work on this subject, intitled *An Introduction to Mensuration*. Several books on the subject have been published since the above, which, notwithstanding, still maintain their high reputation.

Particular rules for measuring the various kinds of geometrical figures and solids will be found under their respective heads; but as a collection of examples of the mensuration of distances capable of application to the purposes of enginery and architecture is a desideratum in science, the following, likely to occur in general practice, are here inserted.

Mensuration of Lines.

Problem I.—*Any two sides of a right-angled triangle being given, to find the third.*

Case I.—When the two legs are given, to find the hypothenuse.

Rule.—Add the squares of the two legs together, and the square root of the sum will give the hypothenuse.

Example 1.—In the right-angled triangle, A B C, are given the base, A B, equal to 195 feet, and the perpendicular, B C, = 28 feet: what is the length of the hypothenuse, A C?

```
     195            28
     195            28
    ----           ----
     975           224
    1755           56
    195            ----
    ----           784
(A B)² = 38025
(B C)² =   784
    ----------
    3,88,09 (197 = A C
    1
   ----
29 ) 288
     261
    -----
387 ) 2709
      2709
```

Example 2.—If the span, A B, of a roof, be 24 feet, and the height, D C, 5 feet, what should be the length of the rafters, A C and C B.

This is resolved into two equal and similar right-angled triangles, as follows:—

$24 \div 2 = 12$, the half base.

$(12^2 + 5^2)^{\frac{1}{2}} = 13$, the answer.

Case II.—When the hypothenuse and one of the legs are given, to find the other leg.

Rule.—From the square of the hypothenuse take that of the given leg; and the square root of the difference will be the leg required.

Example 1.—In the right-angled triangle, A B C, are given the hypothenuse D C, 601, the perpendicular A C, 240; required the base.

$(601^2 - 240^2)^{\frac{1}{2}} = 551$, the answer.

Example 2.—In a roof, whose span, A B, is 45 feet 6 inches, and the rafters, A C or B C, 25 feet 5 inches; required the height, D C, of the roof.

```
  45 .. 6         25 .. 5
  12              12
  ----            ----
2 ) 546        Rafter, 305 inches.
```

Base of each triangle, 273 inches.

Then will $(305^2 - 273^2)^{\frac{1}{2}} = 136$ Inches $= 11$ Feet .. 4 Inches the answer.

Example 3.—In a roof, whose rafters are each 26 feet, and the perpendicular height 10 feet, what is the span or distance between the feet of the rafters?

$(26^2 - 10^2)^{\frac{1}{2}} = 24$ feet, half the span.

Consequently, 48 feet is the distance between the feet of the rafters.

Examples for Practice.

1. Given the hypothenuse, 1625 yards, and the perpendicular, 400; required the base.—*Answer*, 1575 yards.

2. Wanted to prop a building with raking-shores at the height of 25 feet from the ground, having several pieces of wood of equal length which might be used for the purpose, each 30 feet long; how far must the bottom of the shores be placed from the base of the building?—*Answer*, 16,583.

The following rule for the construction of right-angled triangles, the sides of which shall be commensurable with each other, may be found useful in the practice of constructing roofs.

Rule.—Take any two square numbers at pleasure; then their sum, their difference, and the double product of their roots, will give the sides of a right-angled triangle, which shall be commensurable with each other.

Example 1.—Let the two square numbers 1 and 4 be taken: the roots of which are 1 and 2.

Then $4 + 1 = 5$, the hypothenuse.
$4 - 1 = 3$, one of the legs,
and $2 \times 2 \times 1 = 4$, the other leg, equal to double the product of the roots; consequently, 3, 4, 5, are the numbers required, and are the least numbers by which a right-angled triangle can be constructed.

Example 2.—Let the two square numbers be 144 and 25.
Then $144 + 25 = 169$, the hypothenuse.
$144 - 25 = 119$, one of the legs.
$2 \times 12 \times 5 = 120$, the other leg.
In this manner an infinite variety of ratios may be found for the sides of right-angled triangles.

The above rule may be found in some books of arithmetic; but having obtained the three sides, suppose 169, 119, 120, the following progressive table of ratios may be constructed, by adding 10 continually to the fourth column, and the opposite number of the vertical arithmetical progressive column on the left hand to each horizontal number in the second and third columns, which will generate those immediately below.

Example.—To generate the numbers 194, 144, 130: Add 25 to 169, and the sum will be 194, the hypothenuse of the triangle. In like manner, $25 + 119 = 144$, one of the legs;

and by adding 10 to 120, we have 130, the other leg. And thus, in every instance, each horizontal number will be generated by adding the number in the vertical left-hand column to each of the two adjacent numbers in the second and third columns of the same horizontal line, and by adding 10 to the number expressed in the fourth.

Generating numbers.	Sides of a right-angled triangle, expressed by any three of the horizontal numbers.			Ratio of the two legs.
25	169	119	120	$1\frac{1}{119}$
27	194	144	130	$1\frac{7}{65}$
29	221	171	140	$1\frac{31}{140}$
31	250	200	150	$1\frac{1}{3}$
33	281	231	160	$1\frac{71}{160}$
35	314	264	170	$1\frac{47}{85}$
37	349	299	180	$1\frac{119}{180}$
39	386	336	190	$1\frac{72}{95}$
41	425	375	200	$1\frac{7}{8}$
43	466	416	210	$1\frac{103}{105}$
45	509	459	220	$2\frac{19}{220}$
47	554	504	230	$2\frac{22}{115}$
49	601	551	240	$2\frac{71}{240}$
51	650	600	250	$2\frac{2}{5}$
53	701	651	260	$2\frac{131}{260}$
55	754	704	270	$2\frac{164}{270}$
57	809	759	280	$2\frac{199}{280}$
59	866	816	290	$2\frac{118}{145}$
61	925	875	300	$2\frac{11}{12}$
63	986	936	310	$3\frac{3}{155}$
65	1049	999	320	$3\frac{39}{320}$
67	1114	1064	330	$3\frac{33}{165}$
69	1181	1131	340	$3\frac{111}{340}$
71	1250	1200	350	$3\frac{3}{7}$
73	1321	1271	360	$3\frac{191}{360}$
75	1394	1344	370	$3\frac{117}{185}$
77	1469	1419	380	$3\frac{279}{380}$
79	1546	1496	390	$3\frac{326}{390}$
81	1625	1575	400	$3\frac{15}{16}$
83	1706	1656	410	$4\frac{8}{205}$

Problem II.—*To find the length of a cylindrical helix.*

Rule.—Multiply the circumference of the base by the number of revolutions; to the square of the product add the square of the height of the spiral, or the square of the distance of the axis from the beginning to the end; and the square root of the sum will be the length of the spiral.

The form of the cylindric helix is a right-angled triangle, the base of which is the number of revolutions, and the height that of the spiral: *i. e.*, if the whole were unwound and stretched upon a plane, the development would be a right-angled triangle.

Example 1.—Required the length of a screw twisting round a cylinder 22 inches in circumference, $3\frac{1}{2}$ times, and extending along the axis 16 inches.

22	16
$3\frac{1}{2}$	16
66	96
11	16
77 base of the development.	256
77	
539	
539	
5929 square of the base.	

[Continued—

5929 square of the base.
256 square of the altitude.

6185 (78.64 inches, the answer.
49

148) 1285
1184

1566) 10100
9396

15724) 70400
62896

7504

Example 2.—Required the number of feet of hand-railing for a semicircular stair, consisting of 9 winders, each $6\frac{1}{2}$ inches high, the diameter of the well-hole being 18 inches.

Problem III.—*The chord and versed sine of an arc of a circle being given, to find the diameter.*

Rule 1.—Divide the sum of the squares of the sine and the versed sine by the versed sine itself, and the quotient is the diameter.

Example 1.—Given, the chord, A B = 48 feet, and the versed sine, D E = 18 feet; required the diameter.

$$\frac{48}{2} = 24, \text{ the sine, or half chord.}$$

Then $\frac{24^2 + 18^2}{18} = 50$, the diameter required.

This arithmetical operation of finding the radius is much preferable to the geometrical construction, the calculation being so easy, and performed in a very small compass; whereas the other mode requires a floor, or flat surface, to describe it upon, which cannot at all times be obtained; recourse must therefore be had to a temporary floor of rough boarding, which requires an immense time in the preparation, and when done is not much to be depended upon.

Examples for Practice.

A room is to be constructed with a cylindric bow, the plan being the segment of a circle, whose chord is 18 feet, and the height of the segment 6 feet; what length of a rod will be necessary to describe the arc?

A bridge is to be constructed of a cylindric intrados, the section of which is to be the segment of a circle, to span 100 feet, and to rise 33 feet; what length of a line, or wire, will be necessary to describe the arc?

Rule 2.—As the versed sine is to the half chord, so is the half chord to a fourth proportional; add this fourth proportional to the versed sine, and the sum is the diameter: thus, take the dimensions in the preceding example; we have

$$18 : 24 :: 24 : \frac{24 \times 24}{18} = 32;$$

then 32 + 18 = 50, the diameter.

Problem IV.—*In the segment of a circle are given the chord, and its distance from the centre; to find the radius of the circle.*

Rule.—Add the square of the half chord to the square of the distance; and the square root of the sum will be the radius of the circle.

Example 1.—Let the chord, A B, be 8 feet, and the distance of A B from the centre, C D, 3 feet; required the radius of the circle.

Here $\frac{8}{2} = 4$ the half chord.

Then $(4^2 + 3^2)^{\frac{1}{2}} = 5$, the answer.

Or thus, at full length.

4	3
4	3
—	—
16	9
9	
—	
25 (5, the answer.	

Example 2.—In Stewart's *Ruins of Athens*, vol. II. pl. vi. ch. 1, are given, in a section of the columns of the portico of the temple of Minerva at Athens, the distance between the chords of two opposite equal and parallel flutes, 6 feet 1.8 inches, and the chord of each flute 11.688 inches; required the diameter of the column, which he has omitted.

6 1.8
12
———
2) 73.8 diameter reduced to inches.
———
36.9

2) 11.688
———
5.844 half chord.

Inches.

$(36.9^2 + 5.844^2)\ \frac{1}{2} = 37.36$ the radius nearly.

Problem V.—*The radius of a circle being given, and the chord of a segment of that circle: to find the versed sine of the lesser segment.*

Rule.—*Method* 1.—Subtract the square of the half chord from the square of the radius, and the square root of the difference will be the cosine; subtract the cosine from the radius, and their difference will be the versed sine of the lesser segment; that is, $v = r - (r^2 - y^2)^{\frac{1}{2}}$.

Example.—A weir is to be constructed across a river, in the arc of a circle of 250 feet radius; the span of the river, or chord, to be 200 feet; what is the versed sine of the lesser segment?

$250 - (250^2 - 100^2)^{\frac{1}{2}} = 20\ 87122$, the versed sine required.

N. B. If the versed sine of the greater segment is required, add the cosine to the radius, and the sum will be the versed sine.

Method 2.—When the chord is very small, and the diameter large.

As the diameter of the circle is to the half chord, so is the half chord to the versed sine, nearly.

Example 1.—Suppose a bridge is to be executed, 56 feet in diameter, the breadth or chord of each stone on the face and on the intrados of the arch being 12 inches; what is the versed sine, or height of the arc of a single stone?

56
12
———
672 : 6 : : 6
6
———
672) 36.000(.053 inches nearly.
33 60
———
2 400
2 016
———
384

Example 2.—Supposing the diameter of the earth to be 7957 miles, how much does the curvature rise in a chord of 2 miles?

We have 7957 : 1 : : 1 : .000125 of a mile, which reduced gives 7.92 inches nearly for the rise of the arc.

This would also be the distance that the curvature of the earth would fall from the tangent in one mile.

N. B. The deflection of the arc from the level is as the square of the distance from the point of contact nearly. This proportion would give the same result as the method by which this example is wrought.

Problem VI.—*Given the distance between the two parallel sides of a trapezoid, and the breadth of the lesser end; to find the breadth of the greater end, so that the sides may tend to a point at any given distance.*

Note.—The distance from the lesser end to the given point is here termed *the distance of the point of convergence.*

Rule.—As the given distance is to the sum of that distance, and the distance to the point of convergence; so is the breadth of the lesser end to that of the greater.

Example 1.—Given the distance, E F, between the parallel sides, A B and D C, of a trapezoid A B C D, equal to 3 feet; the breadth of the lesser end, D C, 2 feet; and the distance, E G, from the lesser end, D C, to the point, G, of the meeting of the inclined sides, A D and B C, 58 feet; required the breadth, A B, of the greater end.

$58 : 58 + 3 : : 2 : \frac{(58 + 3) \times 2}{58} = 2.103$, the breadth of the greater end.

Example 2.—A stone weir is to be constructed across a river, in the form of the segment of a circle, with the convex side of the arc towards the stream; the joints of the stones being all to tend to the centre: now the length of each stone in the direction of a radial is 4 feet, the radius 250 feet, and the breadth of the lesser end of the stone 1 foot; required the breadth of the upper end of the stones.

	Foot.	In.	Sec.
Answer, 1.016 feet, or,	1	0	2

This problem is also useful in perspective, in the drawing of two lines towards a vanishing point.

Example 3.—A bridge is to be constructed of a cylindric intrados, the section of which is the segment of a circle of 28 feet radius, the length of the archstones are to be 2 feet, and their breadth in front of the arch and on the intrados 1 foot; required the breadth of the thick end of the stone.

28 : 28 + 2 : : 1 to the answer.

Or,
28 : 30 : : 1
1
—
28)30(1.0714 the breadth of the greater end, as required.
28
———
200
196
———
40
28
———
120
112
———
8

Or, the answer may be reduced to the workman's rule for taking his dimensions, thus:

1.0714
12
.8568
8
6.8544
4
3.4176

This gives one foot and very nearly seven-eighths of an inch, the foot being divided into twelve equal parts, called *inches*, and each inch into eight equal parts; the workmen seldom regard anything less than the sixteenth part of an inch.

This example corresponds to Problem V. Method 2, which ascertains the versed sine of the arc of the stone of a bridge, weir, or the like, of a given radius and given chord: it likewise ascertains the taper that the stones should have in the direction of a radius. The mould of the section of the stones may therefore be found by calculation, and the arc described by Problem LII. of the article GEOMETRY, almost within the compass of the section itself, without having recourse to the long distance of a centre, which not only requires an inconvenient degree of space, but occasions great loss of time in the preparation.

PROBLEM VII.—*To find any point in the arc of the segment of a circle at the extremity of an ordinate; the radius of the circle, the chord of the arc, and the distance of the ordinate from the middle of the chord, being given.*

RULE.—Find the versed sine by Problem V. subtract it from the radius, and the remainder will be the cosine; subtract this cosine from the square root of the difference of the squares of the radius and of the distance from the middle of the chord to the ordinate, and the difference will give the length of the ordinate.

Example.—Suppose the radius, A D, of the segment, G E H, to be 250 feet, the chord, G H, 200 feet, and the distance from the middle B, of the chord to the ordinate, C D, 50 feet; required the ordinate, C D.

The versed sine I E, will be found to be 20.871, by Problem V., consequently, $250 - 20.871 = 229.129$ the cosine; therefore $(250^2 - 50^2)^{\frac{1}{2}} - 229.129 = 15.820$ feet, the answer.

In the following examples, the radius and chord are the same as in the last; but the variation is in the distance of the ordinate from the middle of the chord.

EXAMPLES FOR PRACTICE, TO BE ANSWERED.

Let the distance from the middle of the chord to the ordinate be 10; required the ordinate.—*Answer.*

Let the distance from the middle of the chord to the ordinate be 20; required the ordinate.—*Answer.*

Let the distance from the middle of the chord to the ordinate be 30; required the ordinate.—*Answer.*

Another rule, without finding the versed sine, is as follows:

First.—Find the cosine of G E, the half arc, thus: from $(250)^2$ viz. the square of the radius, subtract $(100)^2$ viz. the square of the sine, or half chord, 200; and the square root, 229.129, of the remainder gives A B, the cosine of the arc G E.

Secondly.—Find the cosine of the arc D E in the same manner, thus; from $(250)^2$ viz. the square of the radius, subtract $(50)^2$, viz. the square of the sine, or half chord, of 100, that is, the distance from B to C; and the square root, 244.949, of the remainder gives A I the cosine of the arc D E.

Thirdly.—Subtract the cosine, A B = 229.129, of the greater arc G E, from the cosine A I = 244.949 of the lesser arc, D E; and the remainder, B I = 15.82, is equal to the ordinate C D.

PROBLEM VIII.—*Given the chord of a very large segment of a circle, and the radius of the circle; to find any number of points in the arc, and thence to describe it.*

RULE.—Divide the chord into any number of convenient equal parts each way from the middle, and erect ordinates upon the points of division; calculate the length of each ordinate by the last problem; find the versed sine to a chord not less than the distance between the two most remote adjacent points in the ends of the arc; describe an arc to this chord and versed sine by Problem LII. of the article GEOMETRY; then procure a board equal to the length of the chord, and curve its edge to the arc; with the curved edge draw an arc between every two points of the extended arc, and the entire arc will be formed.

N. B. There are several methods of describing segments of circles, as shown under the article GEOMETRY; but none so eligible, upon a large scale, where accuracy is required, as the above. It will be found convenient to erect the ordinates ten feet apart on each side of the middle of the chord, though the last distance at each end, between the extreme ordinate and the extreme of the curve, should be less than the intermediate 10 feet distances. Boards in general do not exceed 10 or 12 feet; but a twelve-foot board will be sufficient for ten-foot distances on the chord, in most cases, even when the versed sine rises high in proportion to the chord.

Example.—An engineer intending to construct a stone weir over a river, in the arc, A L M, of a circle; the chord, A M, of which being 200 feet, and the radius 250 feet; required the length of the ordinates at 10 feet distance from each other, and the versed sine to a chord of 12 feet, for completing the arc.

N L, the versed sine	20.871	Problem V.
O K, the first ordinate . . .	20.671	Problem VII.
P I, the second ditto	20.07	ditto.
Q H, the third ditto	19.065	ditto.
R G, the fourth ditto	17.651	ditto.
S F, the fifth ditto	15.82	ditto.
T E, the sixth ditto	13.565	ditto.
U D, the seventh ditto . . .	10.872	ditto.
V C, the eighth ditto	7.726	ditto.
W B, the ninth ditto	4.11	ditto.

These ordinates are respectively calculated at 10, 20, 30, 40, 50, 60, 70, 80, 90 feet distance from the middle of the chord to each ordinate.

It now remains to calculate the versed sine corresponding to a chord of 12 feet of the same arc as that of the weir: This will be found by Problem V. to be .072 of a foot, or very nearly seven-eighths of an inch, being, as workmen say, bare measure. Curve the edge of a twelve-foot board to a versed sine of seven-eighths of an inch; then lay the curved edge, with the concave side towards the chord, successively between every two points, A, B; B, C; C, D, &c., drawing each part until the whole arc is completed to the chord A M.

N. B.—A boarding is generally fixed to a timber grating or framing, supported by piles, for the foundation of the stone-work.

PROBLEM IV.—*In a parabola having two abscissas and an ordinate to one of them, to find the ordinate of the other.*

RULE.—As the abscissa of the given ordinate is to the abscissa of the required ordinate, so is the square of the ordinate of the former abscissa to the square of the ordinate of the latter. Then the root of the fourth term so found will be the ordinate required.

Example.—In the parabola, A B C A, are given the base, or double ordinate, A C, 18 feet, the height, or abscissa, B D, 16 feet, and the abscissa, B E, 8 feet; required the ordinate, E F.

$\frac{18}{2} = 9$, the ordinate.

and $9^2 = 81$.

$16 : 8 :: 81 : \frac{81 \times 8}{16} = 40.5$ the square of E F.

Therefore, $40.5^{\frac{1}{2}} = 6.364 =$ E F, the ordinate required.

In this manner any number of ordinates, and consequently of points, may be found in the curve, so as to construct the figure. This method is the most appropriate for use in the formation of the curve, when the abscissa is greater than the ordinate, or equal to it.

PROBLEM V.—*To find any point in the curve of a parabola by means of an abscissal parallel, or transverse ordinate; the height, or abscissa, the ordinate, and the distance of the transverse ordinate from the abscissa, being given.*

Note.—A transverse ordinate, or abscissal parallel, is a right line terminated by the curve and by the base parallel to the abscissa, commonly called a *diameter*, in this particular curve.

RULE.—Multiply the difference of the squares of the ordinate and of the distance of the abscissal parallel, or transverse ordinate, from the abscissa, by the height; divide the product by the square of the ordinate, and the quotient will give the height of the transverse ordinate.

Or, thus: Take any two numbers, in the proportion of the ordinate, or half base, and the distance between the abscissa and transverse ordinate; call these numbers respectively A and B: multiply the difference of the squares of A and B by the height; divide the product by the square of A; and the quotient will give the transverse ordinate.

Example.—In the parabola, A B C, are given the abscissa, B D, 8 feet, the ordinate, A D, 40 feet, and the distance, D E, 16 feet; to find the abscissal parallel, or the transverse ordinate, E F.

$$\frac{(40^2 - 16^2) \times 8}{40^2} = 6.72 \text{ feet, the answer.}$$

Or, because 5 and 2 are in the same proportion as 40 and 16, we have $\frac{(5^2 - 2^2) \times 8}{5^2} = 6.72$ feet, as before.

This method, as it avoids the square root, will not only be easier than the last, of finding a point in the curve of the parabola, but will be much more accurate when the abscissa is less than the ordinate.

PROBLEM XI.—*Given the abscissa and ordinate of a parabola, to find any number of equidistant diameters, or abscissal parallels, and consequently points, in the curve, at the extremities.*

Take the simple arithmetical progression of the numerical scale 1, 2, 3, 4, 5, &c. till the last contain as many units as the number of equal parts intended to be contained in the ordinate. Then if the last number represent the ordinate, the preceding numbers, 1, 2, 3, &c., will represent the respective distances that each transverse ordinate is from the abscissa. Proceed with these numbers as distances, and calculate as in the last Problem, and the several results will give the ordinates.

Or thus: If a double ordinate be given, and the number of transverse ordinates be even, or the equal parts of the double ordinate odd, take the odd numbers of the arithmetical progression 1, 3, 5, 7, &c., and proceed as above: and having found the transverse ordinates, let the real base, or double ordinate, be divided into the equal parts required, and perpendiculars erected at the points of division, and made respectively equal to the results on each side of the abscissa, will give the transverse ordinates, and consequently as many points in the curve.

This method applies to the construction of a parabola of very great extent, as the extrados of a bridge, not for one arch only, but for the upper line of a series of arches. The parabolic curve is well adapted to bridges, as it gets quicker towards the middle, and therefore the contrast with the land is not so violent as the circular arc, which has the same curvature at the ends as in the middle. The use of transverse ordinates in constructing the curve, is not only more expeditious in calculation, but more accurate in ascertaining the curve at the vertex.

SYNOPSIS OF THE PRINCIPAL RULES OF MENSURATION.

THEOREM I. RULE 1.—The circumference, c, of a circle being given, to find the diameter, d.

$$d = \frac{c}{3.1416}.$$

THEOREM II. RULE 2.

$$d = \frac{7c}{22}.$$

THE RECTIFICATION OR DEVELOPMENT OF CURVES.

THEOREM I. RULE 1.—To rectify or develop the circumference of a circle.

$$c = 3.1416\, d.$$

THEOREM II. RULE 2.

$$c = \frac{22\,d}{7}.$$

THEOREM III. RULE 1.—To rectify the arc of a circle, the radius, r, and the sine, s, of half the arc, being given.

Let z be the length of the arc required, in all the following cases; then

$$z = 2\,s + \frac{1.1\,q}{2.3}\text{A} + \frac{3.3\,q}{4.5}\text{B} + \frac{5.5\,q}{6.7}\text{C}, \text{ \&c. where } q = \frac{s^2}{r^2},$$

and A, B, C, the preceding terms.

THEOREM IV. RULE 2.—Let h equal the chord of the half arc, and c equal the chord of the whole arc.

$$z = \frac{8\,h - c}{3}, \text{ by Huygens.}$$

THEOREM V. RULE 3.—The diameter, d, the versed sine, v, and the chord, c, being given:

$$z = c + \frac{4\,v\,c}{6\,d - 5\,v} = c \times \frac{6\,d - v}{6\,d - 5\,v} = 2 \times (dv - v^2)^{\frac{1}{2}} \times \frac{6\,d - v}{6\,d - 5\,d}.$$

THEOREM VI. RULE 4.—The chord, c, and the versed sine, v, being given:

$$z = c + \frac{8\,v^2\,c}{3\,c^2 + 2\,v^2}, \text{ or } c\,\frac{3\,c^2 + 10\,v^2}{3\,c^2 + 2\,v^2}.$$

THEOREM VII. RULE 5.—The sine, s, and versed sine, v, of half the arc being given:

$$z = 2s + \frac{8v^2 s}{6s^2 + v^2}, \text{ or } 2s\,\frac{6s^2 + 5v^2}{6s^2 + v^2}.$$

THEOREM VIII. RULE 6.—The diameter, d, the sine, s, and versed sine, v, of half the arc, being given:

$$z = \frac{22ds}{11d - 8v}, \text{ or } 22s\,\frac{s^2 + v^2}{11s^2 + 3v^2}.$$

THEOREM IX. RULE 7.—The radius, r, the chord, c, and versed sine, v, being given:

$$z = c + \frac{cv}{3r} + \frac{v^3}{cr}.$$

THEOREM X. RULE 1.—To rectify the curve of an ellipsis, the major axis, t, and the minor axis, c, being given:

$$z = A - \frac{d}{2.2}A - \frac{3d}{4.4}B - \frac{3.5d}{6.6}C - \frac{5.7d}{8.8}, \text{ \&c., where}$$

$d = \frac{t^2 - c^2}{t^2}$; and A, B, C, &c., are the preceding terms.

THEOREM XI. RULE 2.

$$z = \frac{23t + 21c}{14}.$$

AREAS OF PLANE SURFACES.

In the following theorems, let A be the proposed area.

THEOREM I.—To find the area of a parallelogram; the length, l, and the breadth, b, at right angles to the length, being given:

$$= l\,b.$$

THEOREM II. RULE 1.—To find the area of a triangle; the base, b, and the perpendicular height, h, from the opposite angle, being given:

$$A = \frac{bh}{2}.$$

THEOREM III. RULE 2.—The three sides, a, b, c, being given, let s be the half sum of the three sides, then

$$A = (s \times \overline{s-a} \times \overline{s-b} \times \overline{s-c})^{\frac{1}{2}}.$$

THEOREM IV. RULE 3.—Given, b, the base, and s, the half sum of the two opposite sides:

$$A = \tfrac{1}{4}\,(\overline{s^2 - b^2} \times \overline{b^2 - d^2})^{\frac{1}{2}}.$$

THEOREM V.—To find the area of a polygon; the side, s, the number, n, of the sides of the polygon, and the radius, r, of the inscribed circle, being given:

$$A = \frac{rsn}{2}.$$

THEOREM VI. RULE 1.—To find the area of a circle; the diameter, d, and circumference, c, being given:

$$\frac{d}{2} \times \frac{c}{2}, \text{ or } \frac{dc}{4}.$$

THEOREM VII. RULE 2.—The diameter, d, being given:

$$.7854\,d^2.$$

THEOREM VIII. RULE 3.—The circumference, c, being given;

$$.0796\,c^2.$$

THEOREM IX.—To find the area of the sector of a circle, the radius, r, and the arc, a, being given:

$$A = r \times \frac{a}{2}, \text{ or } \frac{ra}{2}.$$

THEOREM X.—To find the area of a frustum sector, or part of a circular ring, contained between two radii; the breadth, b, the exterior arc, e, and interior arc, a, of the ring, being given:

$$A = b \times \frac{a + e}{2}.$$

THEOREM XI. RULE 1.—To find the area of the segment of a circle; the diameter, d, and the versed sine, v, being given:

$$A = 2v\,d^{\frac{1}{2}}\,v^{\frac{1}{2}} \times \left(\frac{2}{3} - \frac{v}{5d} - \frac{v^2}{28d^2} - \frac{v^3}{72d^3}\right), \text{ \&c.}$$

Or thus, RULE 2.

$$2v\,d^{\frac{1}{2}}\,v^{\frac{1}{2}} \times \left(\frac{2}{3} - \frac{3v}{5.2d}A - \frac{5v}{7.4d}B - \frac{7.3v}{9.6d}C - \frac{9.5v}{11.8d}D, \text{ \&c.}\right)$$

A, B, C, &c. being the first, second, third, &c. terms.

Or thus, RULE 3.

V being the supplemental versed sine, and $V = d - v$, therefore $d = V + v$; therefore

$$A = 2v\,V^{\frac{1}{2}}\,v^{\frac{1}{2}} \times \left(\frac{1}{1.1.3} + \frac{v}{1.3.5\,V} + \frac{v^2}{3.5.7\,V^2} + \frac{v^3}{5.7.9\,V^3}, \text{ \&c.}\right)$$

Or thus, RULE 4.—Where A, B, C, denote the preceding terms:

$$A = \frac{4}{3}v\,v^{\frac{1}{2}}\,V^{\frac{1}{2}} + \frac{v}{5V}A - \frac{1v}{7V}B + \frac{3v}{9V}C - \frac{5v}{11V}D, \text{ \&c.}$$

THEOREM XII. RULE 5.—The chord, c, and versed sine, v, being given:

$$A = \frac{2cv}{3} + \frac{v^3}{2c}, \text{ or } v\left(\frac{2c}{3} + \frac{v^2}{2c}\right) \text{ or}$$

$$A = \frac{2cv}{3} + \frac{v^3}{2c} - \frac{v^6}{20c^4}, \text{ still nearer.}$$

THEOREM XIII. RULE 6.—The chord, c, of the half arc, and the versed sine, v, of the same, being given:

$$A = \left(c + \frac{4c}{3}\right) \times \frac{4}{10}v, \text{ or } c + \frac{4}{3}d^{\frac{1}{2}}\,v^{\frac{1}{2}} \times \frac{4}{10}v,$$ by Sir Isaac Newton.

THEOREM XIV. RULE 7.—The radius, r, tne sine, s, and the versed sine, v, of half the arc, being given:

$$A = 11rs \times \frac{s^2 + v^2}{11s^2 + 3v^2}.$$

THEOREM XV.—To find the area of an ellipsis; the major axis, M, and the minor, m, being given:

$$A = .7854\,M\,m.$$

THEOREM XVI.—To find the area of an elliptic segment; the length, l, and the altitude, a, being given: also the breadth, b, of the segment of a circle of the same altitude and of the same diameter as the axis of the ellipsis, perpendicular to b.

$$A = \frac{l}{b} \times \left(\frac{2ab}{3} + \frac{a^3}{2c}\right).$$

THEOREM XVII.—To find the area of a parabola; the base, b, and the altitude, a, being given:

$$A = \frac{2ab}{3}.$$

THEOREM XVIII.—To find the area of the sinical curve; the radius, r, and the versed sine, v, of the segment, being given:

$$A = rv.$$

AREAS OF CURVED SURFACES.

THEOREM I.—To find the area of a cylindric surface; the axis, a, and the diameter, d, being given:

$A = 3.1416\,d\,a$ in a right cylinder.

Or $A = p\,a$ in an oblique cylinder, where p is the perimeter.

THEOREM II.—To find the curved surface of a cylindric ungula, $A = \frac{ds - ac}{v}\,h$; where h is the length of the part that is cut, and v the versed sine of the segment which forms the base, and d the diameter.

THEOREM III.—To find the area of the curved surface of a right cone; the side, s, and the circumference, c, of the circumference, being given:

$$A = \frac{sc}{2}.$$

THEOREM IV.—To find the area of the segment of a square dome.

$A = 4\,(s^2 + v^2)$, or $4\,d\,v$; where s is the sine, and v the versed sine of the circular segment which forms the vertical section, or d the diameter of the circle which forms the vertical section.

THEOREM V.—To find the area of a segment of a hemisphere; given the radius, s, of the base, the versed sine, v, and the diameter, d, of the axal section:

$A = 3.1416\,(s^2 + v^2)$, or $3.1416\,d\,v$.

THEOREM VI.—To find the area of the frustum of the segment of a hemisphere; the circumference, c, of the great circle, and the distance, d, of the parallel planes, being given:

$$A = c\,d.$$

THEOREM VII. RULE 1.—To find the surface of a spheroid; given the axis, a, and the diameter, d, of the great circle:

$A = .5236 \times (4\,a\,d + 2\,d^2)$.
Or, $A = 1.0472\,(2\,a\,d + d^2)$.

This is a near approximation.

THEOREM VIII. RULE 2.

$A = .8805\,(2\,a\,d + d^2) + \frac{a^2 + 2\,d^2}{6}$; still nearer to the truth than Rules 1 and 2.

THEOREM IX. RULE 1.—To find the surface of an ellipsoid; the length, a, the breath, b, and the thickness, c, being given:

$$2 \times .5236\,(a\,b + a\,c + b\,c).$$

This rule is a near approximation.

THEOREM X. RULE 2.

$A - 8805\,(a\,b + a\,c + b\,c) + \frac{a^2 + b^2 + c^2}{6}$; it is a nearer approximation than Rule 1.

THEOREM XI.—To find the surface of a semi-circular groin; given the side b.

$$A = 1.1416\,b^2.$$

SOLIDITIES OF BODIES.

THEOREM I.—To find the solidity of a cube.

$S = s^3$, where s is the linear dimension.

THEOREM II.—To find the solidity of a prism.

$S = a\,h$; where a is the area of the base, and h the perpendicular height. This also includes cylinders.

THEOREM III.—To find the solidity of a pyramid.

$S = \frac{ah}{3}$, or $\frac{h}{3} \times a$, or $\frac{a}{3} \times h$; where a is the area of the base, and h the perpendicular height. This also includes cones.

THEOREM IV.—To find the solidity of a wedge, or pyramoid; the two adjoining edges, a and b, of the base, the edge, c, in the same plane with a, and the height, being given:

$$S = \frac{2\,a\,b + c\,b}{6}\,h.$$

THEOREM V.—To find the solidity of the frustum of a pyramoid.

$S = \frac{a\,b + c\,d + 4\,e\,f}{6}\,h$; where a and c are the opposite terminations of a plane of one of the sides; b and d the opposite terminations of the plane of one of the adjoining sides; a and b being adjoining sides of the base, c and d those of the top, e the half sum of a and c, and f the half sum of b and d.

THEOREM VI.—To find the solidity of a cuneoid.

$S = \frac{2\,a\,b + c\,b}{6} \times .7854 \times h$. This formula is the same as that of Theorem V. except the additional multiplier .7854; this solid only differing in construction from the pyramoid in having elliptic sections instead of rectangular ones.

THEOREM VII.—To find the solidity of the frustum of a cuneoid.

$S = \frac{a\,b + c\,d + 4\,e\,f}{6} \times .7854 \times h$; where a and c are the two axes of the elliptic base, and c and d the axes of the elliptic top; c being opposite to a, and d opposite to b. This solid only differs from the frustum of a pyramoid in being circular.

THEOREM VIII.—To find the solidity of the segment of a cylinder.

RULE 1.—$S = a\,l\left(\frac{2\,b}{3} + \frac{a^2}{2\,b}\right)$; where a is the versed sine, b the chord of the base, and l the length of the cylinder.

RULE 2.—$S' = l \times \left(\frac{a\,b + a^2}{2} + \frac{b^2}{56}\right)$; still nearer than Rule 1. when the segment is nearly a semi-cylinder.

THEOREM IX.—To find the solidity of the segment of a square dome.

RULE 1.—$S = 4\,r\,x^2 - \frac{4\,x^3}{3}$; where x is the height, and r the radius of the circle, of which the segment forming the vertical section is a part. *See* vol. i. p. 284 of this Work.

RULE 2.—$S = \frac{a\,s^2}{2} + \frac{2\,a^3}{3}$; where s is the side of the square base, and a the altitude of the dome. *See* vol. i. p. 286 of this Work.

THEOREM X.—To find the solidity of the segment of a hemisphere.

RULE 1.—$s' = p\left(r x^2 - \frac{x^3}{3}\right)$; where p is equal to $4 \times .7854 = 3.1416$; and x and r, as in the preceding Theorem.

RULE 2.—$s = .7854\left(\frac{a s^2}{2} + \frac{2 a^3}{3}\right)$.

This only differs from RULE 2. THEOREM IX. in the base being circular. It gives the contents independent of the diameter of the great circle.

THEOREM XI.—To find the solidity of a truncated square dome, independent of the radius, or diameter, of the vertical section.

$s = a s^2 - \frac{4 a^3}{3}$; where a is the altitude, and s the side, of the square base.

THEOREM XII.—To find the solidity of the frustum of a hemisphere.

$s = .7854\left(a s^2 - \frac{4 a^3}{3}\right)$; being the same as in the last Theorem, except the multiplier .7854.

THEOREM XIII.—To find the solidity of a hollow truncated square dome.

$s = a\,(D^2 - d^2)$; where D is the side of the square base, between the opposite external surfaces, d the side of the square base between the opposite internal surfaces, and a the altitude; supposing the heel to be equally thick.

THEOREM XIV.—To find the solidity of a hollow hemispheric frustum.

$.7854\ a\,(D^2 - d^2)$; being the same as Theorem XIII., excepting the multiplier .7854.

THEOREM XV.—To find the solidity of a paraboloid.

$s = \frac{b\,h}{2}$; where h is the height, and b the area of the base.

THEOREM XVI.—To find the solidity of the frustum of a paraboloid.

$s = \frac{a + b}{2}\,h$; where a and b are the areas of the two ends.

THEOREM XVII.—To find the solidity of an hyperboloid.

$s = \frac{a + b + 4\,m}{6}\,h$; where a and b are the areas of the two ends, and m the area of the middle section. This theorem will also serve to measure a sphere, spheroid, paraboloid, cone, pyramid, pyramoid, or any segment, or frustum of these bodies.

Notes on the preceding Theorems.

RECTIFICATION OF CURVES.

RULE 2, of THEOREM VII. by Huygens, is very neatly expressed by $\frac{8\,h - c}{3}$; but the half chord must either be found geometrically, by bisecting the chord by a perpendicular, and drawing the half chord, or by a very operose arithmetical operation. If $d = 2\,h - c$, then will $c + d + \frac{d}{3}$ be the length of the arc: this affords a very easy geometrical construction; viz., *if to the chord of the whole arc be added the difference of twice the chord of the half arc and the chord of the whole arc, and one-third of the said difference, the sum will be nearly the length of the arc, for* $c + d + \frac{d}{3} = c + (2\,h - c) + \frac{2\,h - c}{3} = \frac{8\,h - c}{3}$.

RULES 3, 4, 5, 6. THEOREMS VII. VIII. IX. and X. were invented by Mr. Nicholson. The circumstance which gave rise to them was a stone weir, or dam, which he had designed and superintended at Denton Holm Head, over the river Caldew, near Carlisle. The form of the weir was that of the segment of a circle, of which the chord was 200 feet, and the versed sine 22 feet; when the work was completed, the contractor for the mason's work was very desirous to have it measured, but at that time, being early in the spring of 1810, the river was flooded so high, that the water ran two feet above the top of the weir; now having the true dimensions, as above, and an exact section of the work, it was only necessary to find the length of the arc, and then the solid contents were easily computed: but, in order to obtain this end, he found that the calculations by the rule of Huygens would require too much trouble for common business, and therefore, as well for present convenience as for anything that might happen in future of a like nature, the following formulas were invented: $L = c\,\frac{6\,d - v}{6\,d - 5\,v}$,

$$\text{or } L = c + \frac{4\,v\,c}{6\,d - 5\,v}, = c\,\frac{3\,c^2 + 10\,v^2}{3\,c^2 + 2\,v^2},$$

$$\text{or } L = c + \frac{8\,v^2\,c}{3\,c^2 + 2\,v^2}, = c\,\frac{6\,s^2 + 5\,v^2}{6\,s^2 + v^2},$$

$$\text{or } L = c + \frac{4\,v^2\,c}{6\,s^2 + v^2}.$$

The second formula, or Rule 4, is derived from the first, by substituting the value of d in terms of c and v; and Rule 5 is also derived from Rule 3, by substituting the value of d in terms of s and v; so that, being derived from each other, they will all give the very same result; and to show how near this is to the truth, the investigation is as follows:

For $c\,\frac{6\,d - v}{6\,d - 5\,v} = 2\,(d\,v - v^2)^{\frac{1}{2}} \times \frac{6\,d - v}{6\,d - 5\,v}$, the quantity $2\,(d\,v - v^2)^{\frac{1}{2}}$, being the value of c, in terms of d and v:

but $2\,(d\,v - v^2)^{\frac{1}{2}} = 2\,d^{\frac{1}{2}}\,v^{\frac{1}{2}} \times \left(1 - \frac{v}{2\,d} - \frac{v^2}{8\,d^2}, \text{ \&c.}\right)$

and $\frac{6\,d - v}{6\,d - 5\,v} = 1 + \frac{2\,v}{5\,d} + \frac{5\,v^2}{9\,d^2}$, &c.

Hence $2\,(d\,v - v^2)^{\frac{1}{2}} \times \frac{6\,d - v}{6\,d - 5\,v} = 2\,d^{\frac{1}{2}}\,v^{\frac{1}{2}} \times$

$$\left(1 - \frac{v}{2\,d} - \frac{v^2}{8\,d^2}, \text{ \&c.}\right) \times \left(1 + \frac{2\,v}{3\,d} + \frac{5\,v^2}{9\,d^2}, \text{ \&c.}\right)$$

$$= 2\,d^{\frac{1}{2}}\,v^{\frac{1}{2}} \times \left(1 + \frac{v}{6\,d} + \frac{7\,v^2}{72\,d^2}, \text{ \&c.}\right)$$

but $2\,d^{\frac{1}{2}}\,v^{\frac{1}{2}} \times \left(1 + \frac{v}{6\,d} + \frac{3\,v}{40\,d^2}, \text{ \&c.}\right)$ is known to express the arc of a circle, whose diameter is d, and its versed sine v; now this last series only differs from the former in the third term, in being less; the excess being $\frac{v}{45\,d^2}$.

Now, to show how far these rules may be depended upon in practice, Mr. Nicholson calculated the following table, where the numbers found answer to segments of different proportions. The results found, both by Huygens' rule and by that of Nicholson, are compared with the result found by an infinite series, which is the criterion; because, by such an infinite series the answer may be found, which can be depended upon, to any number of figures. The result found by the series in the table is therefore true to the last figure, or to the last but one when the next figure would be above 5. In this case, the last figure of the decimal is augmented by unity.

In the table, the first vertical column contains the chords, and is marked C; the second column contains the versed sines of the several segments, and is marked V; the third column contains the lengths of the arcs, according to the dimensions stated in columns C and V in the same horizontal row, and is marked L; and the last column, marked R, shows the ratio, or number of times that the versed sine is contained in the chord. In each cell under L are the three results; the upper one being that of Huygens, the middle one that of the series, and the lower one that of Nicholson.

C	V	L	R
936	155	1002.666 1002.959 1002.9	$6\frac{6}{155}$
24	5	26.666 26.687 26.69	$4\frac{4}{5}$
556	136	631.333 632.252 632.5	$4\frac{1}{68}$
8	3	10.666 10.724 10.743	$2\frac{2}{3}$
240	119	370.666 374.960 375.24	$2\frac{2}{119}$
14	7	21.73 21.991 22.	2

From this table it appears, that in low segments the result is nearly the same by each rule, but that Nicholson's is nearer to the series than that of Huygens; and it becomes much more so in proportion as the segment approaches towards a semicircle: thus, in a semicircle, the length of the arc found by the series is 21.991; the length found by Huygens is 21.73; the difference .261. Now, the length of the arc found by Nicholson's rule is 22, which is ultimately the Archimedean proportion, and the difference between this result and that found by the series is only .009.

In the first horizontal row, both methods agree with the series to four places of figures; in the second, they agree in three places; in the third, fourth, and fifth, they agree in two places; and in the sixth they agree in one. In the first horizontal column, Nicholson's method agrees in five places with the series; in the second, third, and fourth, with three figures of the series; in the fifth, with two figures of the series, and in the last with one figure of the series; but only differs in five figures from the truth by .009.

The length of the arc found by the two approximating rules in low segments, is exceedingly near the true value; but when the result is found by Huygens' rule in high segments, it is very considerably below it, and cannot well be employed in large dimensions.

There is still another rule to be found in books of mensuration, which will give the length of the arc to any exactness, either by finding the number of degrees by means of an instrument, or by trigonometry; the former is not very eligible in practice, and the latter would require too much time to be of real utility amid the hurry of business.

The investigation of Rule 6, Theorem X., from the geometrical division of the arc of the circle into equal parts, by the diameter being divided also into equal parts, is as follows:

Let A D B C be a circle; A B and C D two diameters, intersecting each other in E at right angles; let the diameter, D C, be produced to F, so that the part, C F, without the circle may be three-quarters of the radius, E C, or three-eighths of the diameter, D C; draw D G parallel to A B; take any portion, D I, of the arc D A; join F I; and produce F I to G:

Let D C be denoted by d; then will $\text{F D} = d + \frac{3\,d}{8} = \frac{11\,d}{8}$;

and $\text{F K} = \text{F D} - \text{K D} = \frac{11\,d}{8} - v = \frac{11\,d - 8\,v}{8}$.

Now, the triangles F K I and F D G are similar; therefore F K : F D : : K I : D G;

that is, $\frac{11\,d - 8\,v}{8} : \frac{11\,d}{8} :: s : \text{D G} = \frac{11\,d\,s}{11\,d - 8\,v}$; which is the value of the tangent.

Then, to show how nearly this value is to that of the arc, we have $\frac{11\,d\,s}{11\,d - 8\,v} = \frac{s}{1 - \frac{8\,v}{11\,d}}$;

but $s = (d\,v - v^2)^{\frac{1}{2}} = d^{\frac{1}{2}}\,v^{\frac{1}{2}}\left(1 - \frac{v}{2\,d} - \frac{v^2}{8\,d^2}, \text{\&c.}\right)$

therefore $\frac{s}{1 - \frac{8\,v}{11\,d}} = d^{\frac{1}{2}}\,v^{\frac{1}{2}} \times \frac{1 - \frac{v}{2\,d} - \frac{v^2}{8\,d^2}, \text{\&c.}}{1 - \frac{8\,v}{11\,d}} = d^{\frac{1}{2}}\,v^{\frac{1}{2}} \times \left(1 + \frac{5\,v}{22\,d} + \frac{39\,v^2}{968\,d^2}, \text{\&c.}\right)$ the value of the tangent, which should be equal to that of the arc; but the series expressed in the same terms for the value of the arc, is $d^{\frac{1}{2}} v^{\frac{1}{2}} \times \left(1 + \frac{v}{6\,d} + \frac{3\,v^2}{40\,d^2}, \&c.\right)$ it therefore appears that the value of the tangent is too great to express the value of the arc.

The length of the arc may be ascertained with tolerable exactness by Theorems XII. and XIII., which are thus expressed :—$z = c + \frac{c\,v}{3} + \frac{v^3}{c\,r}$, or $2\,s + \frac{c\,v}{3} + \frac{2\,v^4}{s^3 + v^3}$, by substituting $\frac{s^2 + v^2}{2\,v}$ for r, and $2\,s$ for c, in the first formula.

This rule gives the length of the arc 10.73, when the chord is 8 and the versed sine 3; and the series gives 10.724; and in a semicircle, where the chord is 14 and the versed sine 7, the length of the arc will be 22.16; the proportion of Archimedes would give 22. As this rule depends upon the area of the segment, the investigation will be given under that of Rule 7, Theorem XI, of the areas of plane figures, which follows.

Areas of Plane Figures.

Theorem XII. Rule 5, is a very near approximation to the quadrature of the segment of a circle. It is much easier than any other rule yet shown for the same purpose. It was invented, and first published in the article Mensuration, of *The principles of Architecture*, by Nicholson; since that time, it has been copied into the new edition of Hawney's *Mensuration*. The rule was first given without a demonstration; but it is now supplied with the following investigation.

The expression for the area is $\frac{2\,c\,v}{3} + \frac{v^3}{2\,c}$, where c is the chord, and v the versed sine.

$$\text{Now, } c = 2\,(d\,v - v^2)^{\frac{1}{2}} = 2\,d^{\frac{1}{2}}\,v^{\frac{1}{2}} \times \left(1 - \frac{v}{d}\right)^{\frac{1}{2}} = 2\,d^{\frac{1}{2}}\,v^{\frac{1}{2}} \times \left(1 - \frac{v}{2\,d} - \frac{v^2}{8\,d^2}, \&c.\right)$$

$$\text{therefore } \frac{2\,c\,v}{3} = \frac{4\,d^{\frac{1}{2}}\,v^{\frac{1}{2}}}{3} \times \left(1\,v - \frac{v^2}{2\,d} - \frac{v^3}{8\,d^2}, \&c.\right)$$

$$\frac{1}{c} = \frac{1}{2\,d^{\frac{1}{2}}\,v^{\frac{1}{2}}} \times \left(1 - + \frac{v}{2\,d} + \frac{3\,v^2}{8\,d^2}, \&c.\right)$$

$$\text{Therefore } \frac{v^3}{2\,c} = \frac{v^3}{4\,d^{\frac{1}{2}}\,v^{\frac{1}{2}}} \times 1 + \frac{v}{2\,d} + \frac{3\,v^2}{8\,d^2}, \&c.$$

$$\text{Hence } \frac{2\,c\,v}{3} + \frac{v^3}{2\,c} = \frac{4\,d^{\frac{1}{2}}\,v^{\frac{1}{2}}}{3} \times v - \frac{v^2}{2\,d} - \frac{3\,v^3}{8\,d^2}, \&c. + \frac{v^3}{4\,d^{\frac{1}{2}}\,v^{\frac{1}{2}}} \times 1 + \frac{v}{2\,d} + \frac{3\,v^2}{8\,d^2}, \&c.$$

Now let the last equation be meltiplied by $d^{\frac{1}{2}}\,v^{\frac{1}{2}}$.

$$\text{Then } d^{\frac{1}{2}}\,v^{\frac{1}{2}}\left(\frac{2\,c\,v}{3} + \frac{v^3}{2\,c}\right) = \frac{4\,d\,v}{3} \times \left(v - \frac{v^2}{2\,d} - \frac{v^3}{8\,d^2}, \&c.\right) + \frac{v^3}{4} \times \left(1 + \frac{v}{2\,d} + \frac{3\,v^2}{8\,d^2}, \&c.\right)$$

$$= \frac{4\,d\,v^2}{3} - \frac{4\,v^3}{6} - \frac{4\,v^4}{24\,d}, \&c. + \frac{v^3}{4} + \frac{v^4}{8\,d} + \frac{3\,v^5}{32\,d^2}, \&c.$$

$$= \frac{4\,d\,v^2}{3} - \frac{5\,v^3}{12} - \frac{v^4}{24\,d}, \&c.$$

Now let this last equation be divided by $d^{\frac{1}{2}}\,v^{\frac{1}{2}}$,

$$\text{and we obtain } \frac{2\,c\,v}{3} + \frac{v^3}{2\,c} = \frac{1}{d^{\frac{1}{2}}\,v^{\frac{1}{2}}} \times \left(\frac{4\,d\,v^2}{3} - \frac{5\,v^3}{12} - \frac{v^4}{24\,d}, \&c.\right)$$

$$\text{or } \frac{2\,c\,v}{3} + \frac{v^3}{2\,c} = \frac{1}{d^{\frac{1}{2}}\,v^{\frac{1}{2}}} \times \frac{d^{\frac{1}{2}}\,v^{\frac{1}{2}}}{d^{\frac{1}{2}}\,v^{\frac{1}{2}}} \times \left(\frac{4\,d\,v^2}{3} - \frac{5\,v^3}{12} - \frac{v^4}{24\,d}, \&c.\right)$$

$$\text{or } \frac{2\,c\,v}{3} + \frac{v^3}{2\,c} = \frac{d^{\frac{1}{2}}\,v^{\frac{1}{2}}}{d\,v} \times \left(\frac{4\,d\,v^2}{3} - \frac{5\,v^3}{12} - \frac{v^4}{24\,d}, \&c.\right)$$

$$\text{or } \frac{2\,c\,v}{3} + \frac{v^3}{2\,c} = d^{\frac{1}{2}}\,v^{\frac{1}{2}} \times \left(\frac{4\,v}{3} - \frac{5\,v^2}{12\,d} - \frac{v^3}{24\,d^2}, \&c.\right)$$

$$\text{or } \frac{2\,c\,v}{3} + \frac{v^3}{2\,c} = d^{\frac{1}{2}}\,v^{\frac{1}{2}} \times \left(\frac{4\,v}{3} - \frac{10\,v^2}{24\,d} - \frac{2\,v^3}{48\,d^2}, \&c.\right)$$

$$\text{or } \frac{2\,c\,v}{3} + \frac{v^3}{2\,c} = 2\,v \times d^{\frac{1}{2}}\,v^{\frac{1}{2}} \times \left(\frac{2}{3} - \frac{5\,v}{24\,d} - \frac{v^2}{48\,d^2}, \&c.\right)$$

But $2\,v \times d^{\frac{1}{2}}\,v^{\frac{1}{2}} \times \left(\frac{2}{3} - \frac{v}{5\,d} - \frac{v^2}{28\,d^2}, \&c.\right)$ is known to be the value of the segment, the diameter of which is d, and its versed sine v; then by comparing these two series they will be found to be nearly equal, the former being the greater;

for the first term is $\frac{2}{3}$ in both, and the second term in the approximation only differs from that of the proper series by a quantity less than $\frac{v}{120\,d}$.

From this Theorem, $\frac{2\,c\,v}{3} + \frac{v^3}{2\,c}$, we may derive $c + \frac{c\,v}{3} + \frac{v^3}{c\,r}$, as in Theorem XI. Rule 7, for the rectification of curves.

In the sector A D C E A draw the chord A C and E D perpendicular to A C, cutting A C at B; let A C′ $= c$, and B D $= v$; then B E = D E − D B $= r - v$; consequently the area of the triangle A C E $= \frac{r - v}{2} \times c = \frac{c\,r - c\,v}{2}$; but the area of the segment A D C is $\frac{2\,c\,v}{3} + \frac{v^3}{2\,c}$; therefore the area of the sector A D C E A is equal to $\frac{2\,c\,v}{3} + \frac{v^3}{2\,c} + \frac{c\,r - c\,v}{2} = \frac{c\,v}{6} + \frac{v^3}{2\,c} + \frac{c\,r}{2}$; and if this area be divided by the radius, we obtain $\frac{c\,v}{6\,r} + \frac{v^3}{2\,c\,r} + \frac{c}{2}$, or $\frac{c}{2} + \frac{c\,v}{6\,r} + \frac{v^3}{2\,c\,r}$ for the half arc, or $c + \frac{c\,v}{3\,r} + \frac{v^3}{c\,r}$, for the whole arc. And if $\frac{c^2 + 4\,v^2}{8\,v}$ be substituted for r, we obtain $c + \frac{8\,c\,v^2}{3\,c^2 + 12\,v^2} + \frac{8\,v^4}{c^3 + 4\,c\,v^2}$ for the value of the arc in terms of c and v.

Theorem XIV. Rule 7, of the areas of plane figures, $11\,r\,s \times \frac{s^2 + v^2}{11\,s^2 + 3\,v^2}$, being the area of the segment, the sine of the half arc of which is s, the versed sine v, and the radius r, evidently follows from Theorem X. Rule 6, by multiplying half the arc, $\frac{11\,s}{2} \times \frac{s^2 + v^2}{11\,s^2 + 3\,v^2}$, by the radius r.

Theorem XVI. being $\frac{l}{b} \times \left(\frac{2\,a\,b}{3} + \frac{a^3}{2\,b}\right)$ will easily be obtained from the following consideration, viz., suppose the ellipsis to be completed, and a circle to be described upon the axis, which bisects the base of the elliptic segment; then let the base of the elliptic segment, to be continued, if necessary, meet the circumference of the circle on each side; then it will be as the base of the circular segment is to the base of the elliptic segment, so is the area of the circular segment to the area of the elliptic segment; therefore, if the area of the circular segment be known, that of the elliptic segment will follow; now the area of the circular segment is $\frac{2\,a\,b}{3} + \frac{a^3}{2\,b}$; therefore, $b : l :: \frac{2\,a\,b}{3} + \frac{a^3}{2\,b} : \frac{l}{b} \times \left(\frac{2\,a\,b}{3} \times \frac{a^3}{2\,b}\right)$ the area of the elliptic segment.

Areas of Curved Surfaces.

Theorem VII. Rule 1, is an approximation; and the following will show what dependence is to be placed in the result obtained by calculation.

Let $a =$ the axis of the spheroid;
$b =$ the diameter of the great circle;
and $x =$ an indefinitely small distance, compared with a or d.

Now $.5236\,a\,d^2$ is the expression for the solidity of the spheroid, being two-thirds of its circumscribing cylinder;

then $(d + x)^2 \times (a + x) = a\,d^2 + 2\,a\,d\,x + a\,x^2 + d^2\,x + 2\,d\,x^2 + x^3 = a\,d^2$ nearly, being in excess;
and $(d - x) \times (a - x)$ $\quad a\,d^2 - 2\,a\,d\,x + a\,x^2 - d^2\,x + 2\,d\,x^2 - x^3 = a\,d^2$ nearly, being in defect;
therefore $\quad 4\,a\,d\,x \quad + 2\,d^2\,x \quad + 2\,x^3$ will be the solidity of a thin shell, the thickness of which is x; therefore $4\,a\,d + 2\,d^2 + 2\,x^2$ will be the area of such a shell, or $4\,a\,d + 2\,d^2$, by leaving out the quantity $2\,x^2$, which is indefinitely small: therefore $.5236\,(4\,a\,d + 2\,d^2)$ is the area of a spheroid nearly; it is exactly so when a and d are equal; for then $.5236\,(4\,a\,d + 2\,d^2)$ becomes $.5236 \times 6\,d^2 = 4 \times .7854\,d^2$, but the greater the difference between a and d, the more will the error be; because the thin shell varies more in its thickness.

Corollary 1.—Hence the surface of every rectangular prism with a square base is $4\,a\,d + 2\,d^2$.

Corollary 2.—When $a =$ nothing, then $.5236\,(4\,a\,d + 2\,d^2)$ becomes $.5236 \times 2\,d^2 = 1.0472\,d^2$, instead of $.7854\,d^2$, the area of the base.

Example for the Oblong Spheroid.

50 $= a$	40 $= d$
40 $= d$	40 $= d$
2000 $= a\,d$	1600 $= d^2$
4	2
8000 $= 4\,a\,d$	3200
3200	
11200 $= 4\,a\,d + 2\,d^2$	

.5236
11200
1047200
5236
5236
5864.3200 $= .5236\,(4\,a\,d + 2\,d^2)$.

The true answer is 5882.6385, the difference is therefore only 18.3185, which is not worth regarding in so large a number. In a dome which is the half of an oblong spheroid, the error would only be 9.1592 less than the truth.

Example for an Oblate Spheroid.

40 $= a$	50
50 $= d$	50
2000 $= a\,d$	2500 $= d^2$
4	2
8000 $= 4\,a\,d$	5000
5000	
13000 $= a\,d + 2\,d^2$	

.5236
    13000

15708000
5236

6806.8000 $= .5236\ (4\,a\,d + 2\,d^2)$

The answer ought to be 6830.4507; the error being about 24 less than the truth, which is very trifling in so great a number.

In architecture, we very seldom have domes of such large dimensions; and the value of a foot of plaster, or painting, can never be of any great consequence. This rule will therefore be sufficient for every practical purpose.

The following table contains the areas of the curved surfaces of spheroids of various proportions, according to the formula $.5236 \times (4\,a\,d + d^2)$ and to the real series; the comparison of the results will enable us to judge of the truth of the answer as found by the formula.

Rules.	A	D	Area.	Difference.
Series......	40	40	5026.56	none, being equal.
Formula....	40	40	5026.56	
Series......	50	40	5882.63	18.31 defective.
Formula....	50	40	5864.32	
Series......	60	40	6867.30	65.22 defective.
Formula....	60	40	6702.08	

Let us now try if any addition can be made to amend the above formula, which always gives the result less than the truth. We know, that the quantity to be added must be equal to nothing, when a is equal to d; we also know that the sum of the squares of two quantities is greater than twice their product; and when these quantities are equal, that the sum of their squares and twice their product will be equal: therefore $a^2 + d^2$ is greater than $2\,a\,d$; and the greater the difference between a and d, the more the sum of the squares of a and d will exceed twice the product, $2\,a\,d$, of a and d: thus, when one of the quantities, as d, is nothing in the sum, $a^2 + d^2$, of the squares, the quantity a^2 only remains, and in twice the product $2\,a\,d$, the whole vanishes. Therefore the value of $a^2 + d^2 - 2\,a\,d$ will be greater, as the difference between a and d is greater.

But to show what this difference is, by finding the value of these quantities in the same terms:

Let the greater, $d = a + x$;
then $d^2 = a^2 + 2\,a\,x + x^2$;
and $a^2 + d^2 = 2\,a^2 + 2\,a\,x + x^2$.
Again, $2\,a\,d = 2\,a\,(a + x) = 2\,a^2 + 2\,a\,x$:
now $2\,a^2 + 2\,a\,x + x^2$ is greater than $2\,a^2 + 2\,a\,x$ by x^2; that is, the sum of the squares, $a^2 + d^2$, of a and d, is greater than $2\,a\,d$ by the square of the difference of a and d; therefore the value of $a^2 + d^2 - 2\,a\,d$ will be greater, as a is greater than d. But to show that the square of the difference will not be very great in common cases, let $a = 4$, and $d = 3$, then the square of the difference is only 1; that is, when the difference is 1, the square of the difference will also be 1.

Let us now return to the subject, by adding the quantity proposed to $.5236\ (4\,a\,d + 2\,d^2)$; it will be found by adding $a^2 + d^2 - 2\,a\,d$ to $.5236\ (4\,a\,d + 2\,d^2)$ that the sum will be too great; therefore let the quantity $a^2 + d^2 - 2\,a\,d$ be divided by some number: on trial it appears that the addition of $\frac{a^2 + d^2 - 2\,a\,d}{6}$ to $.5236\ (4\,a\,d + 2\,d^2)$ will give a result very near to the truth, at the same time that it furnishes a very easy formula for architectural purposes, in the mensuration of domes, as will be seen in the following table.

This formula will therefore now stand $.5236\ (4\,a\,d + 2\,d^2) + \frac{a^2 + d^2 - 2\,a\,d}{6} = 1.0472\ (4\,a\,d + 2\,d^2) + \frac{a^2 + d^2 - 2\,a\,d}{6}$, which may again be reduced to this form $.8805\ (2\,a\,d + d^2) + \frac{a^2 + 2\,d^2}{6}$.

Rules.	A	D	Areas.	Difference.
Series......	40	40	5026.56	nothing.
Formula....	40	40	5026.56	
Series......	50	40	5882.63	1.83 in defect
Formula....	50	40	5880.8	
Series......	60	40	6767.30	1.44 in excess.
Formula....	60	40	6768.74	

This table shows the formula sufficiently exact for any practical purpose, at least in all useful propositions of architecture; and therefore confirms Theorem VIII. Rule 2. If a dome upon an elliptic plan, rising half the minor axis, be required to be measured, then the rule for such a dome will be $.4402\ (2\,a\,d + d^2) + \frac{a^2 + 2\,d^2}{12}$.

The approximating formula $2 \times .5236\ (a\,b + a\,c + b\,c)$, Theorem IX. Rule 1, may be thus confirmed: let the three dimensions of the ellipsoid be a, b, c, and let x be a very small increment to be added to a, b, and c, respectively; also a very small decrement to be taken from a, b, and c, respectively; now the solidity of an ellipsoid is $.5236\ a\,b\,c$; then

$$a\,b\,c = (a + x) \times (b + x) \times (c + x) = a\,b\,c + b\,c\,x + a\,c\,x + c\,x^2 + a\,b\,x + b\,x^2 + a\,x^2 + x^3, \text{ nearly;}$$
$$\text{and } a\,b\,c = (a - x) \times (b - x) \times (c - x) = a\,b\,c - b\,c\,x - a\,c\,x + c\,x^2 - a\,b\,x + b\,x^2 + a\,x^2 - x^3, \text{ nearly;}$$
$$\text{therefore } \quad 2\,b\,c\,x + 2\,a\,c\,x \quad + 2\,a\,b\,x \quad + 2\,x^3 \text{ is the}$$

increment of the solid, or the solidity of a shell, the thickness of which is x; consequently, if the increment, $2\,b\,c\,x + 2\,a\,c\,x + 2\,a\,b\,x$, of the solid be divided by x, we shall then obtain $2\,b\,c + 2\,a\,c + 2\,a\,b + 2\,x^2$ for the surface of the solid; but the quantity $2\,x^2$ is indefinitely small, and appears as nothing in comparison of $2\,b\,c + 2\,a\,c + 2\,a\,b$; therefore $2\,b\,c + 2\,a\,c + 2\,a\,b$, or $2\,a\,b + 2\,a\,c + 2\,b\,c$ is nearly equal to the surface of the solid; and consequently, $.5236\ (2\,a\,b + 2\,a\,c + 2\,b\,c)$, or $1.0472\ (a\,b + a\,c + b\,c)$ will be nearly equal to the surface of the ellipsoid.

Corollary 1.—Hence $2\,a\,b + 2\,a\,c + 2\,b\,c$ will be the surface of a rectangular prism, exactly.

Corollary 2.—Let a, b, and c, be each equal to d; then $1.0472\ (a\,b + a\,c + b\,c)$ becomes $1.0472 \times 3\,d^2 = 3.1416\,d^2 = 4 \times .7854\,d^2$, as it ought to be: but the greater the difference between a, b, and c, the more will the error be.

This rule may be corrected in the same manner as Theorem VII. Rule 1; by adding $\frac{a^2 + b^2 + c^2 - a\,b - a\,c - b\,c}{6}$; which being done, the formula may be reduced to .8805 $(ab+ac+bc)+\frac{a^2+b^2+c^2}{6}$, which gives Theorem X. Rule 2.

Notes on the Solidities of Bodies.

The method of the middle section has never been noticed by any writer in a practical way. There can be little doubt but this method took its rise from that of equidistant ordinates, first given by Sir Isaac Newton, as we are informed by Shirtcliffe, in his *Art of Gauging*, in the following words:

"I shall lay down a proposition for measuring planes or solids by approximation, a thing of the greatest importance to this part of science, of any that was ever brought for that purpose, since it may be said to contain the whole art of gauging, and that of coppers, stills, tuns, as well as all kinds of casks, whether full or partly empty, either standing or lying.

"*Of measuring curvilinear planes and solids, by approximation.*

"Proposition.—If MQ $= y'$, NR $= y''$, PS $= y'''$ represent three equidistant perpendicular ordinates to the axis of a curve, MNP, whose equation is $y = a + bx + cx^2$, where x stands for any abscissa, QT, and y its ordinate, TO; then, calling QS the distance of the extreme ordinates, l, the measure of the space, QMPS, will be thus expressed:

"Theorem. QMPS $= \overline{y' + y''' + 4y''} \times \frac{l}{6}$.

"For by the preceding principles, the quadrature of the curve, whose abscissa is x, and ordinate $a + bx + cx^2$, will be found $a + \overline{\frac{bx}{2}} + \overline{\frac{cx^2}{3}} \times x$; and this, when x becomes l, is

$$\overline{a + \frac{bl}{2} + \frac{cl^2}{3}} \times l = \overline{6a + 3bl + 2c^2} \times \frac{l}{6}, = \text{QMPS}.$$

But from the equation of the curve we have these three equations,

$$y' = a;$$
$$y'' = a + \frac{bl}{2} + \frac{cl^2}{4};$$
$$y''' = a + bl + cl^2.$$

And by taking the difference of those above, we have

$$y - a = \frac{bl}{2} + \frac{cl^2}{4};$$
$$y''' - y'' = \frac{bl}{2} + \frac{3cl^2}{4}.$$

And the difference of the last gives

$$y''' - 2y'' + a = \frac{cl}{2}.$$

Whence $2cl^2 = 4 \times \underline{y''' - 2y' + a}$; and by the third equation above, $bl = \underline{y''' - a - cl^2}$; therefore $3bl = 3y''' - 3a - 6 \times \overline{y''' - 2y'' + a} = -3y''' + 12y'' - 9a$; put these for $2cl^2$ and $3bl$, in the above expression of the area, and then we have, QMPS, $= \overline{6a + 3bl + 2cl^2} \times \frac{l}{6} = y' + 4y'' + y''' + \frac{l}{6}$. Q. E. D.

"Corollary 1.—The same method of demonstration extends to any number of equidistant ordinates; so if A denotes the sum of the extreme ordinates, B the sum of those next to them, C the sum of the two next following the last, and so on; then we shall have the following tables of areas, for the several numbers of ordinates prefixed to them, viz., for

2. $A \times \frac{l}{2}$;

3. $\overline{A + 4B} \times \frac{l}{6}$;

4. $\overline{A + 3B} \times \frac{l}{8}$;

5. $\overline{7A + 32B + 12C} \times \frac{l}{90}$;

6. $\overline{19A + 75B + 50C} \times \frac{l}{288}$;

7. $\overline{41A + 216B + 27C + 272D} \times \frac{l}{840}$;

8. $\overline{751A + 3577B + 1323C + 2989D} \times \frac{l}{17280}$ &c. &c.

"This method was invented by Sir Isaac Newton, and published by Mr. Jones in 1711; and since prosecuted by Mr. Coats, Mr. De Moivre, and by Mr. Stirling, in a whole treatise entirely built thereon, where such as desire a farther insight into this matter, may find it sufficiently explained, and applied to some of the most intricate parts of mathematics."

This table errs in the last term of the areas corresponding to the ordinates 3, 5, 7, &c., viz., 4 B should only be 2 B, and 12 C should only be 6 C, and so of the rest; that is, they are double what they ought to be.

This error has also escaped the notice of that great mathematician, Mr. Emerson, see p. 29 of his *Differential Method*, published with his *Conic Sections*, 1767, where he has the same table as in *Shirtcliffe's Gauging*; but it has been corrected by Dr. Hutton. *See* his *Mensuration*, large copy, printed in 1770.

To show how this rule may be derived in the simplest manner, in order to approximate any curvilinear surface, of which the ends are parallel, let AEDBA be bounded on one side by a parabolic curve, BCD; and let AB and ED be two diameters, or straight lines, parallel to its axis; and let AE be perpendicular to AD and ED; also let AE be bisected in F; and let FC be drawn parallel to AB or ED; and let BD be drawn cutting FC in G;

and let AB $= q$,
FC $= b$,
and ED $= c$;
also, AF, or FE $= m$:

now FG will be equal to $\frac{a+c}{2}$,

and the part GO will be $b - \frac{a+c}{2}$;

but the space BCDB is equal to a parabola, of which the base is AE, or $2m$, and the height GC, or $b - \frac{a+c}{2} = \frac{2b-a-c}{2}$;

therefore $\frac{2}{3}$ + G C × A E = $\frac{2}{3} \times \frac{2b - a - c}{2} \times 2m = \frac{2m}{3} \times (2b - a - c)$ the area B C D B; but the area of the trapezoid A B D E is equal $\frac{1}{2} \times (a + c) \times 2m = (a + b) \times m$; therefore the area A B C D E A = $(a + c) \times m + (2b - a - c) \times \frac{2m}{3} = \left(a + c + \frac{4b - 2a - 2c}{3}\right) \times m = \frac{3a + 3c + 4b - 2a - 2c}{3} \times m = \frac{a + c + 4b}{3} \times m$, or $\frac{a + 4b + c}{3} \times m$.

Now, let A B C D E F G, &c. be the abscissa of a curve, H I J K L M N, &c. and let A H, B I, C J, be any number of even equidistant ordinates, and let these ordinates be denoted by a, b, c, d, e, f, g, &c. Let us suppose a parabolic curve to pass through every adjoining three; that is, taking in every two adjoining spaces; and let m be the common breadth of every space; then the area of the first two spaces will be $\frac{a + 4b + c}{3} \times m$; the area of the two next spaces will be $\frac{c + 4d + e}{3} \times m$; the area of the two next spaces will be $\frac{e + 4f + g}{3} \times m$, and so on, as far as we please. Now the sum of all these areas will be the area of the whole curve; therefore, $\frac{a + 4b + c}{3} \times m + \frac{c + 4d + e}{3} \times m + \frac{e + 4f + g}{3} \times m$, &c. $= \frac{4b + 4d + 4f + 2c + 2e + a + g}{3} \times m = \frac{4 \times (b + d + f) + 2 \times (c + e) + a + g}{3} \times m$ equal to the area of the curve.

This not only holds true in superficies, but also in solids.

Then, if the intermediate ordinates be called sections, and be numbered 1, 2, 3, &c., the first being called odd, the next even, and so on alternately; the last section will always be odd; then to four times the sum of the odd sections add twice the sum of the even sections, and the two ends; then one-third of the sum being multiplied by the common distance gives the area, which is a near approximation for any curvilinear figure whatever.

Observations on Averaging Surfaces, bounded on one or on two opposite sides by a Curve.

In the mensuration of superficies bounded by curves, the common method of taking the average, or mean, of any number of ordinates, by adding all the ordinates together, and dividing by their number, and multiplying the quotient by the length, is extremely vague.

For let the figure proposed to be measured be A E F H K A, divided by the equidistant ordinates B I, C H, D G. Let A K be denoted by a, B I by b, C H by c, D h by d, E F by e; and let the common distance, A B, or B C, &c., be denoted by m; and let each of the areas, A B I K A, B C H I B, C D G H C, D E F G D, be computed according to the method of measuring a trapezoid; then the sum of the contents will be the area of the whole space, A E F H K A, provided that the lines, K I, I H, H G, G F, be straight, and very nearly equal to the true area, when the figure is bounded on one side by a curve; being in excess when K I H G F is concave, and in defect when convex: then will

$$\frac{a + b}{2} \times m = \text{A B I K A},$$

$$\frac{b + c}{2} \times m = \text{B C H I B},$$

$$\frac{c + d}{2} \times m = \text{C D G H C},$$

$$\text{and } \frac{d + e}{2} \times m = \text{D E F G D}.$$

The sum of these areas is $\left(\frac{a + e}{2} + b + c + d\right) m$; that is, if the half sum of the extreme ordinates be added to the intermediate ones, and the sum multiplied by the common distance, the product will give the area: and it is evident that this will always be the case, whatever be the number of ordinates.

Therefore, let a, b, c, d, &c., to p and q, be any series of ordinates whatever, whereof a is the first term, and p and q the two last; then the area of the curvo-rectilinear space will be generally expressed by $\left(\frac{a + q}{2} + b + c + d, \text{ \&c. to } p\right) \times m$; now, let l = the length; then if n be equal to the number of ordinates, $n - 1$ will be the number of spaces, or areas; therefore $\left(\frac{a + q}{2} + b + c + d, \text{ \&c. to } p\right) \times m = \frac{\left(\frac{a + q}{2} + b + c + d, \text{ \&c. to } p\right) \times l}{n - 1} = \frac{a + q + 2b + 2c + 2d, \text{ \&c. to } 2p}{2n - 2}$, and the value of the average method, viz. $\frac{a + b + c + d, \text{ \&c. to } p + q}{n} \times m \times (n - 1) = \frac{a + b + c + d, \text{ \&c. to } p + q}{n} \times l$; then putting one of these equal to the other, there will result $n \times \frac{a + q}{2} = a + b + c + d$, &c. to $p + q$.

It appears, therefore, that there can be no equality except when the half sum of the extreme ordinates, multiplied by the whole number of terms, is equal to the sum of all the ordinates; which, therefore, must be in arithmetical progression, or amount to such.

The method of averaging will therefore be very uncertain; as the half sum of the two extreme terms, multiplied by the number of ordinates, can be taken in any ratio, with respect to the sum of the ordinates.

The difference between the average method and the true method, would be the very same as the difference between $l \times \frac{a + q}{2 \times (n - 1)}$ and $l \times \frac{a + b + c + d, \text{ \&c. to } p + q}{n \times (n - 1)}$; for if from two unequal quantities equal quantities be taken away, their difference will still be the same; and if to two unequal quantities equal quantities be added, the difference between the sums will still be the same.

If equimultiples be taken of unequal quantities, the difference between the products will be the same multiple of the difference; and if any aliquot part, or equisubmultiple, be taken of two unequal quantities, the difference will be equal to the same submultiple of the former difference; now because the equation $n \times \frac{a+q}{2} = a + b + c + d$, &c., to $p + q$, was obtained by dividing each side of the equation $l \times \frac{a + q + 2b + 2c + 2d, \text{ \&c. to } 2p}{2n - 2} = l \times \frac{a + b + c + d, \text{ \&c. to } p + q}{n}$ by l, and multiply each side respectively by n, $n - 1$, and then adding, or taking away the common parts; by making the divisor l a multiplier, and the multipliers n, $n - 1$, divisors; then multiplying the equation $n \times \frac{a+q}{2} = a + b + c + d$, &c. to $p + q$ by l, and dividing it by n and $n - 1$, there will arise $l \times \frac{a+q}{2 \times (n-1)} = l \times \frac{a + b + c + d, \text{ \&c. to } p + q}{n \times (n-1)}$.

Example.—Let $a = 4$, $b = 12$, $c = 16$, $d = 18$, $p = 19$, $q = 18$, and $l = 10$;

then $l \times \frac{a+q}{2(n-1)} = 10 \times \frac{4 + 18}{2 \times (6 - 1)} = 22$,

and $l \times \frac{a + b + c + d, \text{ \&c. to } p + q}{n + (n-1)} = 10 \times \frac{4 + 12 + 16 + 18 + 19 + 18}{6 \times (6-1)} = 29$; the difference is therefore 7, the same as between $\dfrac{\left(\frac{a+q}{2} + b + c + d, \text{\&c. to } p + q\right)}{n - 1} \times l$, and $\frac{a + b + c + d, \text{ \&c. to } p + q}{n} \times l$.

Mensuration of Artificers' Works. All such works, whether superficial or solid, are computed by the rules proper for the figure of them.

The most common instruments for taking the measures are, a five-feet rod, divided into feet and quarters of a foot; and a rule, either divided into inches, or twelfth parts, and each twelfth part into twelve others; a fractional part beyond this division, measurers seldom, or never, take any account of.

When the dimensions are taken by a rule divided in this manner, the best methods to square the dimensions will then be by duodecimals, by the rule of practice, or by the multiplication of vulgar fractions; but, in the opinion of some, the best method of taking dimensions is with a rule, when each foot is divided into ten parts, and each part into ten other parts, or seconds, because the dimensions may be then squared by the rules of multiplication of decimals, which is by far the shortest and readiest method. Those who contend that duodecimals, or cross multiplication, is the easiest method of squaring dimensions, as well as the most exact, are very much mistaken; for if the dimensions are taken in duodecimals, and reduced to decimals, and then squared, the operation, in this case, will certainly be much longer than if it had been done at once by duodecimals, and sometimes not so exact: but if the dimensions are taken in feet, tenths, &c. the operation will not only be easier and shorter, but in many cases will be much more exact than by duodecimals: the reason is obvious to those who consider that there are many cases in which it will be impossible to express, truly, a decimal scale equal to a duodecimal one; neither will it, in many cases, be possible to express accurately, a duodecimal scale equal to a decimal one; duodecimals have the same property with regard to twelfth parts, as decimals have to tenth parts; therefore, in many cases, duodecimals will sometimes circulate and run on, *ad infinitum*, when reduced from decimals, as decimals will, when reduced from duodecimals; and farther, since duodecimals are expressed by a series of twelfth parts, and decimals by a series of tenth parts, in multiplying each of the parts of the former, the trouble of dividing by twelve will then be unavoidable, and more burdensome to the mind than if the operation had been done by the latter, where there is no such division to be made, but merely to multiply as in common mutiplication, and point off the decimal places in the product.

This last method is always to be preferred, as the most natural, as well as the most easy of the two.

Bricklayers' Work.

The mensuration of brickwork has already been treated of at considerable length under that head, but in order to complete the article, we shall give a few more problems and examples.

Problem I.—*To measure the vacuity of a window.*

Find the area of the outside of the window, and multiply that by the number of half bricks thick, from the face of the sash-frame on the outside, to the face of the wall on the same side; to the area so found, at half a brick thick, add the area of the inside vacuity multiplied by the number of half bricks thick, from the face of the sash-frame on the outside, to the face of the brick-work within the building; also add the area of the vacuity of the recess, the height being taken from the bottom of the sash-frame to the floor, and its width the same as the inside vacuity above; multiply this also by the number of half bricks thick, then the sum of these will be the whole vacuity, or void space in the whole window, at half a brick thick; and if required to be reduced to the standard, divide the area so found by 3, and the area of the contents will be reduced to $1\frac{1}{2}$ brick thick.

Example.—Let the height of the outside vacuity be 8 feet, its breadth 4 feet, and half a brick thick; the height of the inside vacuity 8 feet, and its breadth 4 feet 9 inches, and two bricks thick; the recess is 2 feet 9 inches high, 4 feet 9 inches wide, and half a brick thick; required the area of the whole vacuity, at half a brick thick.

Ft.	In.		
8	0		height of the outside vacuity.
4	0		width of the outside vacuity.
32	0		area of the outside vacuity, half a brick thick.
4	9		width of the inside vacuity.
8	0		height of the inside vacuity.
38	0		
4	0		number of half bricks.
152	0		area of the inside vacuity, half a brick thick.
4	9		width of the inside vacuity.
2	9		height of the recess from the floor to the side of the sash.
9	6		
3	6	9	
13	0	9	area at $1\frac{1}{2}$ brick thick.
3	0	0	
39	2	3	area of the recess, half a brick thick.
32	0	0	
152	0	0	
223	2	3	area of the whole vacuity, half a brick thick.

PROBLEM II.—*To measure any angle chimney, standing equally distant each way from the angle of the room.*

Multiply the breadth, A B, by the height of the story, and the product by the number of half bricks contained in the half breadth, A B, and it will give the solidity at half a brick thick, after deducting the vacuity, or opening of the chimney.

PROBLEM III.—*To measure an angle chimney, when the plane of its breast intersects the two sides of the room unequally distant from the angle.*

From the points A and B, where the plane of the breast intersects the sides of the room, draw two lines, A E, E B, parallel to the two sides of the room; then multiply either of the lines, A E or E B, suppose E B, by the height of the room, and multiply that product by the number of half bricks contained in the other line, A E, and deduct the vacuity as before, and the remainder will be the content, at half a brick thick.

PROBLEM IV.—*To measure an angle chimney, when the plane of the breast projects out from each wall, and unequally distant from the angle of the room.*

Draw the two lines, G F and F H, parallel to the two sides of the room, as before; then multiply the breadth, F H, by the height of the story, and the product contained in the half of the other side, F G; from this product deduct F D, multiplied by the height of the story, and by the number of half bricks contained in the half of F C, and also the vacuity of the chimney.

PROBLEM V.—*To find the area of an arched operture.*

To twice the height at the middle add the height of the jambs; and one-third of the sum multiplied by the breadth of the aperture will give the superficial content, sufficiently near for practice.

Example.—Let the height of the arch be 12 feet, each jamb 10 feet, and the breadth of the aperture 5 feet; what is the superficial content?

Feet.
12
2
24
10
3) 34
$11\frac{1}{3}$
5
$56\frac{2}{3}$ feet, the answer.

But if greater accuracy be required, add the quotient arising from the division of the cube of the altitude by twice the breadth of the aperture, and the sum will be exceedingly near the truth.

Example.—In the foregoing example, the height of the arch is 2 feet, and the chord of the arch, or twice the breadth of the aperture, is 5 feet; then the cube of 2 is 8; and 8 divided by 10, or twice five, gives .8 of a foot for the quantity to be added to the above.

Now the above $56\frac{2}{3}$ = 56.666, &c.
.8

57.466, the area, exceedingly near the truth.

PROBLEM VI.—*To find the area of a wall, or of the foundation of a building, placed upon a curved surface, supposing it to be built upon uneven ground.*

Divide the length into any number of even parts (the more the truer) by parallel vertical sections; call the first of these sections *odd*, the next *even*, the next *odd*, and so on alternately; and thus the first and last sections will always be odd. Then add together four times the sum of the odd sections, twice the sum of the even sections, and the two ends: divide the sum by three times the number of parts that the length is divided into; then multiply the quotient by the length of the wall, and the product will be the superficial content.

Example.—Suppose a brick wall, 32 feet long, to be divided into eight equal parts, by seven sections of the following heights, taken in successive order, 5 feet, 6 feet, 6 feet 2 inches, 6 feet 3 inches, 5 feet 5 inches, 4 feet, 3 feet, the one end 3 feet and the other 2 feet 6 inches; required the area of the wall.

Now, 5 feet, 6 feet 2 inches, 5 feet 5 inches, and 3 feet, are the odd ordinates; and 6 feet, 6 feet 3 inches, 4 feet, are the even ordinates; therefore,

Feet.	In.		Feet.	In.
5	0		6	0
6	2		6	3
5	5		4	0
3	0		16	3
19	7			2
	4		32	6

78	4		= four times the sum of the odd sections.
32	6		= twice the sum of the even sections.
3	0		= the one end.
2	6		= the other end.
3) 116	4		
8) 38	9	4	
4	10	2	
32			
155	1	4	

The following erroneous method is usually practised by measurers and workmen:—

Add all the heights together, and divide the sum by their number; then the quotient, multiplied by the length, is supposed to give the area.

Let us therefore resume the same example by this method:

Feet.	In.		
3	0		
5	0		
6	0		
6	2		
6	3		
5	5		
4	0		
3	0		
2	6		
9) 41	4		the sum of all the heights.
4	7	$1\frac{1}{3}$	
32			
146	11	$6\frac{1}{3}$	the answer, considerably below the truth.

Where the foundation would consist of several straight lines, forming trapezoids, the best method is to find the content of each trapezoid separately; and then adding all the trapezoids together, their sum will be the area of the whole; but if the figure of the ground on which the building is raised be a curve, the measurer will be grossly deceived as to the true contents of the work, unless he divide the length into equal parts, as already recommended.

The contents in brickwork may be found by multiplying the area by 3, and dividing by the number of half bricks.

The following example is added, in order to show the use of the method of equidistant ordinates.

Example.—Let E F G H be a wall of brickwork, or the back of a house, to be built over a public road, or valley, H L G; the under part of the wall is built from the foundation, H L G, up to the level at I K, three bricks thick, and from I K to the top, E F, parallel to it, two bricks and a half thick, to the height of 15 feet, having five windows in it; the vacuities on the outside of each window are 8 feet by 4 feet, and half a brick thick; the vacuities on the inside are 8 feet by 4 feet 9 inches, two bricks thick; the recess on the inside for the finishing of the backs in each window, one and a half brick thick; the height 2 feet 6 inches, from the top of the floor to the sill of the window; the width is that of the vacuity on the inside of the window, viz., 4 feet 9 inches. There is an arched way underneath for carriages, &c. to pass through, whose opening is 12 feet, and its height from the level of the pavement to the crown or top of the arch 11 feet, and the height, from the pavement to the springing of the arch, 9 feet; the under wall is divided into an even number of equidistant spaces, whose ordinates are respectively as follow:—6 feet, 10 feet, 13 feet, 14 feet, 10 feet, 4 feet 6 inches, and 1 foot; the whole length of the building is 50 feet; required the number of bricks, and the quantity of sand and lime to build the said wall.

Explanation.—The under part of the building being an irregular figure, it is measured according to the method of equidistant ordinates, Problem VI.; the upper part is found as in the foregoing examples. The arched way is measured by Problem V. The contents of the windows are obtained by Problem I. Then deduct all the vacuities at half a brick thick from the area of the whole, found as if it were solid, at half a brick thick, as before: the remainder being divided by 3, will reduce it to the standard thickness of one brick and a half.

Feet. In.
10 0
14 0
4 6
———
28 6
4
———
114 0 four times the sum of the even ordinates.
add 46 twice the sum of the odd ordinates.
———
3) 160
———
53 4
50
———
6) 2666 8
444 5 area of the under part of the wall, 3 bricks thick.
6 number of half bricks
———
2666 8 area of the under part of the wall, ½ a brick thick.

Feet.
13
10
—
23
2
—
46

Feet. In.
15 0 height of the upper part of the wall.
50 0 length.
———
750 0 area of the upper part of the wall, 2½ bricks thick.
5 0 number of half bricks.
———
3750 0 area of ditto, ½ a brick thick.
———
8 0
4 0
———
32 0 area of the vacuity on the outside, ½ a brick thick.
5 0 number of windows.
———
160 0 area of the vacuities on the outside of five windows, ½ a brick thick.
———
8 4
4 9
———
33 4
6 3
———
39 7 area of the vacuity of the inside for one window, 2 bricks thick.
5 number of windows.
———
197 11 area of the vacuities for five windows on the inside.
4 half bricks thick.
———
791 8 area of the vacuities on the inside, ½ a brick thick.
———
4 9
2 6
———
9 6
2 4 6
———
11 10 6 area of the vacuity of the recess under each window 1½ brick thick.
5
———
59 4 6 area of the vacuities of the five window backs, 1½ brick thick.
3 number of half bricks.
———
178 1 6 area of the vacuities of the five window backs, ½ a brick thick.
———
11 0 height of the archway, from the pavement to the crown.
2
———
22 0
add 9 0 height from the pavement to the springing of the arch.
———
31 0
10 0 width of the archway.
———
3) 310 0
———
103 4 area of the vacuity of the archway, 3 bricks thick.
6 number of ½ bricks thick.
———
620 0 area of the vacuity of the archway, ½ a brick thick.
———
160 0
791 8
178 1
620 0
———
1749 9 areas of all the vacuities, ½ a brick thick.

Feet.	Inches.	
2666	8	
3750	0	
6416	8	area of the whole $\frac{1}{2}$ a brick thick, as if solid.
deduct 1749	9	
3) 4666	11	true area of the whole, $\frac{1}{2}$ a brick thick.
272) 1555	7	(5 rods 195 feet, reduced to the standard thickness.
1360		
195		

Thus $5.195 \times 4500 = 25726$ number of bricks nearly.
$5.195 \times 1\frac{1}{4} = 7\frac{211}{372}$ cwt. of lime nearly.
$5.195 \times 2\frac{1}{2} = 14\frac{79}{272}$ loads of sand nearly.

To persons, to whom the saving of time is an object, the following tables will be found of great utility in the calculation of brickwork, as well as in the examination of the several operations wrought without them. The explanations and examples of their use will follow.

Table I.

Showing the number of rods contained on the superficies or face of the wall or building, from half a brick to five bricks in thickness, and reduced to the standard measure of one brick and a half thick, being already cast up.

	½ brick.	1 brick.	1½ brick.	2 bricks.	2½ bricks.	3 bricks.	3½ bricks.	4 bricks.	4½ bricks.	5 bricks.
	rd. qr. ft.	rd. qr. ft.	rd. qr. ft.	rd. qr. ft.	rd. qr. ft.	rd. qr. ft.	rd. qr. ft.	rd. qr. ft.	rd. qr. ft.	rd. qr. ft.
1 qr.	0 0 22	0 0 45	0 1 0	0 1 22	0 1 45	0 2 0	0 2 22	0 2 45	0 3 0	0 3 22
2 qr.	0 0 45	0 1 22	0 2 0	0 2 45	0 3 22	1 0 0	1 0 45	1 1 22	1 2 0	1 2 45
3 qr.	0 1 0	0 2 0	0 3 0	1 0 0	1 1 0	1 2 0	1 3 0	2 0 0	2 1 0	2 2 0
1	0 1 22	0 2 45	1 0 0	1 0 22	1 2 45	2 0 0	2 1 22	2 2 45	3 0 0	3 1 22
2	0 2 45	1 1 22	2 0 0	2 2 45	3 1 22	4 0 0	4 2 45	5 1 22	6 0 0	6 2 45
3	1 0 0	2 0 0	3 0 0	4 0 0	5 0 0	6 0 0	7 0 0	8 0 0	9 0 0	10 0 0
4	1 1 22	2 2 45	4 0 0	5 1 22	6 2 45	8 0 0	9 1 22	10 2 45	12 0 0	13 1 22
5	1 2 45	3 1 22	5 0 0	6 2 45	8 1 22	10 0 0	11 2 45	12 1 22	15 0 0	16 2 45
6	2 0 0	4 0 0	6 0 0	8 0 0	10 0 0	12 0 0	14 0 0	16 0 0	18 0 0	20 0 0
7	2 1 22	4 2 45	7 0 0	9 1 22	11 2 45	14 0 0	16 1 22	18 2 45	21 0 0	23 1 22
8	2 2 45	5 1 22	8 0 0	10 2 45	13 1 22	16 0 0	18 2 45	21 1 22	24 0 0	26 2 45
9	3 0 0	6 0 0	9 0 0	12 0 0	15 0 0	18 0 0	21 0 0	21 0 0	27 0 0	30 0 0
10	3 1 22	6 2 45	10 0 0	13 1 22	16 2 45	20 0 0	23 1 22	26 2 45	30 0 0	33 1 22
11	3 2 45	7 1 22	11 0 0	14 2 45	18 1 22	22 0 0	25 2 45	29 1 22	33 0 0	36 2 45
12	4 0 0	8 0 0	12 0 0	16 0 0	20 0 0	24 0 0	28 0 0	32 0 0	36 0 0	40 0 0
13	4 1 22	8 2 45	13 0 0	17 1 22	21 2 45	26 0 0	30 1 22	34 2 45	39 0 0	43 1 22
14	4 2 45	9 1 22	14 0 0	18 2 45	23 1 22	28 0 0	32 2 45	37 1 22	42 0 0	46 2 45
15	5 0 0	10 0 0	15 0 0	20 0 0	25 0 0	30 0 0	35 0 0	40 0 0	45 0 0	50 0 0
16	5 1 22	10 2 45	16 0 0	21 1 22	26 2 45	32 0 0	37 1 22	42 2 45	48 0 0	53 1 22
17	5 2 45	11 1 22	17 0 0	22 2 45	28 1 22	34 0 0	39 2 45	45 1 22	51 0 0	56 2 45
18	6 0 0	12 0 0	18 0 0	24 0 0	30 0 0	36 0 0	42 0 0	48 0 0	54 0 0	60 0 0
19	6 1 22	12 2 45	19 0 0	25 1 22	31 2 45	38 0 0	44 1 22	50 2 45	57 0 0	63 1 22
20	6 2 45	13 1 22	20 0 0	27 2 45	33 1 22	40 0 0	46 2 45	53 1 22	60 0 0	66 2 45
21	7 0 0	14 0 0	21 0 0	28 0 0	35 0 0	42 0 0	49 0 0	56 0 0	63 0 0	70 0 0

(Side label of rows 1–21: The no. of rods contained upon the surface of the wall.)

Table II.

Showing how many bricks are sufficient to build a piece of brickwork containing any number of feet superficial, from 1 to 90,000; and from half a brick to two bricks and a half; and thence, by addition only, to any thickness or number required, at the rate of 4,500 bricks to the rod, and at the statute thickness of one brick and a half, waste included.

Area of the face of wall.	The number of bricks thick, and quantity required.					Area of the face of wall.	The number of bricks thick, and quantity required.				
	½ brick.	1 brick.	1½ brick.	2 bricks.	2½ bricks.		½ brick.	1 brick.	1½ brick.	2 bricks.	2½ bricks.
1	5	11	16	22	27	600	3308	6617	9926	13235	16544
2	11	22	33	44	55	700	3860	7720	11580	15441	19301
3	16	33	49	66	82	800	4411	8823	13235	17647	22058
4	22	44	66	88	110	900	4963	9926	14889	19852	24816
5	27	55	82	110	137	1000	5514	11029	16544	22058	27573
6	33	66	99	132	165	2000	11029	22058	33088	44117	55147
7	38	77	115	154	193	3000	16544	33088	49632	66176	82720
8	44	88	132	176	220	4000	22058	44117	66176	88235	110294
9	49	99	148	198	248	5000	27573	55147	82720	110294	137867
10	55	110	165	220	275	6000	33088	66176	99264	132352	165441
20	110	220	330	441	551	7000	38602	77205	115808	154411	193014
30	165	330	496	661	827	8000	44117	88235	132352	176470	220588
40	220	441	661	882	1102	9000	49632	99264	148896	198529	248161
50	275	551	827	1102	1378	10000	55147	110294	165441	220588	275735
60	330	661	992	1323	1654	20000	110294	220588	330882	441176	551470
70	386	772	1158	1544	1930	30000	165441	330882	496323	661764	827205
80	441	882	1323	1764	2205	40000	220588	441176	661764	882352	1102940
90	496	992	1488	1985	2481	50000	275735	551470	827205	1102940	1378675
100	551	1102	1654	2205	2757	60000	330882	661764	992646	1323528	1654410
200	1102	2205	3308	4411	5514	70000	386029	772058	1158087	1544110	1930145
300	1654	3308	4963	6617	8272	80000	441176	882352	1323528	1704704	2205880
400	2205	4411	6617	8823	11029	90000	496323	992646	1488969	1985292	2481615
500	2757	5514	72	11029	13786						

Table III.

Showing the number of rods contained in any number of feet superficial, from 1 to 10,000; and from ½ a brick to 2½ bricks, and thence, by addition, to any number and to any thickness required, at the rate of 4,500 bricks to the rod.

Feet Super.	½ brick.	1 brick.	1½ brick.	2 bricks.	2½ bricks.
	r. q. ft. in.	r. q. ft. in.	r. q. ft. in.	r. q. ft. in.	r. q. ft. in.
1	0 0 0 4	0 0 0 8	0 0 1 0	0 0 1 4	0 0 1 8
2	0 0 0 8	0 0 1 4	0 0 2 0	0 0 2 8	0 0 3 4
3	0 0 1 0	0 0 2 0	0 0 3 0	0 0 4 0	0 0 5 0
4	0 0 1 4	0 0 2 8	0 0 4 0	0 0 5 4	0 0 6 8
5	0 0 1 8	0 0 3 4	0 0 5 0	0 0 6 8	0 0 8 4
6	0 0 2 0	0 0 4 0	0 0 6 0	0 0 8 0	0 0 10 0
7	0 0 2 4	0 0 4 8	0 0 7 0	0 0 9 4	0 0 11 8
8	0 0 2 8	0 0 5 4	0 0 8 0	0 0 10 8	0 0 13 4
9	0 0 3 0	0 0 6 0	0 0 9 0	0 0 12 0	0 0 15 0
10	0 0 3 4	0 0 6 8	0 0 10 0	0 0 13 4	0 0 16 8
11	0 0 3 8	0 0 7 4	0 0 11 0	0 0 14 8	0 0 18 4
12	0 0 4 0	0 0 8 0	0 0 12 0	0 0 16 0	0 0 20 0
13	0 0 4 4	0 0 8 8	0 0 13 0	0 0 17 4	0 0 21 8
14	0 0 4 8	0 0 9 4	0 0 14 0	0 0 18 8	0 0 23 4
15	0 0 5 0	0 0 10 0	0 0 15 0	0 0 20 0	0 0 25 0
16	0 0 5 4	0 0 10 8	0 0 16 0	0 0 21 4	0 0 26 8
17	0 0 5 8	0 0 11 4	0 0 17 0	0 0 22 8	0 0 28 4
18	0 0 6 0	0 0 12 0	0 0 18 0	0 0 24 0	0 0 30 0
19	0 0 6 4	0 0 12 8	0 0 19 0	0 0 25 4	0 0 31 8
20	0 0 6 8	0 0 13 4	0 0 20 0	0 0 26 8	0 0 33 4
21	0 0 7 0	0 0 14 0	0 0 21 0	0 0 28 0	0 0 35 0
22	0 0 7 4	0 0 14 8	0 0 22 0	0 0 29 4	0 0 36 8
23	0 0 7 8	0 0 15 4	0 0 23 0	0 0 30 8	0 0 38 4
24	0 0 8 0	0 0 16 0	0 0 24 0	0 0 32 0	0 0 40 0
25	0 0 8 4	0 0 16 8	0 0 25 0	0 0 33 4	0 0 41 8
26	0 0 8 8	0 0 17 4	0 0 26 0	0 0 34 8	0 0 43 0
27	0 0 9 0	0 0 18 0	0 0 27 0	0 0 36 0	0 0 45 4
28	0 0 9 4	0 0 18 8	0 0 28 0	0 0 37 4	0 0 46 8
29	0 0 9 8	0 0 19 4	0 0 29 0	0 0 38 8	0 0 48 4
30	0 0 10 0	0 0 20 0	0 0 30 0	0 0 40 0	0 0 50 0
31	0 0 10 4	0 0 20 8	0 0 31 0	0 0 41 4	0 0 51 8
32	0 0 10 8	0 0 21 4	0 0 32 0	0 0 42 8	0 0 53 4
33	0 0 11 0	0 0 22 0	0 0 33 0	0 0 44 0	0 0 55 0
34	0 0 11 4	0 0 22 8	0 0 34 0	0 0 45 4	0 0 56 8
35	0 0 11 8	0 0 23 4	0 0 35 0	0 0 46 8	0 0 58 4
36	0 0 12 0	0 0 24 0	0 0 36 0	0 0 48 0	0 0 60 0
37	0 0 12 4	0 0 24 8	0 0 37 0	0 0 49 4	0 0 61 8
38	0 0 12 8	0 0 25 4	0 0 38 0	0 0 50 8	0 0 63 4
39	0 0 13 0	0 0 26 0	0 0 39 0	0 0 52 0	0 0 65 0
40	0 0 13 4	0 0 26 8	0 0 40 0	0 0 53 4	0 0 66 8
41	0 0 13 8	0 0 27 4	0 0 41 0	0 0 54 8	0 1 0 4
42	0 0 14 0	0 0 28 0	0 0 42 0	0 0 56 0	0 1 2 0
43	0 0 14 4	0 0 28 8	0 0 43 0	0 0 57 4	0 1 3 8
44	0 0 14 8	0 0 29 4	0 0 44 0	0 0 58 8	0 1 5 4
45	0 0 15 0	0 0 30 0	0 0 45 0	0 0 60 0	0 1 7 0
46	0 0 15 4	0 0 30 8	0 0 46 0	0 0 61 4	0 1 8 8
47	0 0 15 8	0 0 31 4	0 0 47 0	0 0 62 8	0 1 10 4
48	0 0 16 0	0 0 32 0	0 0 48 0	0 0 64 0	0 1 12 0
49	0 0 16 4	0 0 32 8	0 0 49 0	0 0 65 4	0 1 13 8
50	0 0 16 8	0 0 33 4	0 0 50 0	0 0 66 8	0 1 15 4
60	0 0 20 0	0 0 40 0	0 0 60 0	0 1 12 0	0 1 32 0
70	0 0 23 4	0 0 46 8	0 1 2 0	0 1 25 4	0 1 48 8
80	0 0 26 8	0 0 53 4	0 1 12 0	0 1 38 8	0 1 65 4
90	0 0 30 0	0 0 60 0	0 1 22 0	0 1 52 0	0 2 14 0
100	0 0 33 4	0 0 66 8	0 1 32 0	0 1 65 4	0 2 30 8
200	0 0 66 8	0 1 65 4	0 2 64 0	0 3 62 8	1 0 61 4
300	0 1 32 0	0 2 64 0	1 0 28 0	1 1 60 0	1 3 24 0
400	0 1 65 4	0 3 62 8	1 1 60 0	1 3 57 4	2 1 54 8
500	0 2 30 8	1 0 61 4	1 3 24 0	2 1 54 8	3 0 17 4
600	0 2 64 0	1 1 60 0	2 0 56 0	2 3 52 0	3 2 48 0
700	0 3 29 4	1 2 58 8	2 2 20 0	3 1 49 4	4 1 10 8
800	0 3 62 8	1 3 57 4	2 3 52 0	3 3 46 8	4 3 41 4
900	1 0 28 0	2 0 56 0	3 1 16 0	4 1 44 0	5 2 4 0
1000	1 0 61 4	2 1 54 8	3 2 48 0	4 3 41 4	6 0 34 8
2000	2 1 54 8	4 3 41 4	7 1 28 0	9 3 14 8	12 1 1 4
3000	3 2 48 0	7 1 28 0	11 0 8 0	14 2 56 0	18 1 36 0
4000	4 3 41 4	9 3 14 8	14 2 56 0	19 2 29 4	24 2 2 8
5000	6 0 34 8	12 1 1 4	18 1 36 0	24 2 2 8	30 2 37 4
6000	7 1 28 0	14 2 56 0	22 0 16 0	29 1 44 0	36 3 4 0
7000	8 2 21 4	17 0 42 8	25 2 64 0	34 1 17 4	42 3 38 8
8000	9 3 14 8	19 2 29 4	29 1 44 0	39 0 58 8	49 0 5 4
9000	11 0 8 0	22 0 16 0	33 0 24 0	44 0 32 0	55 0 40 0
10000	12 1 1 4	24 2 2 8	36 3 4 0	49 0 5 4	61 1 6 8

Table IV.

Showing the value of reduced brickwork per rod, calculated at the several prices of £3 5s.—£3 10s.—£3 15s.—£4.—£4 5s.—and £4 10s. per rod, for mortar, labour, and scaffolding, and of bricks from £1 10s. to £3 per thousand; allowing 4,500 bricks to a rod.

Bricks, per thousand.			Mortar and labour, £3 5s. per rod.			Mortar and labour, £3 10s. per rod.			Mortar and labour, £3 15s. per rod.		
£.	s.	d.	£.	s.	d.	£.	s.	d.	£.	s.	d.
1	10	0	10	0	0	10	5	0	10	10	0
1	12	0	10	9	0	10	14	0	10	19	0
1	14	0	10	18	0	11	3	0	11	8	0
1	16	0	11	7	0	11	12	0	11	17	0
1	18	0	11	16	0	12	1	0	12	6	0
2	0	0	12	5	0	12	10	0	12	15	0
2	2	0	12	14	0	12	19	0	13	4	0
2	4	0	13	3	0	13	8	0	13	13	0
2	6	0	13	12	0	13	17	0	14	2	0
2	8	0	14	1	0	14	6	0	14	11	0
2	10	0	14	10	0	14	15	0	15	0	0
2	12	0	14	19	0	15	4	0	15	9	0
2	14	0	15	8	0	15	13	0	15	18	0
2	16	0	15	17	0	16	2	0	16	7	0
2	18	0	16	6	0	16	11	0	16	16	0
3	0	0	16	15	0	17	0	0	17	5	0

Bricks, per thousand.			Mortar and labour, £4 0s. per rod.			Mortar and labour, £4 5s. per rod.			Mortar and labour, £4 10s. per rod.		
£.	s.	d.	£.	s.	d.	£.	s.	d.	£.	s.	d.
1	10	0	10	15	0	11	0	0	11	5	0
1	12	0	11	4	0	11	9	0	11	14	0
1	14	0	11	13	0	11	18	0	12	3	0
1	16	0	12	2	0	12	7	0	12	12	0
1	18	0	12	11	0	12	16	0	13	1	0
2	0	0	13	0	0	13	5	0	13	10	0
2	2	0	13	9	0	13	14	0	13	19	0
2	4	0	13	18	0	14	3	0	14	8	0
2	6	0	14	7	0	14	12	0	14	17	0
2	8	0	14	16	0	15	1	0	15	6	0
2	10	0	15	5	0	15	10	0	15	15	0
2	12	0	15	14	0	15	19	0	16	4	0
2	14	0	16	3	0	16	8	0	16	13	0
2	16	0	16	12	0	16	17	0	17	2	0
2	18	0	17	1	0	17	6	0	17	11	0
3	0	0	17	10	0	17	15	0	18	0	0

Table V.—Showing the value of brickwork reduced to one brick and a half thick, from 5s. 8d. per rod, to £20 per rod; and from a farthing to 1s. 6d. per foot.

Per foot.	Per rod.			Per foot.	Per rod.			Per foot.	Per rod.		
0d.	£.	s.	d.	6d.	6	16	0	12d.	13	12	0
¼	0	5	8	¼	7	1	8	¼	13	17	8
½	0	11	4	½	7	7	4	½	14	3	4
¾	0	17	0	¾	7	13	0	¾	14	9	0
1d.	1	2	8	7d.	7	18	8	13d.	14	14	8
¼	1	8	4	¼	8	4	4	¼	15	0	4
½	1	14	0	½	8	10	0	½	15	6	0
¾	1	19	8	¾	8	15	8	¾	15	11	8
2d.	2	5	4	8d.	9	1	8	14d.	15	17	4
¼	2	11	0	¼	9	7	0	¼	16	3	0
½	2	16	8	½	9	12	8	½	16	8	8
¾	3	2	4	¾	9	18	4	¾	16	14	4
3d.	3	8	0	9d.	10	4	0	15d.	17	0	0
¼	3	13	8	¼	10	9	8	¼	17	5	8
½	3	19	4	½	10	15	4	½	17	11	4
¾	4	5	0	¾	11	1	0	¾	17	17	0
4d.	4	10	8	10d.	11	6	8	16d.	18	2	8
¼	4	16	4	¼	11	12	4	¼	18	8	4
½	5	2	0	½	11	18	0	½	18	14	0
¾	5	7	8	¾	12	3	8	¾	18	19	8
5d.	5	13	4	11d.	12	9	4	17d.	19	5	4
¼	5	19	0	¼	12	15	0	¼	19	11	0
½	6	4	8	½	13	0	8	½	19	16	8
¾	6	10	4	¾	13	6	3	¾	20	2	4

Table VI.

Showing what number of plain tiles, or pan-tiles, will cover any area from 1 to 10,000 feet.

Feet Super.	Plain tiles. Gauges.			Pan-tiles. Gauges.		
	6 inch.	6¼ inch.	7 inch.	11 inch.	12 inch.	13 inch.
1	7½	7	6½	1⅔	1½	1⅓
2	15	14	13	3⅓	3	2⅔
3	22½	21	19½	5	4½	4
4	30	28	26	6⅔	6	5⅓
5	37½	35	32½	8⅓	7½	6⅔
6	45	42	39	10	9	8
7	52½	49	45½	11⅔	10½	9⅓
8	60	56	52	13⅓	12	10⅔
9	67½	63	58½	15	13½	12
10	75	70	65	16⅔	15	13⅓
20	150	140	130	33⅓	30	26⅔
30	225	210	195	50	45	40
40	300	280	260	66⅔	60	53⅓
50	375	350	325	83⅓	75	66⅔
60	450	420	390	100	90	80
70	525	490	455	116⅔	105	93⅓
80	600	560	520	133⅓	120	106⅔
90	675	630	585	150	135	120
100	750	700	650	166⅔	150	133⅓
200	1500	1400	1300	333⅓	300	266⅔
300	2250	2100	1950	500	450	400
400	3000	2800	2600	666⅔	600	533⅓
500	3750	3500	3250	833⅓	750	666⅔
600	4500	4200	3900	1000	900	800
700	5250	4900	4550	1166⅔	1050	933⅓
800	6000	5600	5200	1333⅓	1200	1066⅔
900	6750	6300	5850	1500	1350	1200
1000	7500	7000	6500	1666⅔	1500	1333⅓
2000	15000	14000	13000	3333⅓	3000	2666⅔
3000	22500	21000	19500	5000	4500	4000
4000	30000	28000	26000	6666⅔	6000	5333⅓
5000	37500	35000	32500	8333⅓	7500	6666⅔
6000	45000	42000	39000	10000	9000	8000
7000	52500	49000	45500	11666⅔	10500	9333⅓
8000	60000	56000	52000	13333⅓	12000	10666⅔
9000	67500	63000	58500	15000	13500	12000
10000	75000	70000	65000	16666⅔	15000	13333⅓

A general Explanation of the Tables and their Construction.

In Tables, which may be calculated by a proportion, in which one of the terms is constantly the same, and consequently the other two only variable, the given data, or numbers, are always of two kinds; one of the kinds is placed in one row, and the other in another row, at a right angle therewith; the former being parallel to the edges of the page, and upon the left hand, and the other perpendicular to the said edges, and at the top of the page: we shall call the former, the given vertical column; and the latter, the given horizontal row; the first part of the given horizontal row over the given vertical column, contains the title of this column; and the given numbers of this horizontal row follow each other in succession, having each a separate cell with the title at the top; then other rows are made in a line with each cell, parallel to the given vertical column, so that the respective numbers which form the said columns may also line with the numbers in the left-hand vertical column: then each of these numbers, so disposed, are to be the answers of the two numbers at the extremity of the legs in each given row. From this it appears, that the answer is in the concourse of the given column and row, traced from each given datum parallel to the given columns in which the data are inserted. All the useful variations of one of the given species, or kinds, are expressed by one or several arithmetical progressions, in the given vertical column, and the other species in an arithmetical progression in the given horizontal row. If the given vertical column consist only of one arithmetical progression, the answer for any number in the said column, between the first and the last, may be obtained at once: but if the given vertical column consist of several arithmetical progressions, *viz.* from 1 to 10, from 10 to 100, from 100 to 1000, &c., the common difference of the following progression being 10 times greater than that which precedes it, then the given number belonging to the vertical column must be divided into component parts, so as to correspond with as many of the numbers to be found in the progressions; each of the answers are to be taken out separately, and added together, and the sum will be the answer in full. Where the given vertical column consists of one or more arithmetical progressions, so will each vertical column of answers consist of as many arithmetical progressions, and each horizontal row of answers will also form an arithmetical progression; therefore in the construction of the Table, there is no necessity for calculating by the rule of proportion, nor even by plain division or multiplication, except in the first or uppermost two numbers in the first and second vertical columns of answers; the difference of each of these numbers, so found, is the common difference of the progression in the first horizontal row of answers; then this common difference being added to that at the head of the second column gives the next towards the right hand, or the uppermost answer at the head of the third vertical column; the common difference being added to this sum, again gives the next succeeding answer, and so on to the end of the horizontal progression: proceed with each vertical column by adding the common difference in the same way throughout each progression, if more than one; observing, that whatever number of times the common difference of any following progression in the given vertical column contains the common difference in the preceding progression, so must the common difference of any following corresponding progression, in any vertical column of answers, contain the common difference of the arithmetical progression immediately preceding in the same column.

One thing may be observed in each vertical column, where the answers consist of integers only, and where there are several arithmetical progressions, from 1 to 10, from 10 to 100, from 100 to 1000, and where each progression is formed of 10 terms, all the numbers of the first progression are to be found respectively in as many of the first figures of the second progression, and all the figures of each number in the second progression are to be respectively found in as many of the first figures of each of the numbers in the third progression, and so on, whatever be the number of progressions: therefore, if the last progression be constructed, the whole of the progressions upwards may also be constructed: for whatever number of figures each number of the lower progression consists of, each number of the progression immediately above will respectively consist of the same, wanting the right-hand figure; likewise the third progression will have the same number of figures in each number, wanting one, that each respective number has in the second progression, or wanting two that each respective number in the undermost progression has. So that, by proper attention, one small Table, consisting only of 10 horizontal rows, will give the answer for any number whatever.

In Tables where the given columns consist of different denominations, the answers may be first obtained in one denomination, and afterwards each of the answers may be divided into the several denominations it will resolve into, in order to facilitate the construction of the Tables.

TABLE I.

Explanation.—At the head of this table, over each vertical column, is the thickness of the wall in bricks and half bricks, *viz.* from $\frac{1}{2}$ a brick to 5 bricks; the first vertical column, or that on the left hand, contains the number of rods, from $\frac{1}{4}$ to 21, and each succeeding column towards the right shows the number of rods, quarters, and feet, reduced to a brick and a half, according to the thickness expressed at the top of the column, and to the number of rods to be found in the same horizontal line in the first column.

Use.—Suppose a wall, $2\frac{1}{2}$ bricks thick, contained 8 rods, how many standard rods does the wall contain? Look for 8 rods in the first column, carry your eye horizontally to the $2\frac{1}{2}$ brick column, in which you will find 13 1 22; that is, 13 rods, 1 quarter, and 22 feet; and so proceed for any other quantity and thickness.

Construction of the Table.—Multiply the number of superficial rods expressed in any number of the first column, by the number of half bricks that the wall is in thickness, divide the product by 3, and the quotient will exhibit the number of reduced rods: multiply the remainder, if any, by 272, and $\frac{1}{3}$ of the product will be reduced feet; the inches not being noticed. Now, as 68 feet are the quarter of a rod, the quotient, if it equal or exceeds 68, must be divided thereby, and the last quotient will give the quarters of a rod, and the remainder, if any, will be feet.

Example.—Let it be required to find to the quantity of reduced work in a wall $2\frac{1}{2}$ bricks thick, the superficial measure being 8 rods:

```
      8
      5  half bricks           Then 68) 90 (1
   ----                                 68
3) 40                                   --
   ------                               22
   13   90
```

	Rds.	Ft.		R.	Qt.	Ft.
That is	13	90	=	13	1	22

And thus for any other number of superficial rods. A Table, similar to the above, may be found in Leadbeater's *Gentleman's and Tradesman's Assistant*, second edition; and also in Crosby's *Builder's Price Book.*

TABLE II.

Explanation and Use.—The first column contains the number of superficial feet, from 1 to 10 inclusive, the common difference being 1; from 10 to 100 inclusive, the common difference being 10; from 100 to 1000 inclusive, the common difference being 100; from 1000 to 10,000 inclusive, the common difference being 1000; and from 10,000 to 90,000 inclusive, the common difference being 10,000. The adjacent vertical columns, towards the right, show the number of bricks respectively required to build a wall at the thickness of $\frac{1}{2}$, 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$ bricks, according to the superficial feet expressed by the number in the first vertical column, in the same horizontal line.

Let it be required to find the number of bricks necessary to build a wall half a brick thick, containing an area of 4850 feet: Divide the number into its component parts thus, 4850 = 4000 + 800 + 50, then look for each of these parts separately, and you will find, that

	4000	will require	22058	add these together,
	800	„ „	4411	
	50	„ „	275	
and the whole	4850	„ „	26744	

Again, let it be required to find the number of bricks that will build a wall two bricks thick, containing an area of 35,864 feet: then say, 35,864 = 30000 + 5,000 + 800 + 60 + 4, and you will find that—

30000	will require	661764
5000	„ „	110294
800	„ „	17647
60	„ „	1323
4	„ „	88
35864	„ „	791116

Construction.—Reduce the standard rod of 272 feet, and the given area, into walls of half a brick thick; then say, as the number of feet in the standard, thus reduced, is to the area reduced to the same thickness, so is 4,500 bricks, the quantity required to build the former, to the quantity required to build the latter.

Example I.—How many bricks will be required to build a wall containing an area of 35,864 feet, two bricks thick?

```
Then 272          35864
       3              4
     ---          ------
     816    :     143456  : :  4500
                    4500
                  --------
                  71728000
                 573824
                 ---------
           816) 645552000 (791117 the answer.
                 5712
                 ----
                  7435
                  7344
                  ----
                    912
                    816
                    ---
                    960
                    816
                    ----
                    1440
                     816
                    ----
                    6240
                    5712
                    ----
                     528
```

The answer is within one of what is obtained from the Tables; the difference arises from the fractions being lost, in adding the several parts together.

Example II.—How many bricks will be required to build a partition wall, half a brick thick, containing an area of 4850 feet?

```
      272          4850
        3             1
      ---          ----
Then  816    :     4850  : :  4500
                   4500
                 -------
                 2425000
                19400
                --------
          816) 21825000 (26746 the number required;
                1632
                ----
                 5505
                 4896
                 ----
                  6090
                  5712
                  ----
                   3780
                   3264
                   ----
                    5160
                    4896
                    ----
                     264
```

which is rather more than the aggregate found by the Tables, the remainders being omitted in adding the component parts together.

In this manner, by the rule of proportion, every number in the Table may be found. Or if the solidity of the wall be divided by the solidity of a brick, both of the same dimension, the quotient will give the number of bricks; but this operation will not be shorter than the above.

In Salmon's *Architect's Assistant*, is a Table similar to that above described, showing the number of bricks necessary to build a wall, from half a brick to two bricks and a half thick inclusive, and from one foot on the surface, to 27,000 inclusive. The column of feet goes on from unity to 100 inclusive, the common difference being one; then from 100 to 1,000 inclusive, the common difference being 100; and lastly from 1,000 to 27,000 inclusive, the common difference being 1,000.

But there is no advantage in a long table, unless the number could be found at once without addition, which is not generally the case. The short Table here introduced, is extended farther than Salmon's, and is much more handy.

Another Table, of the same description, was published by Mr. J. Leadbeater, and assistants, in his *Gentleman's and Tradesman's Complete Assistant.* The progression of the numbers expressing the area is exactly the same as in Salmon's, except that the latter author's work contains two horizontal lines more than the former; the one ending in 27,000, the other in 25,000; and with the exception of the following numbers, all the others correspond:

In the one-brick column, opposite 35, Salmon has 381, and Leadbeater 386, the difference is 5, but Leadbeater is right.

In the same column, opposite 45, Salmon has 502, and Leadbeater 503: but the number ought to be 496.

In the brick-and-half column, opposite 53, Salmon has 876, and Leadbeater 878; the true number is 876, or more nearly 877: in this instance they differ but little from the truth.

In the one-brick column, opposite 62, Salmon has 689, and Leadbeater 696; which are both in excess; the true number being 683, or very nearly 684. The greatest difference is 12 or 13 that Leadbeater is beyond the truth.

In the brick-and-half column, opposite 84, Salmon has 1389, and Leadbeater 1380; which are both in excess; the true number being 1356. Salmon, who has the greatest, exceeds the truth by 33.

In the same column, opposite 97, Salmon has 1604, and Leadbeater 1614: Salmon is right.

And lastly, in the two-and-a-half brick column, opposite 12,000, Salmon has 343,087, and Leadbeater 353,087, which are both vastly beyond the truth, which is 330,882. Salmon is therefore 12,205 in excess, and Leadbeater 22,205.

These differences are so great, and the nearest so wide of the truth, that one must suppose, either that these gentlemen were governed by no regular rule, or that they were very careless; for indeed they might have come nearer to the required number at a mere guess.

But if in the few numbers here examined, such enormous differences appear, what may not be expected from the far greater part of them?

It may perhaps happen that these differences, as they are few, are typographical errors; and should this be the case, it is most probable that one has copied from the other. The quotations from these works are from the second edition; Salmon's is dated 1748, and Leadbeater's 1769.

In Crosby's *Builder's Price Book*, by Phillips, for 1811, is a similar Table; and I am sorry to find, in a book of so much reputation, that the same numbers are to be found as in Salmon's and Leadbeater's, except in the four following:

In the one-brick column, opposite 20, Crosby has 223, and Salmon and Leadbeater, each, 220, the true number.

In the two-brick column, opposite 300, Crosby has 6626, and Salmon and Leadbeater, 6616, the true number.

In the two-and-a-half brick column, first, opposite 50, Crosby has 1476, and Salmon and Leadbeater, 1478; but the true number is 1378: Secondly, opposite 5000, Crosby has 145,953, and Salmon and Leadbeater, 142,953; whereas the true number is 137,867.

These numbers are so nearly alike in the three books here mentioned, that the differences appear to be no more than typographical errors; whence we may conclude that Leadbeater's *Assistant* has been copied from Salmon's, and the Table in Crosby's from one of them; for though it is much contracted, the errors in the numbers are the same.

If compilers in general would be at the necessary pains of examining what they intend to adopt, three-fourths of the books that are published on scientific subjects would never have appeared; the far greater part of them are made from scraps of others, and many are exactly the same in substance, only slightly varied in the arrangement, or in a single word now and then; and even whole paragraphs or sections are frequently to be met with, and sometimes whole works are copied, without any acknowledgment of the original author. Such is the case with the three authors alluded to; neither of the latter two takes any notice of the first; but taking it for granted that he is right, and depending upon this, they each make the part thus adopted their own, little suspecting that these antiquated works would ever undergo re-examination. But happy it is for scientific subjects, and for original writers, that there are still some few men of principle who will pry to the bottom of the greatest difficulties, and undergo the most laborious calculations; and though such authors as those referred to, may have credit in the mean time for what they have done, they must be ultimately exposed to that censure which their works so justly deserve.

There is hardly a number in the latter part of these Tables but is wrong, in some instances even to thousands: but as I have put the reader in possession of a method by which to examine them, he may do it at his leisure; or he may compare any of the other numbers with those here inserted.

When such errors arising from carelessness, are to be found in a single Table of a Price Book, is there not reason to suppose that in other parts, not examined, they abound equally, and therefore create a doubt as to the degree of dependence to be placed in any one article? There is no man perfect; and when different ideas crowd upon the mind of a writer at the same time, in treating of subjects that have not been before investigated, he may inadvertently insert a wrong word, or a typographical error may escape his notice; but in most cases this will be easily detected, as other parts of the subject will readily ascertain the author's meaning, or otherwise it may be deduced from a palpable contradiction in terms, where only one idea could be meant.

Table III.

Explanation.—The first vertical column contains the contents of the wall in superficial feet, the given row the thickness in bricks and half-bricks, and the other vertical columns the answers.

Use.—What is the quantity of reduced brickwork in a wall containing 5,348 feet superficial and $2\frac{1}{2}$ bricks thick?

Say, $5,348 = 5,000 + 300 + 48$: then we have by the Table,

	R.	Qr.	Ft.	In.
5000 will require	30	2	37	4
300 " "	1	3	24	0
48 " "	0	1	12	0
consequently 5348 " "	32	3	5	4

The same found by the rule thus:

```
         5348
            5
      -------
      3)26740
      -------     R. Qr. Ft. In.
   272)8913 4 (32  3   5  4, the answer, as
       816                         before.
       ----
        753
        544
       ----
    68)209(3
       204
       ----
         5
```

The rule here applied is the same as Rule I. p. 50, vol 1. As the first progression goes on from 1 to 50 inclusive, and two adjacent numbers differing by unity, any number from 50 to 1 may be taken at once.

Example.—In a wall of two bricks thick, containing an area of 47 feet, what is the standard measure?

In the meeting of the 2-brick column and the horizontal row from 47, you have 62 feet 8 inches, the answer required.

In constructing a table, such as this, with different denominations, it will be much more ready to find the whole numbers, as in the last Table, in the least denomination, and afterwards to divide each respective number by as many as will make one of the next denomination; then the quotient is so many of this denomination, and the remainder, if any, so many of the first; and if the quotient exceed the number that makes one of the third denomination, divide it by this number, and the second quotient is so many of the third denomination, and the remainder, if any, so many of the second; and so on, as long as division can be made.

Table IV.

Explanation and Use.—As the prices of bricks and of labour may vary in any ratio in respect of each other, it is convenient to have a price at once agreeable to these variations, which can be easily obtained from this Table. The given price of bricks per thousand is arranged in the first vertical column, the price of mortar and labour in the given horizontal row, and the required price per rod is found, as in the other Tables, in the point or place of intersection of the horizontal row and vertical column, carried from each of the given prices.

Example.—What is the price of a rod of brickwork, when the rate of bricks is £1 18s. per thousand, and the price of mortar and labour £3 10s. per rod?

Carry your eye horizontally from £1 18s. in the given column of bricks, until you come to the vertical column under £3 10s. the given price of labour and mortar; and you will find £12 1s. the price of the rod, as required.

Construction.—Multiply the price of bricks per thousand by $4\frac{1}{2}$, and add the product to the price of labour at the top, and you will have the price per rod, as in the Table. Let us take the above as an example: then (£1 18s.) $\times$ $4\frac{1}{2}$ = £8 11s. the price of bricks in a rod, to the product; add £3 10s. the price of labour and mortar, and you will have £12 1s. as before.

This Table might be otherwise constructed, by giving a Table of the variations of lime and sand, but then it would be much longer. The articles of labour, lime, and sand, are classed together, upon the supposition or probability, that the increase or decrease of either of the two is nearly in the same ratio; but should it prove otherwise, and the disparity be great, a Table must be constructed upon different principles.

Table V.

Explanation and Use.—This Table consists of only two vertical columns; the price per foot is contained in the first and the price per rod in the second column. So that if the price per foot be given, you have the price per rod in the same horizontal line; or the very reverse is sometimes necessary, when the price per rod is given, to know the price per foot.

Example.—What will 3r. 258ft. of reduced brickwork come to, at £2 16s. 8d. per rod? First multiply £2 16s. 8d. by 3; look for £2 16s. 8d. under the column per rod, on the left hand of it, you have $0\frac{1}{2}$d. for the price per foot; therefore multiply 258 feet by $\frac{1}{2}$, that is, divide it by 2, and you will have the number of pence, which divided by 12 will give the shillings. Thus:

```
 £.   s.   d.          Feet.
 2   16    8          2)258
           3          -----
 -----------        12)129
 8   10    0          -----
     10    9            10 9
 -----------
 9    0    9
```

To perform such operations entirely by rule is sometimes very tedious.

Construction.—The quantity of superficial feet in a rod is 272; this being multiplied by the price per foot, gives evidently the price per rod: Suppose $0\frac{3}{4}$d. per foot, what is the price per rod?

```
Thus:            272
multiplied by      3
                 ---
               4)816
                 ---
              12)204 pence per rod.
                 ---
                  17 shillings.
```

Table VI.

Explanation.—The different gauges are contained in the top row, the given areas in the first vertical column, and the answers in the succeeding vertical columns.

Example.—How many tiles are sufficient, at a 7-inch gauge, to cover an area of 5.349 feet?

Here 5349 = 5000 + 300 + 40 + 9.

```
          Now,  5000  will require  32,500
                 300    "     "      1,950
                  40    "     "        260
                   9    "     "         58½
                ----                ------
     therefore  5349    "     "     34,768½
```

Or thus, by calculation:—It is evident that the numbers are as the areas: suppose it is ascertained that 52 plain tiles will cover 8 feet superficial, at a 7-inch gauge, we shall then have, as the area of 8 feet, is to the area of 5,349 feet, so is 8 tiles, the number required for 8 feet, to the number of tiles required, $34{,}768\frac{1}{2}$.

```
Thus 8  :  5349  : :  52
             52
         ------
          10698
         26745
         ------
       8)278148
         ------                [by the Table.
         34768½ the answer, as above found
```

It may be observed in this, as all the foregoing Tables, that any two numbers in any vertical column, are in the same ratio as any other two opposite numbers in any other vertical column; that is, as any number in any vertical column is to any other number in the same column, so is any number opposite the former in any other column to the number opposite the latter in this last column.

The following memoranda, extracted principally from an useful little work entitled the Student's Guide to Measuring and Vaulting Artificers' work, may prove useful.

Size and Weight of Various Articles.

	Length.		Breadth.		Thickness.		Weight.	
	Ft.	In.	Ft.	In.	Ft.	In.	lbs.	oz.
Stock bricks........... each	0	8¾	0	4½	0	2½	5	0
Paving " .... ditto	0	9	0	4½	0	1¾	4	0
Dutch clinkers......... ditto	0	6¼	0	3	0	1½	1	8
12-Inch paving tiles .... ditto	0	11¾	0	11¾	0	1½	13	0
10-Inch " " .... ditto	0	9¾	0	9¾	0	1	8	9
Pan-tiles.............. ditto	1	1½	0	9½	0	0½	5	4
Plain tiles .... ditto	0	10½	0	6½	0	0⅝	2	5
Pan-tile laths, per 10-feet bundle	120	0	0	1½	0	1	4	6
Ditto, per 12-feet bundle ..... (A bundle contains 12 laths.)	144	0	0	1½	0	1	5	0
Plain tile laths, per bundle.... (Thirty bundles of laths make a load.)	500	0	0	1	0	0¼	3	0

A bricklayer's hod measures 1 foot, 4 inches, × 9 inches × 9 inches, and contains 20 bricks.

A single load of sand is 27 cubic feet, or 1 cubic yard, and contains 18 heaped or 21 striked bushels, and 23½ cubic feet equal one ton.

A double load of sand is 54 cubic feet, or 2 cubic yards.

A measure of lime is 27 cubic feet, or 1 cubic yard, and contains from 16 to 18 bushels.

Quantities.

A rod of brickwork measures 16 feet, 6 inches × 16 feet, 6 inches, or 272 feet, 3 inches superficial, 1½ brick, or 13½ inches thick, called the standard thickness, or 306 cubic feet, or 11½ cubic yards; and weighs 13 tons.

A rod of brickwork, laid to a 12-inch gauge, *i. e.* four courses to measure 1 foot in height, requires 4353 stock bricks.

Ditto, laid to 11½-inch gauge, requires 4533 stock bricks.

A foot of reduced brickwork requires 16 bricks.

These calculations are made without allowance for waste, and indeed there is very little, as nearly every part is worked in, and much space is occupied by timbers, flues, &c., for which no deduction is made in measurement; and therefore, in the erection of dwelling houses, containing flues and bond timbers, 4300 stocks is quite sufficient, and this is the usual number allowed for a rod of brickwork.

5370 stocks to the rod, if laid dry; 4900 ditto, in wells and circular cess-pools.

A rod of brickwork, laid four courses to gauge 12 inches, contains 235 feet cube of bricks, and 71 feet cube of mortar, and the average weight is about 15 tons.

A rod of brickwork requires 1½ cube of chalk lime, and 3 loads of sand, or 36 bushels of cement and 36 bushels of sharp sand.

A cubic yard, or load of mortar, requires 9 bushels of lime and one load of sand.

The proportion of mortar or cement, when made up to the materials in their unmixed state, is as two to three.

Facing requires 7 bricks per foot superficial.

Gauged arches, 10 ditto ditto.

Brick-nogging, per yard superficial, requires 30 bricks on edge, or 45 laid flat.

Paving.

Description.		Number required.
Stock bricks, laid flat .	. per yard	36
Ditto, on edge . .	—	52
Paving bricks, laid flat .	—	36
Ditto, on edge . .	—	82
Dutch clinkers, ditto . .	—	140
12-inch paving tiles . .	—	9
10-inch ditto.	—	13

Tiling.

	Gauge—Inches.	Number required.
Pan-tiles per square . . .	12	150
Ditto ditto	11	164
Ditto ditto	10	180

A square of pan-tiling requires 1 bundle of laths, and 1½ hundred of 6d. nails.

Plain tiles, per square . .	4	600
Ditto ditto . . .	3½	700
Ditto ditto . . .	3	800
Ditto ditto . . .	laid flat	210

A square of plain tilling requires one bundle of laths and nails, one peck of tile-pins, and 3 hods of mortar.

The laths are sold in bundles of 3, 4, and 5 feet lengths; a bundle of 3 feet contains 8 score; 4 feet, 6 score; and 5 feet, 5 score. The nails used are fourpenny; and the number required for a bundle of 5 feet and 6 feet laths, are 500 and 600 respectively.

Calculation of Labour.

Digger.—The amount of digging which a man can perform in a day depends so much on the nature of the soil on which he has to operate, that it is almost impossible to fix a Constant for this description of labour. The following data may, however, serve as a slight guide:

In loose ground a man will throw up about 10 cubic yards per day, but in hard or gravelly soil, where hacking is necessary, from 3 to 5 cubic yards, according to the hardness of the ground, will be a fair day's work.

Wheeling is estimated by the run of 20 yards. A gang of 3 men, 2 for filling and 1 for wheeling, will remove about 30 yards per day to this distance; and the labour for removing earth may be calculated according to the distance, allowing 3 men to the first run, and an additional man for every 20 yards of distance. [17½ cubic feet of clay weighs one ton. 18 cubic feet of common earth weighs one ton.]

The following table, though far from complete, contains Constants for all the principal descriptions of bricklayer's work.

Concrete.—Labour in mixing, wheeling, throwing in from a stage, and puddling (when required to be done), including erection of scaffolding, per yard cube . . .335
(The Constant to be multiplied by the rate of wages for a labourer per day.)

Brickwork, per rod 4.941
(To be multiplied by the rate of wages of a bricklayer and labourer per day.)

Extra labour to malm facings 014
(To be multiplied by the rate of wages for a bricklayer per day.)

Paving.

Brick paving, laid flat in sand .	. per yard	.046
on edge in sand . .	—	.075
flat in mortar . . .	—	.056
edge in mortar . . .	—	.084
Paving brick laid flat in sand . .	—	.046
on edge in sand . .	—	.106
laid flat in mortar . .	—	.175
on edge in mortar . .	—	.121
Clinker paving on edge in sand .	—	.132
10 or 12-inch tile paving . . .	—	.010

Tiling.

Pan-tiling, laid dry	per square	.422
pointed outside	—	.685
inside	—	.790
Plain tiling laid to a 4-inch gauge	—	.739
to a $3\frac{1}{2}$-inch gauge	—	.764
to a 3-inch gauge	—	.790

The above Constants all to be multiplied by the rate of wages for a bricklayer and labourer per day.

Masons' Work.

Masons' work is measured in the same manner as bricklayers', so far as the superficial content is concerned.

The joints of the plane surface of an ashlar wall are measured in breath, according to the thickness of the ashlar work, which is generally about six inches; and the two surfaces which are supposed to come in contact, or to be cemented, both of the vertical and horizontal joints, are accounted as only one surface, as in cornices; and are supposed to be equivalent to that of the vertical facing of the wall after being rubbed smooth.

In brick walls, stone strings must correspond to the thickness of the bricks. Strings are generally bevelled, or weathered, upon the upper side, and grooved on the under side: the weathering is denominated *sunk work*, and the grooving, *throating*. Stone sills in common use are about $4\frac{3}{4}$ inches thick, and 8 inches broad; they are weathered at the top, which reduces the front, or vertical face, to about 4 inches, and the horizontal surface at top to about $1\frac{1}{2}$ inch on the inside; so that the part taken away is $6\frac{1}{2}$ inches broad, and three-quarters of an inch deep. Sills of windows, when inserted in the wall, most commonly project about $2\frac{1}{2}$ inches. The horizontal plane part, left on the inside of the top, the vertical part, or face, and the horizontal part on the lower side without the wall, are denominated *plain work*; the sloping part is the *sunk work*. Plain and sunk work are measured by the foot superficial; throating by the foot run; and are thus entered in the measurer's book:

$$\text{adding}\begin{cases}1\frac{1}{2}\\4\\2\frac{1}{2}\end{cases}$$

the sum is 8 inches for the breadth of the plain work in the sill, according to the dimensions stated.

Ft.	In.	
4	0	Plain work.
0	8	
4	0	Sunk work.
0	$6\frac{1}{2}$	
2 { 0	8	Plain to end.
0	$4\frac{1}{2}$	
4	0	Run of throating.

The sawing is not taken into account.

Cornices are measured by girting round the mouldings; that is, round all the vertical and under sides: this is denominated *moulded work*.

Thus, suppose a cornice to project one foot, and to girt two feet, and to be 40 feet in length; then the dimensions are entered as below:

Ft.	
40	Moulded work.
2	
40	Sunk work at top.
1	

To this must be added all the vertical joints.

All cylindrical work is measured in the girt, and the surface is acounted equivalent to plane work taken twice.

Thus, suppose a cylinder girts 4 feet 9 inches, and is in height 12 feet, then the dimensions are written as follow:

Ft.	In.	
12	0	Super plain work.
4	9	Double measure.

Rough stone, or marble, is measured by the foot cube; but for workmanship, the superficies are measured before it is sunk, for plain work; one bed, and one upright joint, are also accounted plain work, as before stated; then to take the plain sunk work, or circular, if any, and the straight moulded work, or circular moulded work, if there be any such. In taking the dimensions, particular care is required to distinguish these different species of work in the progressive state of preparing the stone. Throatings, and all narrow sinkings, are measured by the foot running measure. In taking the dimensions of moulded work, the mouldings must be girt with a string.

The contents of pavements, slabs, and chimney-pieces, are found by superficial measure; as also stones under two inches thick are valued according to the same measure; but those that are solid by the foot cube.

The construction of rubble-walls is not known in London, from the want of stone; but in many countries such erections are very general.

The standard thickness of rubble-wall is 2 feet; the content is first found in feet and inches, then divided by 9, which reduces it to superficial yards; and the yards are again divided by 36, which reduces it to roods, should the superficial content in yards admit of such division: when the wall is above 2 feet, it is reduced to that standard by adding one-eighth, one-fourth, one-half, according as the additional thickness may be 3 or 6 inches, or a foot.

Weight of Stone.

Purbeck stone,	14	cubic feet, weight	one ton.
Portland —	16	ditto	ditto
Bath —	17	ditto	ditto
Yorkshire —	15	ditto	ditto
Granite	$13\frac{1}{2}$	ditto	ditto
Marble	13	ditto	ditto
Purbeck paving	50	feet superficial	ditto
Ditto step 13 by $6\frac{1}{2}$	25	feet run	ditto

Valuation of Labour.

Table of Constants for the different descriptions of mason's work.

N.B.—The factor to be applied is the rate of wages for a mason per day.

Labour.—Squaring and laying new York or Purbeck.

		Days.
Paving, per foot superficial		.021
If in courses, add		.010

Labour on Portland or similar, per foot superficial.

N.B.—Sawing to be taken as half plain work.

Plain work, to bond stones	per foot superficial	.140
to beds and joints	ditto	.181
rubbed face	ditto	.209
ditto circular	ditto	.291
Sunk work, rubbed	ditto	.250
circular	ditto	.313
Moulded work, rubbed	ditto	.292
circular	ditto	.417

	Per foot superficial.	Days.
Circular work to shafts of columns, having the neck moulding, or part of the base, worked in the same stone	ditto	.334
Circular or spherical work to domes or balls	ditto	.500
If rubbed add extra	ditto	.049
Taking up, squaring, and re-laying old paving	ditto	.042
Add, if in courses,	ditto	.015

Labour on statuary or vein marble, including sawing, working, and polishing

	Per foot superficial.	Days.
Plain work	ditto	.875
Circular ditto	ditto	1.250
Sunk ditto	ditto	1.667
Moulded ditto	ditto	2.334
Circular sunk ditto	ditto	2.334
Circular moulded ditto	ditto	3.000
On Old Work.		
Old vein marble chimney re-set	ditto	.125
Ditto square and re-set	ditto	.167
Ditto sanded, grounded, and squared	ditto	.209
Ditto and re-set	ditto	.250
Ditto cleaned and re-set	ditto	.250
Ditto sanded, polished, and re-set	ditto	.350
Ditto sawed, sanded, polished, squared, and re-set	ditto	.626

Carpenters' Work.

Definition.—By carpenters' work is meant the measuring of common centres, groined centres, floors, partitions, centering, bond-timbers, lintels, wall-plates, and roofs.

For the general customs see the article Carpenters' work.

Problem I.—*To measure the centering of a cylindrical vault.*

Rule.—Multiply the length of the vault in feet, by the circumference of the arch, for the breadth; and divide the product by 100, if greater than the same, and the quotient will give the number of squares and feet.

Example I.—How many squares of centering are there in a vault, whose length is 18 feet 6 inches, and circumference 31 feet 6 inches?

By duodecimals.		By vulgar fractions.
Feet.	In.	
31	6	31½
18	6	18½
		15½+¼
248	0	9
310	0	248
9	0	31
15	6	
0	3	5,82,¾
582	9	

582 9 or 5 squares, 82 feet, 9 inches.

By decimals.

```
 31.5
 18.5
 ----
 1575
2520
315
 -------
5,82.75
```

Problem II.—*To measure naked floors, whether for materials, or workmanship.*

Rule I.—If there be any number of pieces of timber of the same scantlings and length, and the solidity of one of them; and that solidity multiplied by the number of pieces will give the solidity of the whole.

Rule 2.—If the pieces be of the same scantling, but of different lengths, add all the different lengths together, multiply the sum by the area of the end of one of the pieces, and the product will give the solidity of the whole.

Rule 3.—If the pieces be of different scantlings, but of the same length, find the areas of the ends of all the pieces, and the sum of these areas being multiplied by the common length, will give the solidity of the whole number.

Rule 4.—If some of the pieces be of one scantling, equal among themselves, and others of the pieces of another scantling, equal among themselves, but all of the same length; multiply the area of the ends of each, by the number of such as are of the same seantling, add the products together, and their sum, multiplied by the common length, will give the solidity.

Rule 5.—If the lengths vary, as well as the scantlings, find the solidity of each piece separately, and the sum will give the solidity of the whole.

Note.—Wherever a tenon is made, the length of the piece must be taken from the ends of the tenons, and not from the shoulders.

If the floors be fixed in the building, the distance the timber goes into the wall, which is about one-third of the thickness of the wall, must be added to the length of the respective pieces that are clear of the walls.

The best method of finding the solidity of a joist, where the length is given in feet, inches, &c., and the dimension of the section in inches, is to multiply the inches together, and throw the twelves out of the product; also throw the twelves out of the length, and multiply these together.

Example.—Suppose a joist 15 feet long, 3 inches by 9; the product is 27, which divided by 12 gives 2 feet 3 inches; also 15 divided by 12 gives 1 foot 3 inches; then

```
1 3
2 3
---
2 6
  3 9
-----
2 9 9
```

Suppose the girder, to be 1 foot broad, 1 foot 2 inches deep, and 20 feet long; there are eight bridging-joists, whose scantlings are 3 inches by 6½ inches, and 20 feet long; that is, of the same length with the girder; there are also eight binding-joists, whose lengths are 9 feet, and their scantlings 8½ inehes by 4 inches; the ceiling-joists are 24 in number, each 6 feet long, 4 inches by 2½ inches; required the solidity of the whole, either for materials or workmanship.

```
    1 2
    1
    ---
    1 2 area of the end of the girder.
      6 6
      3
      -----
    1 7 6 area of the end of a bridging-joist.
    8       number of bridging-joists.
    -----
    1 1 0 0
add 1 2       the area of the end of the girder.
    ---                          [bridging-joists.
    2 3 sum of the areas of the ends of the girder and
    20  common length.
    ---
    45  feet, the solidity of the girder and bridging-joists.
```

8 6 depth.
4 thick.

2 10 0
9

2 1 6 solidity of a binding-joist.
8

17 feet, solidity of all the binding-joists.
2 6
4

10 0 area of the end of a ceiling-joist.
6

5 inches, solidity of a ceiling-joist.
24 number of ceiling-joists.

10 feet, solidity of the ceiling-joists.
17
45

72 feet, sum of all the solidities in the whole floor.

Problem III.—*To measure roofing, or partitions, either for materials or workmanship.*

All timbers in a roof, or partition, are measured in the same manner as floors, excepting king-posts and queen-posts, &c., when there is a necessity for cutting out parallel pieces of wood from their sides, in order that the ends of such braces as come against them may have, what is called by workmen, a *square butment.* To measure the workmanship of such pieces, or posts, take their breadth and depth, at the widest part, multiply them by the length, and the product will give the solidity for workmanship. To find the quantity of materials, if the pieces sawn out are 2½ inches thick, or more, they are esteemed pieces of timber fit for use; when more than two feet long, their lengths should not be esteemed so long by 5 or 6 inches, because the saw cannot enter the wood with much less waste, and consequently the pieces must be deducted from the whole solidity, and the remainder will give the quantity of materials; but if the pieces cut out be less than 2½ inches, the whole post must be measured as solid for the materials, because pieces cut out are of little use.

Example.—Let the tie-beam be 36 feet long, 9 inches wide, by 1 foot 2 inches deep; the king-post, is 11 feet 6 inches high, 1 foot broad at the bottom, by 5 inches thick: out of this are sawn two pieces from the sides, 3 inches thick and 7 feet long; the braces, are 7 feet 6 inches long, 5 inches by 5 inches; the rafters are 19 feet long, 10 inches by 5 inches each; the struts are 3 feet 6 inches long, and 4 inches by 5 inches; required the measurement for workmanship, and also for materials.

1 2
9

10 6
3

31 6 solidity of the tie-beam.
5
5

2 1
15 lengths of the two braces added together.

2 7 3

5
10

4 2
3 2

8 4
12 6

13 2 4 solidity of both rafters.
1
5

5
11 6

4 9 6 solidity of the king-post, as if solid.

3
5

1 3
7

8 9 solidity of the two pieces cut from the sides.

4
5

1 8
7

11 8 solidity of the struts.

Consequently,

Feet.	In.	″	
31	6	0	tie-beam.
2	7	3	braces.
18	2	4	rafters.
4	9	6	king-post.
	11	8	solidity of the struts.
53	0	9	solidity of the roof for workmanship.
	8	9	
52	4	0	solidity for materials.

Valuation of Carpenters' and Joiners' Work.

Memoranda.

50 cubic feet of timber equal one load.
100 feet superficial, equal one square.
120 deals are called one hundred.
A reduced deal is 1½ in. thick, 11 inches wide, and 12 ft. long.
120 12 feet 3 inch deals, equal 5¾ loads of timber.
400 feet superficial of 1½ in. plank or deals, equal one load.
Planks are 11 inches wide, deals 9 inches; and battens 7 inches.

A square of flooring requires—	Number of 12 feet boards.
Laid rough	12¼
Ditto edges shot	12½
Wrought and laid folding	13
— straight joint	13½
— — and ploughed and tongued	14
	Number of 12 feet battens.
One square of wrought folding floors requires	17
Ditto straight joint	18

Weight of Timber.

39 cubic feet of	oak	equal	1 ton.
65 —	fir	—	do.
66 —	deals	—	do.
60 —	elm	—	do.
51 —	beech	—	do.
45 —	ash	—	do.
35 —	mahogany	—	do.

JOINERS' WORK.

In boarded flooring, the dimensions must be taken to the very extreme parts, and from thence the squares are to be computed; out of which deductions are to be made for staircases, chimneys, &c.

Weather-boarding is done by the yard square, and sometimes by the square, containing 100 superficial feet.

Boarded partitions are measured by the square; out of which must be deducted the doors and windows, except they are agreed to be included.

Windows are generally made and valued by the foot superficial, and sometimes by the window. When they are measured, the dimensions must be taken in feet and inches, from the under side of the sill to the upper side of the top rail, for the height; and for the breadth, from outside to outside of the jambs; the product of these is the superficial content. For farther particulars, see the article JOINERY.

Example.—How many feet does a piece of dwarf wainscoting contain, that is 18 feet 7 inches long, and 5 feet 3 inches high?

By cross multiplication.	By decimals.
18 6	18.5
5 3	5.25
1 6	925
54	370
30	925
12) 85	97.125
7 1	
90	
97 1 6	

PAINTERS' WORK.

This work is measured by the yard square, and the dimensions are taken in feet, inches, and tenths.

In painters' work, every part that is coloured is measured; consequently the dimensions must be taken with a line girt over the mouldings. Ornamental work must be paid double measure; and if carved, at per value, according to the time.

Iron or wood railings, balusters, &c., to be measured on both sides as solid work, at per yard superficial. The following contracts may be used for common work—

First coat, including stopping	.027
Second, and following coats	.019

PLASTERERS' WORK.

This is done by the yard square, and the dimensions are taken in feet and inches.

When a room consists of more than four quoins, the additional corners must be allowed at per foot run.

In measuring ceilings with ribs, the superficies must first be taken for the plain work; then an allowance must be made for each mitre, and the ribs must be valued at so much per foot run, according to the girt, or by the foot superficial, allowing moulded work.

In measuring common work, the principal things to be observed are as follow:

1. To make deductions for chimneys, windows, and doors.
2. To make deductions for rendering upon brickwork, for doors and windows.
3. If the workman find materials for rendering between quarters, one-fifth must be deducted for quarters; but if workmanship only is found, the whole must be measured as whole work, because the workman could have performed the whole much sooner, if there had been no quarters.
4. All mouldings in plaster work are done by the foot superficial, as joiners do, by girting over the mouldings with a line.

When rooms have cornices, measure the ceiling or walls, including half the width or height of the cornice respectively, except when the cornices are bracketed, and then only measure up to them. In measuring the length of cornices, take the size of the room, taking one projection in and one out, and girt the cornices. Enriched friezes, &c., must be measured first as plain work, and the enrichments taken separately afterwards.

Valuation of Plasterers' Work.—Calculation of Materials.

1 hundred of lime = 25 striked bushels (old measure).

	Materials.	Labour.
100 yards of render set require	$1\frac{1}{2}$ hod. of lime. 1 double load of sand. 4 bushels of hair.	Plasterer, Labourer and Boy, 3 days each.
130 yards of lath plaster, and set require	1 load of laths. 10,000 nails. $2\frac{1}{2}$ hds. of lime. $1\frac{1}{2}$ dble. lds. of sand. 7 bushels of hair.	Plasterer, Labourer, and Boy, 6 days each.

Lathing.

1 bundle of laths and 384 nails will cover 5 yards.

Render only.

$187\frac{1}{2}$ yards require . . . . . $1\frac{1}{2}$ hod. of lime. 2 double loads of sand. 5 bushels of hair.

Floating requires more labour, but not more than half the quantity of stuff as rendering.

Setting only.

375 yards require . . . . $1\frac{1}{2}$ hod. of lime. 5 bushels of hair.

20 per cent. is always allowed on the prime cost of the materials.

Calculation of Labour.

The decimal is to be multiplied by the rate of wages for plasterer, labourer, and boy, per day.

	Days.
Rough render	.019
Floating render	.021
Setting	.016
Lathing	.019
If circular work, add on the lathing, and also on each coat of plastering	.008
If to groins, add as before	.001

GLAZIERS' WORK.

Glaziers' work is measured by the foot superficial, and the dimensions are taken in feet, tenths, hundredths, &c. For this purpose, their rules are generally divided into decimal parts, and their dimensions squared according to decimals.

Circular, or oval windows, are measured as if they were rectangular; because in cutting the squares of glass there is a very great waste, and more time is expended than if the windows had been of a rectangular form.

Example.—How many feet superficial of glazing does a window contain, that is 7.25 high and 3.75 wide?

```
   7.25
   3.75
   ----
   3625
  5075
 2175
 -------
 27.1875 feet, the answer.
```

Plumbers' Work.

This is generally done by the pound, or hundredweight.

Sheet lead, used in roofing, for guttering and valleys, is in weight from 7lb. to 12lb. per foot; and for ridges from 6lb. to 8lb.

The following table will show the weight of a foot, according to several thicknesses.

The thickness is set in tenths and hundredths of an inch, in the first vertical column; and the weight opposite, in the same horizontal line, in the second vertical column on the right hand: the integers show the number of pounds avoirdupois, and the decimals the number of thousandth parts above the integer: so that the weight of a square foot of $\frac{1}{10}$ or .10 of an inch thick is 5lb. and 899 thousandth-parts.

Thickness.	lbs. to a sq. foot.
.10	5.899
.11	6.489
$\frac{1}{9}$ = .11 &c.	6.554
.12	7.078
$\frac{1}{8}$ = .125	7.373
.13	7.668
.14	8.258
$\frac{1}{7}$ = .14 &c.	8.427
.15	8.848
.16	9.438
$\frac{1}{6}$ = .16 &c.	9.831
.17	10.028
.18	10.618
.19	11.207
$\frac{1}{5}$ = .20	11.797
.21	12.387

Example.—What is the weight of a sheet of lead, 25 feet 6 inches long, and 3 feet 3 inches broad; at 8½lb. to the square foot?

```
   3.25
   25.5
   ----
   1625
  1625
  650
  ------
  82.875
     8.5
  ------
  414375
 663000
 -----------
 704.4375lbs., as required.
```

Lead-headed nails, wall-hooks, and hold-fasts, are charged at per piece; clout-nails by the hundred: all kinds of pipes are charged at per foot run according to size of bore. Washers, plugs, valves, &c., at so much each. Joints are charged separately.

Paviors' Work.

Paviors' work is done by the square yard.

Example.—Suppose a pathway to be 45 feet 6 inches long, and the breadth 12 feet 3 inches; how many square yards does it contain?

```
     45.5 length.
    12.25 breadth.
    -----
     2275
     910
    910
   455
   -------
9) 557.375
   -------
   61.930 the number of yards required.
```

The decimals will be reduced to feet by multiplying them by 9; thus,

```
  .930
     9
 -----
 8.370 feet.
```

It is not necessary to go any farther, as the value of the next denomination is not worth the trouble.

Slaters' Work.

If the roof be equally hipped on all sides with a flat at top, and the plan of the building be rectangular, add the length and breadth of two adjoining sides at the eaves, and the length and breadth of two adjoining sides of the flat together; multiply the sum by the breadth of the slope, and the product will give the area of the space that is covered.

Add the number of square feet produced by multiplying the girt of the roof by the length of a slate at the eaves, to the area, for the trouble of putting on the double row of slates; also add the number of square feet produced by multiplying the length of the hips by one foot in breadth, for the trouble of cutting the slates where they meet, to the said area; and the sum will be the whole contents, so as to make a compensation for the trouble and waste of materials.

Example.—Suppose a house 40 feet 6 inches in width and 60 feet 3 inches in length; the breadth of the slope 15 feet 9 inches, the breadth of the flat 12 feet, and the length 31 feet 9 inches.

```
     Ft.  In.
     40   6
     60   3
     12   0
     31   9
    -------
    144   6
     15   9
    ----------
          4   6
   1296
     90
    -----
12) 1390
    ---------
    115  10
    720
    144
    -------------
   2275  10   6 the area.
```

To this area add the allowances for workmanship and waste.

If there be no flat, add the two adjoining sides and twice the length of the ridge, for the length; multiply the sum by the breadth of the slope, for the area of the space covered; then add the allowances as before.

Mensuration of Timber.

The following rules are from Dr. Hutton's Mensuration.

"Problem I.—*To find the area or superficial feet in a board or plank.*

"Rule.—Multiply the length by the mean breadth.

"*Note.*—When the board is tapering, add the breadth at the two ends together, and take half the sum for the mean breadth.

By the sliding rule.—Set 12 on B to the breadth in inches on B; then against the length in feet on B, is the content on A, in feet and fractional parts.

"*Example* 1.—What is the value of a plank, whose length is 12 feet 6 inches, and mean breadth 11 inches; at 1½*d.* per square foot?

	By decimals.		By duodecimals.
	12.5		12 6
	11		11
12	137.5	1½*d.* is ⅛	11 5 6
1½*d.* is ⅛	11.46		1*s.* 4½*d.*
	1*s.* 5*d.* ans.	5 in. is	0 ½
			1*s.* 5d.

"*By the sliding rule.*

"As 12B : 11A : : 12½B : 11½A.

"That is, as 12 on B is to 11 on A, so is 12½ on B to 11½ on A.

"*Example* 2.—Required the content of a board, whose length is 11 feet 2 inches, and breadth 1 foot 10 inches.—Answer, 20 feet, 5 inches, and 8 seconds.

"*Example* 3.—What is the value of a plank, which is 12 feet 9 inches long, and 1 foot 3 inches broad, at 2½*d.* a foot—Answer, 3*s.* 3¾*d.*

"*Example* 4.—Required the value of five oaken planks, at 3*d.* per foot, each of them being 17½ feet long; and their several breadths as follow, namely, two of 13½ inches in the middle; one of 14¼ inches in the middle, and the two remaining ones, each 18 inches at the broader end, and 11¼ at the narrower.—Answer, £1 5*s.* 8¼*d.*

"Problem II.—*To find the solid content of squared or four-sided timber.*

Rule.—Multiply the mean breadth by the mean thickness, and the product again by the length, and the last product will give the content.

"*By the sliding rule.*

	C		D		D		C
"As	length	:	12 or 10	: :	quarter girt	:	solidity.

"That is, as the length in feet on C, is to 12 on D when the quarter girt is in inches, or to 10 on D when it is in tenths of feet; so is the quarter girt on D, to the content on C.

"*Note* 1.—If the tree taper regularly from the one end to the other, either take the mean breadth and thickness in the middle, or take the dimensions at the two ends, and then half their sum for the mean dimensions.

"2. If the piece do not taper regularly, but is unequally thick in some parts, and small in others, take several different dimensions, add them all together, and divide their sum by the number of them, for the mean dimensions.

"3. The quarter-girt is a geometrical mean proportional between the mean breadth and thickness; that is, the square root of their product. Sometimes unskilful measurers use the arithmetical mean instead of it, that is, half their sum; but this is always attended with error, and the more so as the breadth and depth differ the more from each other.

"*Example* 1.—The length of a piece of timber is 18 feet 6 inches, the breadth at the greater and less end 1 foot 6 inches and 1 foot 3 inches, and the thickness at the greater and less end 1 foot 3 inches and 1 foot: required the solid content.

Decimals.		Duodecimals.
1.5		1 6
1.25		1 3
2) 2.75		2) 2 9
1.375	mean breadth	1 4 6
1.25		1 3
1.0		1 0
2) 2.25		2) 2 3
1.125	mean depth	1 1 6
1.375	mean breadth	1 4 6
5625		1 1 6
7875		4 6
3375		6 9
1125		
1.546875		1 6 6 9
18.5	length	18 6
7734375		27 10 1 6
12375000		9 3 4
1546875		
28.6171875	content	28 7 4 10

"*By the sliding rule.*

	B		A		B		A
"As	1	:	13½	: :	16½	:	223, the mean square.
	C		D		C		D
"As	1	:	1	: :	223	:	14.9, quarter-girt.
	C		D		D		C
"As	18½	:	12	: :	14.9	:	28.6, the content.

"*Example* 2.—What is the content of the piece of timber, whose length is 24½ feet, and the mean breadth and thickness each 1.04 feet?—Answer, 26½ feet.

"*Example* 3.—Required the content of a piece of timber, whose length is 20.38 feet, and its ends unequal squares, the side of the greater being 19½ inches, and the side of the less 9¾ inches.—Answer, 29.7562 feet.

"*Example* 4.—Required the content of a piece of timber, whose length is 27.36 feet; at the greater end the breadth is 1.78, and thickness 1.23; and at the less end the breadth is 1.04, and thickness 0.91?—Answer, 41.278 feet.

"Problem III.—*To find the solidity of round or unsquared timber.*

"Rule 1, or Common Rule.—Multiply the square of the quarter-girt, or of one-fourth of the mean circumference, by the length, for the content.

"*By the sliding rule.*—As the length upon C : 12 or 10 upon D : : quarter girt, in 12ths or 10ths, on D : content on C.

"*Note* 1.—When the tree is tapering, take the mean dimensions, as in the former Problems, either by girting it in the middle for the mean girt, or at the two ends, and take half the sum of the two. But when the tree is very irregular divide it into several lengths, and find the content of each part separately.

"2. This rule, which is commonly used, gives the answer about one-fourth less than the true quantity in the tree, or nearly what the quantity would be after the tree is hewed square in the usual way; so that it seems intended to make an allowance for the squaring of the tree. When the true quantity is desired, use the second rule given below.

"*Example* 1.—A piece of round timber being 9 feet 6 inches long, and its mean quarter-girt 42 inches; what is the content?

Decimals.		Duodecimals.
3.5	quarter girt	3 6
3.5		3 6
175		10 6
105		1 9
12.25		12 3
9.5	length	9 6
6125		110 3
11025		6 1 6
116.375	content	116 4 6

"*By the sliding rule.*

	C		D		D		C
As	9.5	:	10	: :	35	:	116⅓
Or	9.5	:	12	: :	42	:	116⅓

"*Example* 2.—The length of a tree is 24 feet, its girt at the thicker end 14 feet, and at the smaller end 2 feet; required the content.—Answer 96 feet.

"*Example* 3.—What is the content of a tree, whose mean girt is 3.15 feet, and length 14 feet 6 inches?—Answer, 8.9922 feet.

"*Example* 4.—Required the content of a tree, whose length is 17¼ feet, and which girts in five different places as follows, namely, in the first place 9.43 feet, in the second 7.92, in the third 6.15, in the fourth 4.74, and in the fifth 3.16.—Answer, 42,5195.

"Rule 2.—Multiply the square of one-fifth of the mean girt by double the length, and the product will be the content, very near the truth.

"*By the sliding rule.*—As the double length on C : 12 or 10 on D : : ⅕ of the girt, in 12ths or 10ths, on D : content on C.

"*Example* 1.—What is the content of a tree, its length being 9 feet 6 inches, and its mean girt 14 feet?

Decimals.		Duodecimals.
2.8	⅕ of girt	2 9 7
2.8		2 9 7
224		5 7 2
56		2 1 3
7.84		1 8
19		
7056		7 10 1
784		19
148.96	content	148 11 7

"*By the sliding rule.*

	C		D		D		C
As	19	:	10	: :	28	:	149.
Or	19	:	12	: :	$33\frac{6}{16}$	:	149.

"*Example* 2.—Required the content of a tree, which is 24 feet long, and mean girt 8 feet.—Answer, 122.88 feet.

"*Example* 3.—The length of a tree is 14½ feet, and mean girt 3.15 feet; what is the content?—Answer, 11.51 feet.

"*Example* 4.—The length of a tree is 17¼ feet, and its mean girt 6.28; what is the content?—Answer, 54.4065 feet.

"*Note* 1.—That part of a tree, or of the branches, which is less than 2 feet in circumference, or 6 inches quarter-girt, is cut off; not being accounted timber.

"2.—Fifty cubic feet of timber make a load; and therefore, to reduce feet to loads, divide them by 50."

Example.—How many loads of timber are there in 248 feet?

5,0) 24,8

4 48

So that this quantity contains four loads and 48 feet.

It is customary, however, to make a difference between square and round timber, in many places. The load of round timber containing 50 cubic feet, while that of square timber contains only 40. This allowance is reasonable, on account of the waste.

"A Table,

"*For readily finding the Content of Trees, according to the common Method of Measuring Timber.*

"Rule.—Seek the quarter-girt in the first column towards the left-hand, and take out the number opposite. Multiply that number by the length of the tree in feet, &c., and the product will be the content in solid feet, &c.

In.	Ft. In. " ''' ''''	In.	Ft. In. " ''' ''''	In.	Ft. In. " ''' ''''	In.	Ft. In. " ''' ''''	In.	Ft. In. " ''' ''''	In.	Ft. In. " ''' ''''
6	0 3 0 0 0	10½	0 9 2 3 0	15	1 6 9 0 0	19½	2 7 8 3 0	24	4 0 0 0 0	28½	5 7 8 3 0
¼	0 3 3 0 9	¾	0 9 7 6 9	¼	1 7 4 6 9	¾	2 8 6 0 9	¼	4 1 0 0 9	¾	5 8 10 6 9
½	0 3 6 3 0	11	0 10 1 0 0	½	1 8 0 3 0	20	2 9 4 0 0	½	4 2 0 3 0	29	5 10 1 0 0
¾	0 3 9 6 9	¼	0 10 6 6 9	¾	1 8 8 0 0	¼	2 10 2 0 9	¾	4 3 0 6 9	¼	5 11 3 6 9
7	0 4 1 0 0	½	0 11 0 3 0	16	1 9 4 0 0	½	2 11 0 3 0	25	4 4 1 0 0	½	6 0 6 3 0
¼	0 4 4 6 9	¾	0 11 6 0 9	¼	1 10 0 0 9	¾	2 11 10 6 9	¼	4 5 1 6 9	¾	6 1 9 0 9
½	0 4 8 3 0	12	1 0 0 0 0	½	1 10 8 3 0	21	3 0 9 0 0	½	4 6 2 3 0	30	6 3 0 0 0
¾	0 5 0 0 9	¼	1 0 6 0 9	¾	1 11 4 6 9	¼	3 1 7 6 9	¾	4 7 3 0 9	¼	6 4 3 0 9
8	0 5 4 0 0	½	1 1 0 3 0	17	2 0 1 0 0	½	3 2 6 3 0	26	4 8 4 0 0	½	6 5 6 3 0
¼	0 5 8 0 9	¾	1 1 6 6 9	¼	2 0 9 6 9	¾	3 3 5 0 9	¼	4 9 5 0 9	¾	6 6 9 6 9
½	0 6 0 3 0	13	1 2 1 0 0	½	2 1 6 3 0	22	3 4 4 0 0	½	4 10 6 3 0	31	6 8 1 0 0
¾	0 0 4 6 9	¼	1 2 7 6 9	¾	2 2 3 0 9	¼	3 5 3 0 9	¾	4 11 7 6 9	¼	6 9 4 6 9
9	0 6 9 0 0	½	1 3 2 3 0	18	2 3 0 0 0	½	3 6 2 3 0	27	5 0 9 0 0	½	6 10 8 3 0
¼	0 7 1 6 9	¾	1 3 9 0 9	¼	2 3 9 0 9	¾	3 7 1 6 9	¼	5 1 10 6 9	¾	7 0 0 0 9
½	0 7 6 3 0	14	1 4 4 0 0	½	2 4 6 3 0	23	3 8 1 0 0	½	5 3 0 3 0	32	7 1 4 0 0
¾	0 7 11 0 9	¼	1 4 11 0 9	¾	2 5 3 6 9	¼	3 9 0 6 9	¾	5 4 2 0 9	¼	7 2 8 0 9
10	0 8 4 0 0	½	1 5 6 3 0	19	2 6 1 0 0	½	3 10 0 3 0	28	5 5 4 0 0	½	7 4 0 3 0
¼	0 8 9 0 9	¾	1 6 1 6 9	¼	2 6 10 6 9	¾	3 11 0 0 9	¼	5 6 6 0 0	¾	7 5 4 6 9

Scholium.—In measuring squared timber, unskilful measurers usually take one-fourth of the circumference, or girt, for the side of a mean square; which quarter girt therefore multiplied by itself, and the product multiplied by the length, they account the solidity, or content: when the breadth and thickness are nearly equal, this method will give the solidity pretty near the truth; but if the breadth and thickness differ considerably, the error will be so great, that it ought by no means to be neglected.

"Thus, suppose we take a balk, 24 feet long, and a foot square throughout; and consequently its solidity 24 cubic feet: if this balk be slit exactly in two, from end to end, making each piece 6 inches broad, and 12 inches thick, the true solidity of each will be 12 feet; but, by the quarter-girt method, they would amount to much more; for the false quarter girt, being equal to half the sum of the breadth and thickness, in this case will be 9 inches, the square of which is 81, which being divided by 144, and the quotient multiplied by 24. the length, we obtain $13\frac{1}{2}$ feet for the solidity of each part; and consequently the two solidities together make 27 feet, instead of 24.

"Again, suppose the balk to be so cut, that the breadth of one piece may be 4 inches, and that of the other 8 inches. Here the true content of the less piece will be 8 feet, and that of the greater 16 feet. But, proceeding by the other method, the quarter-girt of the less piece will be 8, whose square, 64, multiplied by 24, and the product divided by 144, gives $10\frac{2}{3}$ feet instead of 8. And by the same method, the content of the greater piece will be $16\frac{2}{3}$ feet, instead of 16. And the sum of both is $27\frac{1}{3}$ feet, instead of 24 feet.

"Farther, if the less piece be cut only 2 inches broad, and the greater 10 inches; the true content of the less piece would be 4 feet, and that of the greater 20. But, by the other method, the quarter-girt of the less piece would be 7 inches, whose square, 49, being divided by 6, gives $8\frac{1}{6}$ feet, instead of 4, for the content. And, by the same method, the content of the greater piece would be $20\frac{1}{6}$, instead of 20 feet. So that their sum would be $28\frac{1}{3}$, instead of 24 feet.

"Hence it is evident, that the greater the proportion between the breadth and depth, the greater will the error be, by using the false method; that the sum of the two parts, by the same method, is greater, as the difference of the same two parts is greater, and consequently the sum is least when the two parts are equal to each other, or when the balk is cut equally in two; and lastly, that when the sides of a balk differ not above an inch or two from each other, the quarter-girt method may then be used, without inducing an error that will be of any material consequence.

"Problem IV.—*To find where a piece of round tapering timber must be cut, so that the two parts, measured separately, according to the common method of measuring, shall produce a greater solidity than when cut in any other part, and greater than the whole.*

"Rule.—Cut it through exactly in the middle, or at half of the length, and the two parts will measure to the most possible, by the common method.

"*Example.*—Supposing a tree to girt 14 feet at the greater end, 2 feet at the less, and consequently 8 feet in the middle; and that the length is 32 feet.

"Then, by the common method, the whole tree measures to only 128 feet; but when cut through at the middle, the greater part measures 121, and the less part to 25 feet; whose sum is 146 feet; which exceeds the whole by 18 feet, and is the most that it can be made to measure to by cutting it into two parts.

"Demonstration.—Put G = the greatest girt, g = the least, and x = the girt at the section; also L = the whole length, and z = the length to be cut off the less end.

"Then, by similar figures, $L : z :: G - g : x - g$. Hence $x = \frac{Gz - gz}{L} + g$. But $(g + x)^2 . z + (G + x)^2 . (L - z)$ = a maximum; whose fluxion being put equal to nothing, and the value of x substituted instead of it, there results $z = \frac{1}{2} L$. Q. E. D.

"Corollary.—By thus bisecting the length of a tree, and then each of the parts, and so on, continually bisecting the lengths of the several parts, the measure of the whole will be continually increased.

"Problem V.—*To find where a tree should be cut, so that the part next the greater end may measure to the most possible.*

"Rule.—From the greater girt take 3 times the less; then, as the difference of the girts is to the remainder, so is one-third of the whole length, to the length from the less end to be cut off.

"Or, cut it where the girt is one-third of the greatest girt.

"*Note.*—If the greatest girt do not exceed three times the least, the tree cannot be cut as is required by this problem. For, when the least girt is exactly equal to one-third of the greater, the tree already measures to the greatest possible; that is, none can be cut off, nor indeed added to it, continuing the same taper, that the remainder or sum may measure to so much as the whole: and when the least girt exceeds one third of the greater, the result by the rule shows how much in length must be added, that the result may measure to the most possible.

"*Example.*—Taking here the same example as before, we shall have, as $12 : 8 :: \frac{3}{32} : 7\frac{1}{9}$ = the length to be cut off; and consequently the length of the remaining part is $24\frac{8}{9}$; also $\frac{14}{3} = 4\frac{2}{3}$ is the girt of the section. Hence the content of the remaining part is $135\frac{41}{81}$ feet; whereas the whole tree, by the same method, measures only to 128 feet.

"Demonstration.—Using the same notation as in the last demonstration; we have here also $x = \frac{Gz - gz}{L} + g$, and $(G + x)^2 . (L - x)$ = a maximum; which, treated as before, gives $z = \frac{G - 3g}{G - g} \times \frac{1}{3} L$. And $x = \frac{G - g}{L} z + g \frac{1}{3} G$, by substituting the above value of z. Q. E. D.

"Problem VI.—*To cut a tree so as that the part next the greater end may measure, by the common method, to exactly the same quantity as the whole measures to.*

Rule.—Call the sum of the girts of the two ends s, and their difference d, then multiply by the sum of d and $4s$, thus:

$$d \times (d + 4s).$$

From the root of the product take the difference between d and $2s$, thus:

$$\sqrt{(d^2 + 4ds)} - 2s + d.$$

Then, As twice d—is to the remainder,
So is the whole length—to the length to be cut off;

Thus calling the whole length L, and the part to be cut off l, we have:

$$2d : \sqrt{(d^2 + 4ds)} - 2s + d :: L : l = \frac{L}{2d}$$
$$\times (\sqrt{(d^2 + 4ds)} - 2s + d).$$

Example.—Using still the same numbers as in the preceding examples, we have, $s = 16$, $d = 12$, and $L = 32$.

$$l = \frac{L}{2d} \times (\sqrt{(d^2 + 4ds)} - 2s + d) = \frac{32}{2 \times 12} \times$$
$$(\sqrt{(12^2 + 4 \times 12 \times 16)} - 2 \times 16 + 12) = \frac{4}{3} \times$$
$$(\sqrt{(144 + 768)} - 20)\frac{4}{3} \times (\sqrt{(912)} - 20) = \frac{4}{3} \times$$
$$(30.1993377 - 20) = \frac{4}{3} \times 10.199337 = 13.5991198$$ the length to be cut off.

Therefore the length of the remaining part is 32 — 13.5991168 = 18.4008832.

And if s be taken from the root, viz. $\sqrt{(d^2 + 4ds)}$ half the remainder will be the girt of the section. Therefore, according to the numbers given, the girt of the section $\frac{\sqrt{(d^2 + 4ds)} - s}{2} = \frac{30.1993377 - 16}{2} = 7.0996688.$

Hence the girt in the middle of the greater part is $\frac{14 + 7.099669}{2} = 10.549834$, whose fourth part is 2.637458;

and consequently the content of the same part is $2.637458^2 \times 18.40083 = 128$, the very same as the whole tree measures to, notwithstanding above one-third part is cut off the true length.

"*Note.*—The principles of these last three Problems are also applicable to the new, or second rule, in page 361, and indeed to any other approximate rule, or such as is not founded on the rule for the frustum of a cone.

"DEMONSTRATION.—Using still the same notation, we shall have $s^2 L = (L - 2) \times (G + x)^2$; hence, instead of x, substituting its value $\frac{dz}{L} + g$, we obtain $z = \frac{L}{2d} \times (\sqrt{(4s + d).d}) - (2s + d)$.

"And hence $x = \frac{1}{2}(\sqrt{(4s + d).d}) - \frac{1}{2}s$. Q. E. D."

Rules have already been given for measuring the areas of circular segments, which may at least be depended upon to three places of figures, and which we have thought sufficiently correct for most practical purposes; but where greater accuracy is required, the following Table will carry the approximation to five or six figures.

The construction which comes after the Table depends upon the following series for the segment of a circle.

The area of the segment is $A + \frac{Av}{5V} - \frac{1Bv}{7V} + \frac{3Cv}{9V} - \frac{5Dv}{11V} + \frac{7Ev}{13V}$, &c. where $A = \frac{4v}{3}\sqrt{vV}$, B, the second, C the third, &c. *See* also Rules 3 and 4, Theorem XI., page 171, which are the same in principle as this.

A TABLE

Of the Areas of the Segments of a Circle, whose diameter is Unity, and supposed to be divided into 1000 *equal Parts.*

Height.	Area Seg.	Height.	Area Seg.	Height.	Area Seg.	Height.	Area Seg.
.001	.000042	.075	.026761	.149	.073161	.223	.130605
.002	.000119	.076	.027289	.150	.073874	.224	.131438
.003	.000219	.077	.027821	.151	.074587	.225	.132272
.004	.000337	.078	.028356	.152	.075306	.226	.133108
.005	.000470	.079	.028894	.153	.076026	.227	.133945
.006	.000618	.080	.029435	.154	.076740	.228	.134784
.007	.000779	.081	.029979	.155	.077469	.229	.135624
.008	.000951	.082	.030526	.156	.078194	.230	.136465
.009	.001135	.083	.031076	157	.078921	.231	.137307
.010	.001329	.084	.031629	.158	.079649	.232	.138150
.011	.001533	.085	.031186	.159	.080380	.233	.138995
.012	.001746	.086	.032745	.160	.081112	.234	.139841
.013	.001968	.087	.033307	.161	.081846	.235	.140688
.014	.092199	.088	.033872	.162	.082582	.236	.141537
.015	.002438	.089	.034441	.163	.083320	.237	.142387
.016	.002685	.090	.035011	.164	.084059	.238	.143238
.017	.002940	.091	.035585	.165	.084801	.239	.144091
.018	.003202	.092	.036162	.166	.085544	.240	.144944
.019	.003471	.093	.036741	.167	.086289	.241	.145799
.020	.003748	.094	.037323	168	.087036	.242	.146655
.021	.004031	.095	.037909	.169	.087785	.243	.147512
.022	.004322	.096	.038497	.170	.088535	.244	.148371
.023	.004618	.097	.039087	.171	.089287	.245	.149230
.024	.004921	.098	.039680	.172	.090041	.246	.150091
.025	.005230	.099	.040276	.173	.090797	.247	.150953
.026	.005546	.100	.040875	.174	.091554	.248	.151816
.027	.005867	.101	.041476	.175	.092313	.249	.152680
.028	.006194	.102	.042080	.176	.093074	.250	.153546
.029	.006527	.103	.042687	.177	.093836	.251	.154412
.030	.006865	.104	.043296	.178	.094601	.252	.155280
.031	.007209	.105	.043908	.179	.095366	.253	.156149
.032	.007558	.106	.044522	.180	.096134	.254	.157019
.033	.007913	.107	.045139	.181	.096903	.255	.157890
.034	.008273	.108	.045789	.182	.096674	.256	.158762
.035	.008638	.109	.046381	.183	.098147	.257	.159636
.036	.009008	.110	.047005	.184	.099221	.258	.160510
.037	.009383	.111	.047632	.185	.099997	.259	.161386
.038	.009763	.112	.048262	.186	.100774	.260	.162263
.039	.010148	.113	.048894	.187	.101553	.261	.163140
.040	.010537	.114	.049528	.188	.102334	.262	.164019
.041	.010931	.115	.050165	.189	.103116	.263	.164899
.042	.011330	.116	.050804	.190	.103900	.264	.165780
.043	.011734	.117	.051046	.191	.104685	.265	.166663
.044	.012142	.118	.052090	.192	.105472	.266	.167546
.045	.012554	.119	.052736	.193	.106261	.267	.168430
.046	.012971	.120	.053380	.194	.107051	.268	.169315
.047	.013392	.121	.054036	.195	.107842	.269	.170902
.048	.013818	.122	.054689	.196	.108636	.270	.171089
.049	.014247	.123	.055345	.197	.109430	.271	.171978
.050	.014681	.124	.056003	.198	.110226	.272	.172867
.051	.015119	.125	.056663	.199	.111024	.273	.173758
.052	.015561	.126	.057326	.200	.111823	.274	.174649
.053	.016007	.127	.057991	.201	.112624	.275	.175542
.054	.016457	.128	.058658	.202	.113426	.276	.176435
.055	.016911	.129	.059327	.203	.114230	.277	.177330
.056	.017369	.130	.059999	.204	.115035	.278	.178225
.057	.017831	.131	.060672	.205	.115842	.279	.179122
.058	.018296	.132	.061348	.206	.116650	.280	.180019
.059	.018766	.133	.062026	.207	.117460	.281	.180918
.060	.019239	.134	.062707	.208	.118271	.282	.181817
.061	.019716	.135	.063389	.209	.119083	.283	.182718
.062	.020196	.136	.064074	.210	.119897	.284	.183619
.063	.020680	.137	.064760	.211	.120712	.285	.184521
.064	.021168	.138	.065449	.212	.121529	.286	.185425
.065	.021659	.139	.066149	.213	.122347	.287	.186329
.066	.022154	.140	.066833	.214	.123167	.288	.187234
.067	.022652	.141	.067528	.215	.123988	.289	.188140
.068	.023154	.142	.068225	.216	.124810	.290	.189047
.069	.023659	.143	.068924	.217	.125634	.291	.189955
.070	.024168	.144	.069625	.218	.126459	.292	.190864
.071	.024680	.145	.070328	.219	.127285	.293	.191775
.072	.025195	.146	.071033	.220	.128113	.294	.192684
.073	.025714	.147	.071741	.221	.128942	.295	.193596
.074	.026236	.148	.072450	.222	.129773	.296	.194509

Table of Areas, &c.,—Continued.

Height.	Area Seg.	Height.	Area Seg.	Height.	Area Seg.	Height.	Area Seg.
.297	.195422	.348	.243074	.399	.292390	.450	.342782
.298	.196337	.349	.244026	.400	.293396	.451	.343777
.299	.197252	.350	.244980	.401	.294349	.452	344772
.300	.198168	.351	.245934	.402	.295330	.453	.345768
.301	.199085	.352	.246889	.403	.296311	.454	.346764
.302	.200003	.353	.247845	.404	.297292	.455	.347759
.303	.200922	.354	.248801	.405	.298273	.456	.348755
.304	.201841	.355	249757	.406	.299255	.457	.349752
.305	.202761	.356	.250715	.407	.300238	.458	.350748
.306	.203863	.357	.251673	.408	.301220	.459	.351745
.307	.204605	.358	.252631	.409	.202203	.460	.352741
.308	.205527	.359	.253590	.410	.303187	.461	.353789
.309	.206451	.360	.254550	.411	.304171	.462	.354736
.310	.207376	.361	.255510	.412	.305155	.463	.355732
.311	.208301	.362	.256471	.413	.306140	.464	.356730
.312	.209227	.363	.257433	.414	.307125	.465	.357727
.313	.210154	.364	.258395	.415	.308110	.466	.358725
.314	.211082	.365	.259357	.416	.309096	.467	.359723
.315	.212011	.366	.260320	.417	.310081	.468	.360721
.316	.212940	.367	.261284	.418	.311068	.469	.361719
.317	.213871	.368	.262248	.419	.312054	.470	.362717
.318	.214802	.369	.263213	.420	.313041	.471	.363715
.319	.215733	.370	.261178	.421	.314029	.472	.364713
.320	.216666	.371	.265144	.422	.315016	.473	365712
.321	.217599	.372	.266111	.423	.316004	.474	.366710
.322	.218533	.373	.267078	.424	.316992	.475	.367709
.323	.219468	.374	.268048	.425	.317981	.476	.368708
.324	.220401	.375	.269013	.426	.318970	.477	.369707
.325	.221340	.376	.269982	.427	.319959	.478	.370706
.326	.222277	.377	.270951	.428	.320948	.479	.371705
.327	.223215	.378	.271920	.429	.321938	.480	.372704
.328	.224154	.379	.272890	.430	.322928	.481	.373703
.329	.225093	.380	.273816	.431	.323918	.482	.374702
.330	.226033	.381	.274832	.432	.324909	.483	.375702
.331	.226974	.382	.275803	.433	.325900	.484	.376702
.332	.227915	.383	.276775	.434	.326892	.485	.377701
.333	.228858	.384	.277748	.435	.327882	.486	.378701
.334	.229801	.385	.278721	.436	.328874	.487	.379700
.335	.230745	.386	.279694	.437	.329866	.488	.380700
.336	.231689	.387	.280668	.438	.330858	.489	.381699
.337	.232684	.388	.281642	.439	.331850	.490	.382699
.338	.233580	.389	.282617	.440	.332843	.491	.383699
.339	.234526	.390	.283592	.441	.333836	.492	.384699
.340	.235473	.391	.284568	.442	.334829	.493	.385699
.341	.236421	.392	.285544	.443	.335822	.494	.386699
.342	.237369	.393	.286521	.444	.336816	.495	.387699
.343	.238318	.394	.287498	.445	.337310	.496	.388699
.344	.239268	.395	.288476	.446	.338804	.497	.389699
.345	.240218	.396	.289453	.447	.339798	.498	.390699
346	.241169	.397	.290430	.448	.340793	.499	.391699
.347	.242121	.398	.291411	.449	.341787	.500	.392699

To find the Area of the Segment of a circle by the preceding Table.

Divide the height of the segment by the diameter of the circle, so that the quotient may contain three places of decimals; look for the corresponding number to the quotient in the column height, then take out the number in the same horizontal row in the vertical column, intitled *Area Seg.* at the top; multiply the square of the diameter by the number thus taken out, and the product will be the area of the segment.

Example.—Required the area of the segment of a circle, the height of which is two, and the diameter of the circle 52.

```
52)2.000(.038
    156
    ---
    440
    416
    ---
     24
```

There remains 24, which is $\frac{24}{52} = \frac{6}{13}$.

The area of the segment corresponding to .038, is .009763, but since there is a fraction over and above .038 of $\frac{6}{13}$, find the next greater area .010148; take the difference between these two areas, which is .000385, multiply this difference by the fraction $\frac{6}{13}$, and it gives, .000177, which being added to .009763, gives .009940 for the area of the segment, answering to $.038\frac{6}{13}$.

The table is founded upon the following principle: Let the diameter of a circle be 1, which suppose divided into 1,000 equal parts, through every one of which imagine perpendiculars drawn and continued both ways to the circumference.

Then, since the versed sine is .001, we have $v = .001$ and $\frac{v}{\text{V}} = \frac{.001}{999} = \frac{.1}{999}$; therefore $\text{A} = \frac{4\,v}{3}\sqrt{v\,\text{V}} = \frac{4}{3000}\sqrt{.000999} = .00004214$, and $\text{B} = \frac{\text{A}\,v}{5\,\text{V}} = \frac{.00004215}{999 \times 5} = .00000001$, whence the first number of the table is .00004215.

The second versed sine is $.002 = v$, therefore $\text{V} = .998$ and $\frac{v}{\text{V}} = \frac{2}{998} = \frac{1}{199}$, whence $\text{A} = \frac{8}{3000}\sqrt{.001996} = .00011914$, and $\text{B} = \frac{\text{A}\,v}{5\,\text{V}} = \frac{.00011914}{499 \times 5} = .00000005$; therefore the second number is .00011919.

The third versed sine is $.003 = v$, therefore $\text{V} = 1 - .003 = .997$, whence $\frac{v}{\text{V}} = \frac{4}{997}$, and $\text{A} = \frac{12}{3000}\sqrt{0002991} = .00021876$: also $\text{B} = \frac{\text{A}\,v}{5\,\text{V}} = \frac{.00021876 \times 3}{5 \times 997} = .00000013$; thence the third number of the Table is .00021889.

And by this method the whole might be computed; but after a sufficient number of terms are found at the beginning of the table, the rest may be had (to seven or eight places of decimals) by this rule: let a, β, γ, δ, denote any four terms succeeding in the order of the letters, then $\delta = a + \overline{\beta \times \gamma - \beta}$.

And if any term of this Table be divided by 78539816, or multiplied by its reciprocal, it will produce the common table of segments, when the area is unity.

MERIDIAN, in astronomy, a great circle of the sphere, passing through the zenith, nadir, and poles of the world, crossing the equinoctial at right angles, and dividing the sphere into two hemispheres, the one eastern and the other western.

It is called meridian, from the Latin *meridies*, *noon*, or *mid-day*, because when the sun is in this circle, it is noon in all places situated under it.

MERIDIAN, in geography, a great circle, as PAQD, passing through the poles of the earth P and Q. and any given place at Z. So that the plane of the terrestrial meridian is in the plane of the celestial one.

Hence, 1. As the meridian invests the whole earth, there are several places situated under the same meridian. And, 2. As it is noon-tide whenever the centre of the sun is in the meridian of the heavens, and as the meridian of the earth is in the plane of the former, it follows, that it is noon at the same time, in all places situate under the same meridian. 3. There are as many meridians on the earth as there are points conceived in the equator. In effect, the meridians always change, as the longitude of the place is varied; and may be said to be infinite; each respective place, from east to west, having its respective meridian.

Meridian, *First*, is that from which the rest are accounted, reckoning from west to east. The first meridian is the beginning of longitude.

The fixing of the first meridian is merely arbitrary; and hence different persons, nations, and ages, have fixed it differently; whence some confusion has arisen in geography. The rule among the ancients was, to make it pass through the place farthest to the west that was known. But the moderns, knowing that there is no such place in the earth as can be esteemed the most westerly, the way of computing the longitudes of places from one fixed point is much laid aside.

But without much regard to any of these rules, our geographers and map-makers frequently assume the meridian of the place where they live, or the capital of their country, for a first meridian; and thence reckon the longitudes of their places.

The astronomers, in their calculations, usually choose the meridian of the place where their observations are made, for their first meridian; as Ptolemy, at Alexandria; Tycho Brahe, at Uranibourg; Riccioli, at Bologna; Mr. Flamsteed, at the Royal Observatory at Greenwich; and the French, at the Observatory at Paris.

Meridian Line, an arc, or part of the meridian of the place, terminated each way by the horizon. Or, a meridian line is the intersection of the plane of the meridian of the place with the plane of the horizon, vulgarly called a *north and south line*, because its direction is from one pole towards the other.

The use of a meridian line in astronomy, geography, dialing, &c., is very great, and on its exactness all depends; whence infinite pains have been taken by divers astronomers to fix it with the utmost precision. M. Cassini has distinguished himself by a meridian line drawn on the pavement of the church of S. Petronio, at Bologna, the largest and most accurate in the world; being 120 feet in length. In the roof of this church, 1,000 inches above the pavement, is a little hole, through which the sun's rays, when in the meridian, falling upon the line, mark his progress all the year. When finished, M. Cassini, by a public writing, informed the mathematicians of Europe of a new oracle of Apollo, or the Sun established in a temple, which might be consulted, with entire confidence, as to all difficulties in astronomy.

To draw a meridian line.

On the horizontal plane, from the same centre, c, draw several arcs of circles, B A, *b a*, &c., and on the same centre, c, erect a style, or gnomon, perpendicular to the plane A C B, a foot, or half a foot long. About the 21st of June, between the hours of nine and eleven in the morning, and between one and three in the afternoon, observe the points B, *b*, &c., A, *a*, wherein the shadow of the style terminates. Bisect the arcs A B, *a b*, &c., in D, *d*, &c. If then the same right line, D E, bisect all the arcs, A B, *a b*, &c., it will be the meridian line sought.

As it is difficult to determine the extremity of the shadow exactly, it is best to have the style flat at top, and to drill a little hole, noting the lucid spot projected by it on the arcs A B and *a b*, instead of the extremity of the shadow. Otherwise the circles may be made with yellow, instead of black, &c.

If the meridian line be bisected by a right line, O V, drawn perpendicularly through the point C, O V will be the intersection of the meridian, and first vertical; and, consequently, O will show the east point, and V the west.

Lastly,—If a style be erected perpendicularly in any other horizontal plane, and a signal be given when the shadow of the style covers the meridian line drawn in another plane, noting the apex, or extremity, of the shadow projected by the style, a line drawn from that point through that wherein the style is raised, will be a meridian line.

Meridian Line, on a dial, is a right line arising from the intersection of the meridian of the place with the plane of the dial. This is the line of twelve o'clock, and from hence the division of the hour-line begins.

MERLON, the elevated or solid portion of a battlement which alternates with the embrasures.

MEROS, (Greek,) the middle part of the triglyph. The breadth of the triglyph is divided into six parts; of which five are placed in the middle, two and a half being on either side. The middle one makes the regula, or femur, which the Greeks call *meros*. On either side of this are the channels, sunk as if imprinted with the elbow of a square. To the right and left of these another femur is formed, and at the extremities semi-channels are slanted.

MESAULÆ, in Grecian architecture, passages between the peristylium and hospitalium; the same as the audionas of the Romans. *See* House.

META, the goal in the Roman circus to which the chariots ran.

METAGENAS, a Grecian architect, who wrote a description of the temple of Diana at Ephesus; he also jointly conducted this edifice with his father Ctesiphontes, the Gnossian.

METALS. *See* Materials, Iron, &c.

METATOME, the interval between two dentals.

METEZAU, CLEMENT, a celebrated French architect, who flourished in the former part of the seventeenth century, was a native of Dreux, but settled at Paris, became architect to Louis XIII., and acquired much fame by carrying into execution, with Tiriot, a Parisian mason, the plan suggested by Cardinal Richelieu, for reducing Rochelle by means of an immense dyke, in imitation of what Cæsar had done at Durazzo, and Alexander the Great at Tyre. This scheme was to run a solid wall across a gulf upwards of 740 fathoms, or more than three-quarters of a mile broad, into which the sea rolled with great force, and, when the wind was high, with an impetuosity which seemed to set at defiance the art of man. Those who had undertaken the business were not to be turned aside by any obstacles: they began by throwing in huge rocks, to lay a kind of foundation; upon these were placed vast stones, cemented by the mud thrown up by the sea. These were supported by immense beams, driven into the bottom with incredible labour. It was raised so high that the soldiers were not incommoded by the water even at spring-tides. The platform was nearly 30 feet wide, and 90 feet at the foundation. At each extremity there was a strong fort, in the middle there was an open passage of 150 paces, several vessels being sunk immediately before it, together with high stakes in a double row, and before these thirty-five vessels linked together, so as to form a kind of floating palisade. This amazing dyke was completed in somewhat less than six months, and proved the principal means of occasioning the surrender of the city. So honourable were the exertions of M. Metezau in this business, that his portrait was circulated widely through France, to which were attached the following lines:

> "Dicitur Archimedes Terram potuisse movere;
> Æquora qui potuit sistere, non minor est."

METOCHE, (from the Greek μετοχε), in ancient architecture, a term used by Vitruvius, to signify the space or interval between the dentils of the Ionic, or triglyphs of the Doric orders.

Baldus observes, that, in an ancient MS. copy of that author, the word *metatome* is found for *metoche.* Hence Daviler takes occasion to suspect that the common text of Vitruvius is corrupted, and concludes that it should not be *metoche*, but *metatome*, q. d. *section.*

METOPE, or Metopa, (from μετα, *inter*, *between*, and οπη, *an aperture*), in architecture, the square piece or interval between the triglyphs, in the Doric frieze. In the original Greek the word signifies the distance between one aperture, or hole, and another, or between one triglyph and another; the triglyphs being supposed to be solives, or joists, that fill the apertures.

Vitruvius having shown that the Doric order took its rise from the disposition of the timberwork in the construction of the original hut, proceeds as follows:

"From this imitation, therefore, arose the use of triglyphs and mutules in Doric work: for it cannot be, as some erroneously assert, that the triglyphs represent windows; because triglyphs are disposed in the angles, and over the quarters of the columns, in which places windows are not permitted; for if windows were there left, the union of the angles of buildings would be dissolved; also, if the triglyphs are supposed to be situated in the place of the windows, by the same reason the dentils in Ionic work may be thought to occupy the places of the windows; for the intervals between the dentils, as well as between the triglyphs, are called *metopæ*; the Greeks calling the bed of the joists and assers *opas*, (as we call it *cava*, *columbaria*;) so because the inter-joist is between two opæ, it is by them called *met-opæ*."

As some difficulty arises in disposing the triglyphs and metopes in that just symmetry which the Doric order requires, many architects use this order only in temples.

In the Doric order, it is not the space between the mutules, but the space between the triglyphs, that forms the metope.

From the authority of Stewart, in his *Ruins of Athens*, the following proportions are taken; where observe, that feet are distinguished by the mark (′) being placed over them, and inches thus (″); the numbers following the latter are decimals.

In the Doric portico at Athens, the breadth of the metope, or space between the triglyphs, is 3′ 3″ and 3′ 3″.6, (*see* Chap. I. Plate IV.); the height is 3′ 0″.7, including the band or capital over it, (*see* Plate V.): or without the band, 2′ 9″.05, (*see* Plate VI).

In the temple of Minerva, at Athens, (Vol. ii. Chap. I.) the height of the metope, without its capital, or band, is 3′ 11″.15, (*see* Plate VI.); and the breadth of the metope is 4′ 3″.35.

In the Propylæa, (Vol. II. Chap. V. Plate VI.) the breadth of the metope is 3′ 8″.25, and the height 3′ 9″.85, including the band and the bead over it; and in the entablature of the antæ (Plate IX.) the breadth of the metope is 2′ 8″.734, and the height 2′ 5″, without the band.

In the temple of Theseus, (Vol. III. Chap. I. Plate VI.) the breadth of the metope is 2′ 6″.475, and its height 2′ 8″.55, including a very broad band. So that the height of the tympan, or panel, is universally less than the breadth.

MEXICAN ARCHITECTURE, is remarkable chiefly as forming a specimen of the style and mode of building adopted by the aborigines of the New World. Their resemblance to some of the ancient edifices and forms of building prevalent in the eastern continent is curious, and worthy of comment. The only Mexican buildings of which we have any remains are the teocallis, or houses of God, which are almost universally of the pyramidal form, resembling the pyramids of Egypt, but bearing, it would seem, even a more striking similarity to the famous tower of Babel, as described by Herodotus and modern travellers. *See* Babylonian Architecture. This resemblance is especially pointed out by Humboldt, to whom we are indebted for the greater part of our information on the subject.

These teocallis were solid masses of earth raised up in a pyramidal form, having the shape of a truncated pyramid, and faced either entirely or partially with masonry. In the interior were small cavities similar to those discovered in the Egyptian pyramids, and which were evidently intended for places of sepulture. The sides of the pyramid often face the cardinal points, and are divided into steps or stories on the exterior, in both which particulars they resemble those of Egypt. Their similarity to the tower of Babel is noticed further in the temple at the top of the pyramid, and, the use to which both erections were put as observatories for astronomical purposes.

The largest temple in Mexico is the great pyramid of Cholula, which is constructed of alternate layers of unburnt bricks and clay, and consists of four stories. In the interior are cavities of considerable size, one of which, upon being laid open was found to contain skeletons and a number of curiously painted and varnished vases, thus proving their sepulchral character. The height of the pyramid is 177 feet, the length of a side of the base 1,423 feet, the area on the top 3,500 yards, and the number of steps to the top 120.

At Papantla, in the northern part of Vera Cruz, is a small pyramid, 80 feet square at the base and 60 feet high, divided into seven stories, and ascended by a flight of 57 steps. It is constructed of immense blocks of stone laid in mortar, the faces of which are covered with hieroglyphics, amongst which are to be seen serpents and crocodiles. There are also a number of niches regularly disposed round each story.

A mass of ruins known as the Casa Grande are situated in the gulph of California, on the banks of the Rio Gila: the sides facing the cardinal points are of irregular size, those from north to south measuring 445 feet, while those from east to west are only 276 feet. They are composed of unburnt bricks of irregular size, the walls being 4 feet in thickness, and divided into three stories.

"In the district of Oaxaca, south of Mexico, stands the palace of Mitla, contracted from Mignitlan, signifying, in Aztec, the *place of woe*. By the Tzapotec Indians the ruins are called *leoba* or *luiva* (burial or tomb), alluding to the excavations found beneath the walls. It is conjectured to have been a palace constructed over the tombs of the kings, for retirement, on the death of a relation. The tombs of Mitla are three edifices, placed symmetrically in a very romantic situation. That in the best preservation, and, at the same time the principal one, is nearly 130 feet long. A staircase formed in a pit, leads to a subterranean apartment 88 feet in length and twenty-six in width. This, as well as the exterior part of the edifice, is decorated with fret and other ornaments of similar character. But the most singular feature in these ruins, as compared with other Mexican architecture, was the discovery of six porphyry columns, placed for the support of a ceiling in the midst of a vast hall. They are almost the only ones which have been found in the new continent, and exhibit strong marks of the infancy of the art, having neither base nor capital. The upper part slightly diminishes. Their total height is 19 feet in single blocks of porphyry. The ceiling under which they were placed was formed by beams of sabine wood, and three of them are still in good preservation. The roof is of very large slabs. The number of separate buildings was originally five, and they were disposed with great regularity. The gate, whereof some vestiges are still discernible, led to a court 150 feet square, which, from the rubbish and remains of subterranean apartments, it is supposed was surrounded by four oblong edifices. That on the right is tolerably preserved, the remains of two columns being still in existence. The principal building had a terrace, raised between three and four feet above the level of the court, and serving as a base to the walls it surrounnds. In the wall is a niche with pillars four or five feet above the level of the floor. The stone lintel over the principal door of the hall is in a single block 12 feet long and 3 feet deep. The excavation is reached by a very wide staircase, and is in the form of a cross, supported by columns. The two portions of it which intersect each other at right angles are each 82 feet long by 25 feet wide. The inner court is surrounded by three small apartments having no communication with the fourth, which is behind the niche. The interiors of the apartments are decorated with paintings of weapons, sacrifices, and trophies. Of windows there are no traces. Humboldt was struck with the resemblance of some of the ornaments to those on Etruscan vases of Lower Italy. In the neighbourhood of these ruins are the remains of a large pyramid and other buildings."

The only remarkable monuments in the valley of Mexico, Mr. Humboldt tells us, are the remains of the two pyramids of San Juan de Teotihuacan, on the north-east of the lake Tezcuco, consecrated to the sun and moon, and called by the Indians Tonatiuh Ytzaqual, (house of the sun,) and Metzli Ytzaqual, (house of the moon.) Mr. Bullock visited this site on his return from Themasceltepec. For some time before he reaches the gate of Tezcuco, the traveller is apprised of his approach to a place of ancient importance by a large aqueduct still in use, and the ruins of several stone buildings. The Spanish quarters, built for Cortes, are still entire. Several tumuli are seen on entering the gates, which are supposed to have been teocallis. The most important ruin is what Mr. Bullock calls the site of the palace of the ancient caziques of Tezcuco, which, though in ruins, far surpassed every idea he had formed of ancient Mexican architecture. It extended 300 feet, forming one side of the great square, and was placed on sloping terraces, raised one above another by small steps. Some of these terraces are still entire, and are covered with cement, very hard, and equal in beauty to that found in ancient Roman buildings. From what is known of the extensive foundations of this palace, it must have occupied some acres of ground. It was composed of large blocks of basaltic stone, of about 4 or 5 feet long and 2½ or 3 feet thick, cut and polished with the utmost exactness. The sculptured stones from these ruins have been used in building the modern churches and houses. Heaps of ruins surround it on every side, and Tezcuco, the Athens of Anahuac, as it is called by a Spanish historian, would seem to invite, above all others in Mexico, the attention of the antiquary.

At about two leagues from Tezcuco, is a spot called Bano de Montezuma, Montezuma's Bath, on the summit of a conical hill called Tescosingo. "We scrambled with great difficulty," observes Mr. Bullock, "through bushes and over loose stones, which were in great quantities on all sides, and at last perceived that we were on the ruins of a very large building, the cemented stones remaining in some places covered with stucco, and forming walks and terraces, but much encumbered with earth fallen from above, and overgrown with a wood of nopal, which made it difficult to ascend." He discovered the bath on one of the sides of the hill. "It was cut in the solid rock, and standing out like a martin's nest from the side of a house. It is not only an extraordinary bath, but still more extraordinarily placed. It is a beautiful basin, about 12 feet long by 8 wide, having a well about 5 feet by 4 deep in the centre, surrounded by a parapet or ruin 2 feet 6 inches high, with a throne or chair such as is represented in ancient pictures to have been used by the kings. There are steps to descend into the basin or bath, the whole cut out of living porphyry rock, with the utmost mathematical precision, and polished in the most beautiful manner." The mountains appear to have been covered with palaces, temples, baths, hanging gardens, &c.; and Mr. Bullock was informed that he had seen but the commencement of the wonders of the place.

About two miles from Tezcuco, is the Indian village of Huexotla. Mr. Bullock observed, on his approach, several small pyramids of alternate layers of clay and unburnt brick, one of them had evidently an entrance in the centre, which was discovered by part of it having fallen in; within the town were the foundations of a palace, and two large reservoirs, with which it was supplied with water, remain entire. The ancient wall of the town, almost 30 feet high and very thick, extends to a considerable distance. It is singularly constructed, being divided into five unequal parts. The broadest division is built of large oval stones, with ends standing out, so as to give it the appearance of having been formed of human sculls. and it is divided from the rest by a projecting cornice. Beyond the walls, on the road to Tezcuco, a broad covered-way runs between two huge walls terminating near a river, which appears to have been one of the entrances to the town. Over the bed of the river, which is now dry, there is a remarkable bridge, with a pointed arch nearly 40 feet high, supported on one side by a mass of masonry in a pyramidal shape. It is ascribed to the ancient Mexicans; but if constructed on the principle of the arch, it must have been the work of European architects.

Mr. Bullock visited the celebrated pyramids of San Juan di Teotihuacan. "As we approached them," he says, "the square and perfect form of the largest became at every step more and more visibly distinct, and the terraces could now be counted. We rode first to the lesser, which is the most dilapidated of the two, and ascended to the top, over masses of fallen stone and ruins of masonry, with less difficulty than we expected. On the summit are the remains of an ancient building, 47 feet long and 14 wide; the walls are principally of unhewn stone, 3 feet thick and 8 feet high; the entrance at the south end, with three windows on each side, and on the north end it appears to have been divided at about a third of its length; we soon arrived at the foot of the largest pyramid, and began to ascend. It was less difficult than we expected, though, the whole way up, lime and cement are mixed with fallen stones. The terraces are perfectly visible, particularly the second, which is about 38 feet wide, covered with a coat of red cement 8 or 10 inches thick, composed of small pebble-stones and lime. In many places as you ascend, the nopal trees have destroyed the regularity of the steps, but nowhere injured the general figure of the square, which is as perfect in this respect as the great pyramid of Egypt. We everywhere observed broken pieces of instruments like knives, arrows, spear-heads, &c., of obsidian, the same as those found on the small hills of Cholula; and on reaching the summit, we found a flat surface of considerable size, but which has been much broken and disturbed. On it was probably a temple or some other building; report says, a statue covered with gold. We rested some time on the summit, enjoying one of the finest prospects imaginable, in which the city of Mexico is included. Here I found fragments of small statues and earthenware, and what surprised me more, oyster-shells, the first I had seen in Mexico. In descending, I also found some ornamental pieces of earthenware. The pattern, one of which is in relief, much resembling those of China, the other has a grotesque human face. On the north-east side, about half way down, at some remote period an opening has been attempted. This should have been from the south to the north, and on a level with the ground, or only a few feet above it, as all the remains of similar buildings have been found to have their entrances in that direction. According to the measurements made by Dr. Oteyza, a young Mexican savant, in 1803, the base of the larger pyramid is 682 feet long, and its elevation 180 feet perpendicular; Mr. Bullock thinks its height to be nearly half the base. The other pyramid, that of the moon, is 36 feet lower, and its base much smaller. They are constructed of clay mixed with small stones, covered with a thick facing of porous amygdaloid, over which was a coating of cement. There are four stages subdivided into smaller steps; a stair of hewn stone formerly led to their summits. Early travellers all mention the prevailing tradition, that their interior was hollow. Around them in the plain, there are several hundred smaller ones, in general about 30 feet high; which, according to the tradition, were dedicated to the stars. It is probable, however, that the whole plain was a vast burial-place, its Aztec name was Micaotl, the road of the dead; which the Spaniards, borrowing a word from the language of the island of Cuba, have rendered Llano de los Cues. They are supposed to be the most ancient of all the Mexican monuments."

MEZANINE, or Mezzanine, a word borrowed from the Italians, who call *mezzanini* those little windows, less in height than breadth, which serve to illuminate an attic, or entresole. It is used by some architects, to signify an intermediate apartment, frequently introduced into the principal story when all the rooms are not required to be of the same height; so that where mezanines are introduced, the principal story is divided into two heights, in order to make store-rooms, or lodging-rooms for servants. *See* Apartment.

MEZZO-RELIEVO, a piece of sculpture in half relief. *See* Bas-Relief.

MIDDLE-POST, in a roof, the same as King-Post; which see.

MIDDLE-QUARTERS OF COLUMNS. When the plan or horizontal section of a column is divided into four quadrants, by lines not at right angles to the front, but at an angle of 45 degrees therewith, the four quarters are called the *middle quarters*.

MILE (from the Latin, *mille*, a thousand) a long measure, whereby the English, Italians, and some other nations, express the distance between places. *See* Measure.

In this sense *mile* is used to the same purpose with league, by the French and other nations. The mile is of various extent in different countries. The geographical, or Italian mile, contains a thousand geometrical paces, *mille passus*, whence the term *mile* is derived.

The English mile consists of eight furlongs, each furlong of 40 poles, and each pole of $16\frac{1}{2}$ feet: so that it is equal to 1760 yards, or 5280 feet.

The mile employed by the Romans in Great Britain, and restored by Henry VII., is our present English mile. A degree of the meridian in England, north latitude 52, according to the measurement of Colonel Mudge, is 121,640 yards, or 69.114 miles. A geographical, or sea mile, is the 60th part of such a degree, *i. e.* $2{,}027\frac{1}{3}$ yards; and three sea-miles make a league. A degree of the meridian, in north latitude 45, as measured in France in 1796, is 57,008 toises = 121,512 yards = 69.092 English miles.

Casimir has made a curious reduction of the miles, or leagues, of the several countries in Europe into Roman feet, which are equal to the Rhinland feet generally used throughout the north.

	Feet.
The mile of Italy	50,000
" of England	5,454
" of Scotland	6,000
" of Sweden	30,000
" of Muscovy	3,750
" of Lithuania	18,500
" of Poland	19,850
" of Germany, the small	20,000
" " the middle	22,500
" " the largest	25,000
" of France	15,750
" of Spain	21,270
" of Burgundy	18,000
" of Flanders	20,000
" of Holland	24,000
" of Persia, called also *parasanga*	18,750
" of Egypt, called also *schœnos*	25,000

A Table of the Length of Miles, Leagues, &c. ancient and modern, in English yards.

	Eng. Yards.
Ancient Roman mile	1610.348
Olympic stadium = $\frac{1}{8}$th of an ancient Roman mile	201.2935
Stadium = $\frac{1}{10}$th of an ancient Roman mile	161.0348
Stadium = 1100th part of a degree	111.2
Jewish risin, of which $7\frac{1}{2}$ = an ancient Roman mile	214.713
Gallic leuca = $1\frac{1}{2}$ ancient Roman mile	2415.522
German rast, or common league in France = 2 Gallic leuca	4831.044
Persian parasanga = 2 Gallic leagues	4831.044
Egyptian schœnos = 4 ancient Roman miles	0441.392
German league, or that of Scandinavia = 2 rasts	9662.088
The mile, or league of Germany = 200 Rhenish yards	8239.846
Great Arabian mile, used in Palestine in the time of the Crusades, rated at $1\frac{1}{2}$ ancient Roman mile	2415.713
Modern Roman mile	1628.466
Modern Greek mile of 7 Olympic stadia	1409.0545
Modern French league = 2,500 toises	5328.75
Mile of Turkey, and the common werst of Russia, supposing it seven Olympic stadia	1409.0545
League of Spain = 4 ancient Roman miles	6441.392
Large league of Spain = 5 ditto	8051.74

MILITARY ARCHITECTURE, denotes the art of fortification. *See* Architecture.

MILLSTONE-GRIT, a coarse-grained quartzy sandstone. It is found between the mountain-limestone and the superincumbent coal formations.

MILK-HOUSE, or ROOM, an apartment for keeping milk sweet and good; this apartment ought to be as cool as possible, and on no account exposed to the rays of the sun; consequently a northern situation, when it can be obtained, will be the most eligible for this purpose. *See* Dairy.

MINARET, or Minneret, a Turkish steeple with a balcony, from which a person calls the people to prayers; no bells being permitted in Turkey.

MINION, an iron ore, useful in the composition of mortar; when mixed with a proper quantity of lime, it makes an excellent water-cement. *See* Cement and Mortar.

MINOTAUR, or Minotaurus, a fabulous monster much talked of by the poets; feigned to be half a man and half a bull.

MINSTER, the church belonging to a monastery.

MINSTREL GALLERY, a gallery in old halls, in which the minstrels sat during the feast. There is a gallery so termed near the centre of the choir of Exeter cathedral.

MINUTE, (from the Latin, *minutus*, small) in architecture, usually denotes the sixtieth, but sometimes only the thirtieth, part or division of a module.

MISERERE, a term applied to a seat of peculiar form, found in some of our larger churches and cathedrals. It is in shape like a bracket, and turns up on a hinge. When down, it forms a seat of the usual height and size, and the front beneath the seat is usually carved into a knop of foliage, or otherwise; but when turned up, this front presents a small high seat, which was used to recline against. It falls back out of the perpendicular, so as to retain itself in its position, but will fall forward with the least motion of the occupant.

MITCHELS, among builders, are Purbeck stones, from 15 inches square to 2 feet, squared and hewed ready for building.

MITRE, or Mitra, (from Μιτρα, a head-dress) a pontifical ornament, worn on the head by bishops, and certain abbots, on solemn occasions.

The mitre is a round cap, pointed, and cleft at top, with pendants hanging down on the shoulders, and fringed at both ends. The bishop's is only surrounded with a fillet of gold, set with precious stones; the archbishop's issues out of a ducal coronet. These are never used otherwise than on their coats of arms. Abbots wear the mitre turned in profile, and bear the crosier inwards, to show that they have no spiritual jurisdiction without their own cloisters.

The pope has also granted to some canons of cathedrals the privilege of wearing the mitre. The counts of Lyons are also said to have assisted at church in mitres.

Mitre, in joinery: when two pieces of wood contain equal angles, and one side of the one piece is joined to one side of the other, so that their vertices may coincide, the common seam, or joint, is called a *mitre*, and the pieces themselves are said to be *mitred*.

The whole angle thus joined is generally a right angle, and when this is the case, each of the pieces joined will be forty-five degrees.

Mitering is also employed in dovetail joints, in order to conceal the dovetailing.

Mitre-Box, a trough for cutting mitres, having three sides, open at the ends.

MIXED ANGLE, an angle of which one side is a curve, and the other a straight line.

Mixed Figure, one that is composed of straight lines and curves, being neither entirely the sector nor the segment of a circle; nor the sector or segment of an ellipsis; nor a parabola nor an hyperbola.

MOAT, (from the Latin, *mota*, a ditch) in fortification, a deep trench dug round a town, or fortress, to be defended on the outside of the wall or rampart.

The depth and breadth of a moat often depend on the nature of the soil; according as it is marshy, rocky, or the like. The brink of the moat next the rampart, in any fortification, is called the *scarp*, and the opposite one the *counter-scarp*.

MODEL, (from the Latin, *modulus*, a copy) an original, or pattern, proposed for any one to copy or imitate. St. Paul's cathedral is said to be built after the model of St. Peter's at Rome.

Model is particularly used, in building, for an artificial pattern, made of wood, stone, plaster, or other matter, with all its parts and proportions; for the better guidance of the artificers in executing some great work, and to give an idea of the effect it will have when complete.

In all great buildings it is much the surest way to make a model in relievo; and not to trust to a bare design, or draught. There are also models for the building of ships &c., and for extraordinary staircases, &c.

Model, in painting and sculpture, anything proposed to be imitated.

Hence, in the academies, they give the term *model* to a naked man, disposed in several postures, to afford an opportunity to the scholars of designing him in various views and attitudes.

The sculptors have little models of clay, or wax, to assist them in their design of others that are larger, in marble, &c., and to judge of the attitude and correctness of a figure.

Statuaries likewise give the name *model* to certain figures of clay, or wax, which are but just fashioned, to serve by way of guide in the making of larger, whether of marble or other matter.

MODILLIONS, (French,) in architecture, mutules carved into consoles, placed under the soffit or bottom of the drip of the corona in the Corinthian and Roman orders, for supporting the larmier and sima, or appearing to perform the office of support.

In Grecian architecture, the Ionic order is without modillions in the cornice, as are also the Roman examples of the same order, except the temple of Concord, at Rome, which has both dentils and modillions.

A singular and curious example of a modillion cornice, but contrary to the principles of architecture, is to be found in the interior cornices of the Tower of the Winds, at Athens, in which the projecting part is much thicker than the interior, where the stress seems to lie, and, consequently, gives the idea of weakness.

A singular example of modillions is to be found in the frontispiece of Nero, at Rome, where they consist of two plain faces, separated by a small sima-reversa, and crowned with an ovolo and bead. Another very extraordinary form of modillions is that placed in the frieze of the fourth order of the Coliseum, cut on the outside, or projecting part, of a sima-reversa form.

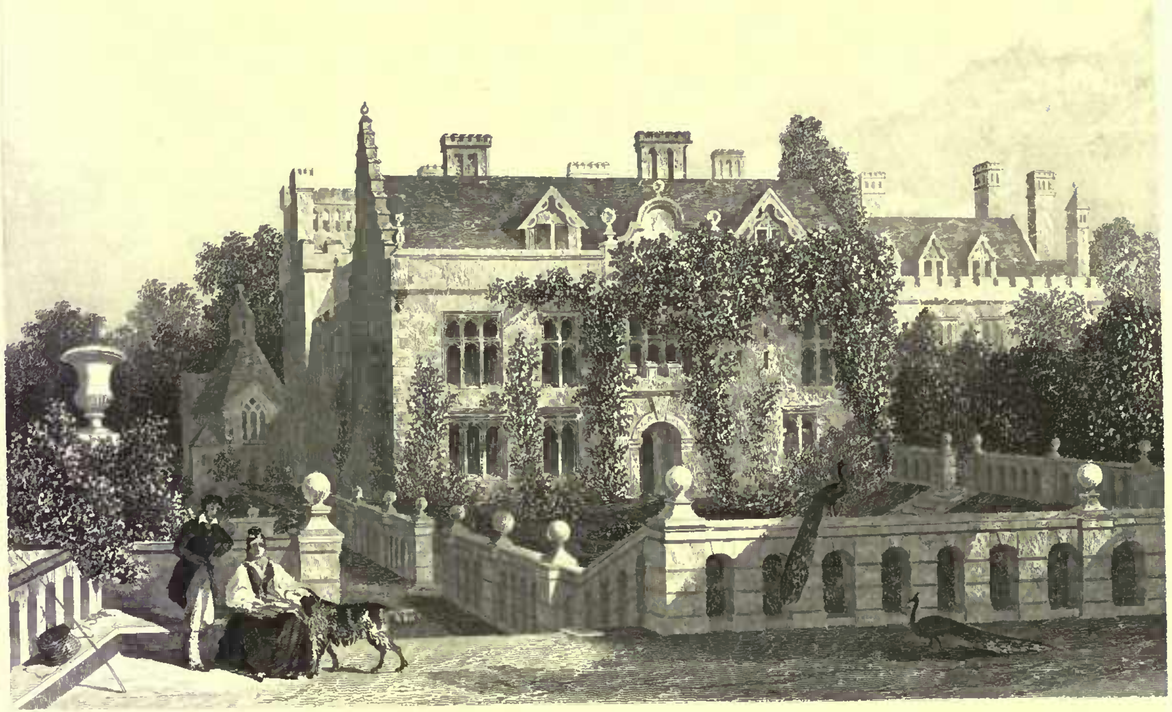
In most examples of the Corinthian and Roman orders, the cornices have both dentils and modillions; but, if the two are used together, in good proportion to the other parts, so as to appear distinctly at a reasonable distance, the cornice will be overcharged, both in proportion and weight, to the other principal members of the entablature, or the entablature to the whole order; the one or the other ought, therefore, to be omitted in the same cornice.

In the general disposition of modillions, if each one is conceived to be divided into two equal parts by a vertical plane at right angles to the surface of the frieze, one of the modillions is so disposed, that its dividing vertical surface will be entirely in a plane passing through the axis of the column, and in the column next the angle of the building there is generally only one modillion between that through which the plane along the axis passes, and the angle of the cornice.

The vertical sides of modillions at right angles to the face, are generally finished with volutes of different sizes, and turned on different sides of the same line; the greater being that next to the vertical surface, to which they are attached, and the lesser at the extremity.

The soffits of the modillions, so constructed, follow the under line of the volutes, and the connecting undulated line which joins them. The upper part of each volute is on the same level, and is attached to a moulding of the sima-inversa form, which returns round it; and this moulding is again attached to the corona, which hangs over the modillion.

In some of the Roman buildings, the modillions are not placed over the axes of the columns, neither upon those at



Newstead Abbey.

THROUGH THY BATTLEMENTS, NEWSTEAD, THE HOLLOW WINDS WHISTLE;
THOU, THE HALL OF MY FATHERS, ART GONE TO DECAY;

IN THY ONCE SMILING GARDEN, THE HEMLOCK AND THISTLE
HAVE CHOKED UP THE ROSE WHICH LATE BLOOM'D IN THE WAY.

the extremes, or over the axes of the intermediate shafts. In the Pantheon, the modillion next each angle of the building has its vertical side, which is opposed to the next modillion, nearer to the central plane of the portico, over the axis of the column, and consequently the whole breadth of the modillion on one side of the axis entirely, and on that side next to the angle of the building. In the whole portico are 47 modillions, including those at each extreme; the intervals are, therefore, 46 in number, and 44 between the columns that are between their axis. The portico is octostyle, and, consequently, the intercolumns are seven in number: from this it will be found, that if the columns were placed equidistantly, the number of intermodillions would be $6\frac{2}{7}$ in number. In this temple the corresponding intervals are very irregular. The two extreme ones are, according to Desgodetz, 9′ $4\frac{1}{2}$″, and 9′ $2\frac{3}{4}$″; the next two, nearer the centre, are 9′ $5\frac{1}{6}$″, and 9′ $1\frac{7}{8}$″; the next two, still nearer to the centre, are exactly equal, being 9′ 5″ each; and the central intercolumniation is 10′ $4\frac{3}{4}$″: so that the modillions appear to be equally divided, without any regard to the axis of the columns. The same irregularity in the disposition of the modillions may be observed in the temple of Concord, and in that of Jupiter the Thunderer. In the three remaining columns of the temple of Jupiter Stator, each column has a modillion placed over its axis, and each intercolumn has three modillions regularly disposed: the distance between the lower ends of the shafts are 3 modules, $4\frac{1}{2}$ parts, and the columns are in height 20 modules, $6\frac{5}{6}$ parts.

In the Pantheon, the modillions are placed in the pediment, contrary to the authority of Vitruvius.

MODULAR PROPORTION, that which is regulated by a module. *See* Module.

MODULATION, (from the Latin, *modulor*, to regulate,) the proportion of the parts of an order.

MODULE, (from the Latin, *modulus*, a pattern,) in architecture, a certain measure taken at pleasure, for regulating the proportions of columns, and the symmetry or distribution of the whole building.

Architects usually choose the diameter, or semi-diameter, of the bottom of the column, for their module; and this they subdivide into parts or minutes.

Vignola divides his module, which is a semi-diameter, into twelve parts, for the Tuscan and Doric; and into eighteen, for the other orders.

The module of Palladio, Scammozzi, M. Cambray, Desgodetz, Le Clerc, &c., which is also the semi-diameter, is divided into 30 parts or minutes, in all the orders.

Some divide the whole height of the column into 20 parts for the Doric, $22\frac{1}{2}$ for the Ionic, 25 for the Roman, &c., and one of these parts they make a module, by which to regulate the rest of the building.

There are two ways of determining the measures, or proportions of buildings: the first by a fixed standard measure, which is usually the diameter of the lower part of the column, called a *module*, subdivided into 60 parts, called *minutes*. In the second there are no minutes, nor any certain and stated division of the module; but it is divided occasionally into as many parts as are judged necessary. Thus the height of the Attic base, which is half the module, is divided either into three, to have the height of the plinth; or into four, for that of the greater torus; or into six, for that of the lesser.

Both these manners have been practised by the ancient as well as the modern architects; but the second, which was that chiefly used among the ancients, is, in the opinion of Perrault, preferable.

As Vitruvius, in the Doric order, has lessened his module, which, in the other orders, is the diameter of the lower part of the column, and has reduced that great module to a mean one, which is a semi-diameter; M. Perrault reduces the module to a third part, for the same reason, viz., to determine the several measures without a fraction. For in the Doric order, beside that the height of the base, as in the other orders, is determined by one of these mean modules; the same module gives likewise the heights of the capital, architrave, triglyphs, and metopes. But our little module, taken from the third of the diameter of the lower part of the column, has uses much more extensive: for, by this, the heights of pedestals of columns, and entablatures, in all orders, are determined without a fraction.

As then the great module, or diameter of the column, has 60 minutes; and the mean module, or half the diameter 30 minutes; our little module has 20. *See* Column.

MOILON, a name given by the French to a kind of stone, that forms the upper crust, and lies round the free-stone, in most quarries. It is an excellent substance for forming the body of fluxes, or soft enamel.

MOINEAU, (French,) in fortification, a flat bastion raised before a curtain when it is too long, and the bastions of the angles too remote to be able to defend each other.

Sometimes the moineau is joined to the curtain, and sometimes it is divided from it by a moat. Here musqueteers are placed, to fire each way.

MOLDING. *See* Moulding.

MOLE, (from the Latin, *moles*,) a massive work of large stones laid in the sea by means of coffer-dams, extending either in a right line, or in the arc of a circle, before a port, which it serves to close, to defend the vessels in it from the impetuosity of the waves, and to prevent the passage of ships without leave.

Mole is sometimes also used to signify the harbour itself.

Mole, among the Romans, was also used for a kind of mausoleum, built in the manner of a round tower on a square base, insulated, encompassed with columns, and covered with a dome.

The mole of the emperor Adrian, now the castle of St. Angelo, was the greatest and most stately of all the moles. It was crowned with a brazen pine-apple, in which was a golden urn containing the ashes of the emperor.

MOMENT or Momentum, (from the Latin,) the impetus, force, or quantity of motion in a moving body; or the word is sometimes used simply for the motion itself. Moment is frequently defined by the *vis insita*, or power by which moving bodies continually change place. In comparing the motion of bodies, the ratio of their momenta is always compounded of the quantity of matter, and the celerity of the moving body; so that the moment of any such body may be considered as a rectangle under the quantity of matter, and the celerity.

And since it is certain, that all equal rectangles have their sides reciprocally proportionable; therefore, if the momenta of any moving bodies be equal, the quantity of matter in one to that of the other, will be reciprocally as the celerity of the latter to that of the former; and, on the contrary, if the quantities of matter be reciprocally proportionable to the celerities, the momenta or quantities in each will be equal.

The moment, also, of any moving body may be considered as the aggregate or sum of all the momenta of the parts of that body; and, therefore, where the magnitudes and number of particles are the same, and where they are moved with the same celerity, there will be the same momenta of the whole. *See* Force.

MONASTERY, a convent, or house, built for the reception of religious devotees; whether it be abbey, priory, nunnery, or the like. The term is only properly applied to the houses of monks, friars, and nuns. The rest are more properly called *religious houses. See* ABBEY.

The houses belonging to the several religious orders, which obtained in England and Wales, were cathedrals, colleges, abbeys, priories, preceptories, commanderies, hospitals, friaries, hermitages, chantries, and free chapels. These were under the direction and management of several officers. The dissolution of houses of this kind began so early as the year 1312, when the Templars were suppressed; and in 1323, their lands, churches, advowsons, and liberties, here in England, were given, by 17 Edw. II. stat. 3, to the priory and brethren of the hospital of St. John of Jerusalem. In the years 1390, 1437, 1441, 1459, 1497, 1505, 1508, and 1515, several other houses were dissolved, and their revenues settled on different colleges in Oxford and Cambridge. Soon after the last period, Cardinal Wolsey, by license of the king and pope, obtained a dissolution of above thirty religious houses, for the founding and endowing his colleges at Oxford and Ipswich. About the same time, a bull was granted by the same pope to Cardinal Wolsey, to suppress monasteries, where there were not above six monks, to the value of 8,000 ducats a year, for endowing Windsor, and King's College, in Cambridge; and two other bulls were granted to Cardinals Wolsey and Campeius, where there were less than twelve monks, and to annex them to the greater monasteries; and another bull to the same cardinals, to inquire about abbeys to be suppressed, in order to be made cathedrals. Although nothing appears to have been done in consequence of these bulls, the motive which induced Wolsey, and many others, to suppress these houses, was the desire of promoting learning; and Archbishop Cranmer engaged in it with a view of carrying on the Reformation. There were other causes that concurred to bring on their ruin: many of the devotees were loose and vicious; the monks were generally thought to be, in their hearts, attached to the pope's supremacy; their revenues were not employed according to the intent of the donors; many cheats in images, feigned miracles, and counterfeit relics, had been discovered, which brought the monks into disgrace; the Observant friars had opposed the king's divorce from Queen Catharine; and these circumstances operated, in concurrence with the king's want of a large supply, and the people's desire to save their money, to forward a motion in parliament, that, in order to support the king's state, and supply his wants, all the religious houses might be conferred upon the crown, which were not able to spend above £200 a year; and an act was passed for that purpose, 27 Hen. VIII. c. 28. By this about 380 houses were dissolved, and a revenue of £30,000 or £32,000 a year came to the crown; besides about £100,000 in plate and jewels. The suppression of these houses occasioned great discontent, and at length an open rebellion: when this was appeased, the king resolved te suppress the rest of the monasteries, and appointed a new visitation; which caused the greater abbeys to be surrendered apace; and it was enacted by 31 Hen. VIII. c. 13, that all monasteries, which have been surrendered since the 4th of February, in the twenty-seventh year of his majesty's reign, and which hereafter shall be surrendered, shall be vested in the king. The knights of St. John of Jerusalem were also suppressed by the 32 Henry VIII., c. 24. The suppression of these greater houses by these two acts, produced a revenue to the king of above £100,000 a year, besides a large sum in plate and jewels. The last act of dissolution, in this king's reign, was the act of 37 Hen. VIII., c. 4, for dissolving colleges, free chapels, chantries, &c., which act was farther enforced by 1 Ed. VI., c. 14. By this act were suppressed 90 colleges, 110 hospitals, and 2,374 chantries and free chapels. The number of houses and places suppressed, from first to last, so far as any calculations appear to have been made, seems to be as follows:

Of lesser monasteries, of which we have the valuation	374
Of greater monasteries	186
Belonging to the hospitallers	48
Colleges	90
Hospitals	110
Chantries and free chapels	2374
Total	3182

Besides the friars' houses, and those suppressed by Wolsey, and many small houses, of which we have no particular account.

The sum total of the clear yearly revenue of the several houses, at the time of their dissolution, of which we have any account, seems to be as follows:

	£.	s.	d.
Of the greater monasteries	104,919	13	3½
Of all those of the lesser monasteries, of which we have the valuation	29,702	1	10½
Knights hospitallers' head house in London	2,385	12	8
We have the valuation of only twenty-eight of their houses in the country	3,026	9	5
Friars' houses, of which we have the valuation	751	2	0¾
Total	140,784	19	3¾

If proper allowances are made for the lesser monasteries, and houses not included in this estimate, and for the plate, &c., which came into the hands of the king by the dissolution, and for the value of money at that time, which was at least six times as much as at present, and we also consider that the estimate of the lands was generally supposed to be much under the real worth, we must conclude their whole revenues to have been immense.

It doth not appear that any computation hath been made of the number of persons contained in the religious houses.

Those of the lesser monasteries dissolved by 27 Hen. VIII. were reckoned at about	10,000
If we suppose the colleges and hospitals to have contained a proportionable number, these will make about	5,347
If we reckon the number in the greater monasteries, according to the proportion of their revenues, they will be about 35,000; but as probably they had larger allowances in proportion to their number than those of the lesser monasteries, if we abate upon that account 5,000, they will then be	30,000
One for each chantry and free chapel	2,374
Total	47,721

But as there were probably more than one person to officiate in several of the free chapels, and there were other houses which are not included within this calculation, perhaps they may be computed in one general estimate at about 50,000. As there were pensions paid to almost all those of the greater monasteries, the king did not immediately come into the full enjoyment of their whole revenues: however, by means of what he did receive, he founded six new bishoprics, viz., those of Westminster, (which was changed by Queen Elizabeth into a deanery, with twelve prebends and a school,) Peterborough, Chester, Gloucester, Bristol, and Oxford. And in eight other sees he founded deaneries and chapters.

by converting the friars and monks into deans and prebendaries, viz., Canterbury, Winchester, Durham, Worcester, Rochester, Norwich, Ely, and Carlisle. He founded also the colleges of Christ-Church in Oxford, and Trinity in Cambridge, and finished King's College Chapel there. He likewise founded professorships of divinity, law, physic, and of the Hebrew and Greek tongues, in both the said universities. He gave the house of Gray Friars, and St. Bartholomew's Hospital, to the City of London; and a perpetual pension to the poor knights of Windsor; and laid out great sums in building and fortifying many ports in the Channel. It is observable, upon the whole, that the dissolution of their houses was an act, not of the church, but of the state, in the period preceding the Reformation, by a king and parliament of the Roman Catholic communion in all points except the king's supremacy; to which the pope himself, by his bulls and licenses, had led the way.

Although few will now be found entirely to approve either the original establishment or continued subsistence of monasteries, yet the destruction of them was felt and lamented, for a considerable time, as a great evil; and with good reason. One inconvenience that attended their dissolution was the loss of many valuable books, which their several libraries contained: for, during the middle ages, religious houses were the repositories of literature and science. Besides, they were schools of education and learning; for every convent had one person or more appointed for this purpose; and all the neighbours that desired it, might have their children taught grammar and church music there, without any expense. In the nunneries also, young females were taught to work and read; and not only people of the lower rank, but most of the noblemen's and gentlemen's daughters, were instructed in those places. All the monasteries were also in effect great hospitals, and were most of them obliged to relieve many poor people every day. They were likewise houses of entertainment for all travellers. And the nobility and gentry provided not only for their old servants in these houses, by corrodies, but for their younger children, and impoverished friends, by making them first monks and nuns, and in time priors and prioresses, abbots and abbesses. On the other hand, they were very injurious to the secular and parochial clergy, by taking on themselves many prebends and benefices, by getting many churches appropriated to them, and pensions out of many others; and by the exemptions they got from the episcopal jurisdiction, and from the payment of tithes. We say nothing now of the laxity of discipline, and acts of moral turpitude, which have been attributed to the inmates of such establishments; which, however greatly they have been exaggerated, did unquestionably prevail in some instances. Such faults, however, are chargeable rather upon individuals, than upon the system, against which the previous objections are of greater weight.

MONKEY, the weight used in pile-driving, which is raised to the top of the machine, and then allowed to fall on the head of the pile.

MONOGRAM, (Greek *εν μονω γραφειν*,) the combination or interlacing of several letters, so as to produce a single cipher or device, employed for the purpose of abbreviation.

MONOLITH, (*μονος*, *single*, and *λιθος*, *a stone*,) a structure consisting of a single colossal stone. The term is applied to such structures found in Celtic remains. *See* Celtic Architecture.

MONOPTERON, or Monoptral Temple (from *μονος*, *single*, and *πτερον*, *a wing*) in architecture, an edifice, consisting of a circular colonnade supporting a dome, without any enclosing wall, and consequently without a cell, as in other temples.

MONOTRIGLYPH, (from *μονος*, *single*, and *τριγλυφος*, *a triglyph*) having only one triglyph between two adjoining columns. The monotriglyph intercolumniation was the general practice in the Grecian Doric; as in the temple of Theseus, and in that of Minerva, at Athens.

Mr. Rively, in his preface to the third volume of Stewart's *Athens*, says, "There is a certain appearance of eternal duration in this species of edifice (meaning a Grecian Doric temple) that gives a solemn and majestic feeling, while every part is perceived to contribute its share to this character of durability. From this rapid sketch, it will readily be seen that no other intercolumniation than that of the monotriglyph can succeed in this dignified order. The Propylæa, indeed, as well as the temple of Augustus, or Agora, has one interval of the space of two triglyphs; but it is easy to perceive, that this deviation from the general principle was merely an accommodation to circumstances; both these buildings requiring a wide opening in the middle of the front. Accordingly, these are the only instances of this deviation to be found at Athens."

In the island of Delos, the portico of Philip, king of Macedon, is another instance.

MONSTRANCE, the vessel in which the consecrated wafer is placed during the benediction; it is usually made of a metal frame, to contain a glass vessel, through which the wafer is seen. Some of them are of very beautiful and rich design.

MONUMENT, (from the Latin, *monumentum*, a memorial) a structure raised to preserve the memory of some eminent person, or to perpetuate some remarkable event.

Monuments at first consisted of stones erected over the tombs of the deceased, on which were engraved the name, and frequently the actions, of the person to whose memory they were reared.

Monuments received different names among the ancients, according to their figure. When the base was square, and the solid erected thereon a prism, the monument was called *steles*; whence square pilasters, or attic columns, are supposed to be derived. When the base was circular, and the solid erected thereon a cone, the monument was called *stylos*. Those monuments that were square at the foot, and tapering therefrom in planes to a point in which the planes ended, were called *pyramids*. Others, which had triangular bases, and their sides ending in a point, were called *obelisks*; being constructed in imitation of the instruments or spits used in roasting the sacrifices.

Monument of Lysicrates. The choragic monument of Lysicrates, commonly called the *Lantern of Demosthenes*, is the most beautiful edifice of antiquity of its size.

This monument, which is exquisitely wrought, stands near the eastern end of the Acropolis. It is composed of three distinct parts. First, a quadrangular basement; secondly, a circular colonnade, the intercolumniations of which are entirely closed up; and, thirdly, a *tholus*, or cupola, with a beautiful ornament upon it.

The quadrangular basement is entirely closed on every side, so as to exclude entrance. On breaking through one of the sides, it was found not to be quite solid; but the void is so small, and irregular, that a man can hardly stand upright in it.

This basement supports the circular colonnade, which was constructed in the following manner: six equal panels of white marble, placed contiguous to each other, on a circular plan, formed a continued cylindrical wall; which of course was divided, from top to bottom, into six equal parts, by the junctures of the panels. On the whole length of each juncture was cut a semicircular groove, in which a Corinthian column was fitted with great exactness, and effectually concealed the junctures of the panels. These columns projected somewhat more than half their diameters from the surface of the cylindrical wall, and the wall entirely closed up the intercolumniation. Over this was placed the entablature, and the cupola, in neither of which any aperture was made, so that there was no admission to the inside of this monument, and it was quite dark. It is, besides, only 5 feet 11¼ inches in the clear, and, therefore, was never intended for a habitation, or even a repository of any kind.

An entrance, however, has been since forced into it, by breaking through one of the panels; probably in expectation of finding treasures here. For in these countries such barbarism reigns at present, every ancient building which is beautiful, or great, beyond the conception of the present inhabitants, is always supposed by them to be the work of magic, and the repository of hidden treasures. At present three of the marble panels are destroyed; their places are supplied by a door, and two brick walls, and it is converted into a closet.

It should be observed, that two tripods with handles to them, are wrought in basso-relievo on each of the three panels which still remain. They are perhaps of the species which Homer and Hesiod describe by the name of *τρίποδες ὠτώεντες*, or *eared tripods.*

The architrave and frieze of this circular colonnade are both formed of only one block of marble. On the architrave is cut the following inscription:

ΛΥΣΙΚΡΑΤΗΣ ΛΥΣΙΘΕΙΔΟΥ ΚΙΚΥΝΕΥΣ ΕΧΟΡΗΓΗΙ
ΑΚΑΜΑΝΤΙΣ ΠΑΙΔΩΝ ΕΝΙΚΑ ΘΕΩΝ ΗΥΛΕΙ
ΛΥΣΙΑΔΗΣ ΑΘΗΝΑΙΟΣ ΕΔΙΔΑΣΚΕ ΕΥΑΙΝΕΤΟΣΗΡΧΕ

From this we may conclude, that on some solemn festival which was celebrated with games and plays, Lysicrates of Kikyna, a demos or borough-town of the tribe of Akamantis, did on behalf of his tribe, but at his own expense, exhibit a musical or theatrical entertainment; in which the boys of the tribe of Akamantis obtained the victory; that in memory of their victory, this monument was erected; and the name of the person at whose expense the entertainment was exhibited, of the tribe that gained the prize, of the musician who accompanied the performers, and of the composer of the piece, are all recorded on it; to these the name of the annual archon is likewise added, in whose year of magistracy all this was transacted. From which last circumstance it appears, that this building was erected above 330 years before the Christian æra; in the time of Demosthenes, Apelles, Lysippus, and Alexander the Great.

Round the frieze is represented the story of Bacchus and the Tyrrhenian pirates. The figure of Bacchus himself, the fauns and satyrs who attend him on the manifestation of his divinity, the chastisement of the pirates, their terror, and their transformation into dolphins, are expressed in this basso-relievo with the greatest spirit and elegance. The cornice, which is otherwise very simple, is crowned with a sort of Vitruvian scroll, instead of a cymatium. It is remarkable, that no cornice of an ancient building, actually existing, and decorated in this manner, has hitherto been published; yet temples, crowned with this ornament, are frequently represented on medals; and there is an example much resembling it, among those ancient paintings which adorn a celebrated manuscript of Virgil, preserved in the Vatican library. This cornice is composed of several pieces of marble, bound together by the cupola, which is of one entire piece.

The outside of the cupola is wrought with much delicacy; it imitates a thatch, or covering, of laurel leaves; edged with a Vitruvian scroll, and enriched with other ornaments. In certain cavities on its upper surface, some ornament, now lost, probably a tripod, was originally placed.

It was the form of the upper surface of the flower, and principally, indeed, the disposition of four remarkable cavities in it, which first led to this discovery. Three of them are cut on the three principal projections of the upper surface; their disposition is that of the angles of an equilateral triangle; in these the feet of the tripod were probably fixed. In the fourth cavity, which is much the largest, and is in the centre of this upper surface, a baluster was in all likelihood inserted; its use was to support the tripod.

It is well known that the games and plays which the ancient Grecians exhibited at the celebration of their greater festivals, were chiefly athletic exercises, and theatric or musical performances; and that these made a very considerable, essential, and splendid part of the solemnity. In order, therefore, to engage a greater number of competitors, and to excite their emulation more effectually, prizes were allotted to the victors; and these prizes were generally exhibited to public view during the time in which these games were celebrated.

Monument, *The*, absolutely so called among us, denotes a magnificent pillar, designed by Sir C. Wren, and erected by order of parliament, in memory of the burning of the city of London, anno 1666, near the place where the fire began. This pillar, begun in 1671 and finished in 1677, is of the Doric order, fluted, 202 feet high from the ground, and 15 feet in diameter, of solid Portland stone, with a staircase in the middle, of black marble, containing 365 steps. The lowest part of the pedestal is 28 feet square, and its altitude 40 feet; the front being enriched with curious basso-relievos. It has a balcony within 32 feet of the top, and the whole is surmounted with a curious and spacious blazing urn of gilt brass.

MOORISH, Moresque, Arabian, or Saracenic Architecture.—The style of building indifferently designated by any one of the above titles, is that which was practised by the Arabs, or Moors, and which, owing to the migratory condition of that race, and to their widely-spread influence, prevailed in many parts of the eastern continent. It is sometimes styled Mohammedan, for under the auspices of that faith it chiefly flourished; and amongst the edifices which Islamism gave rise to, are to be found some of the most magnificent and characteristic examples of the style. Previous to the time of Mohammed the Arabs seem to have possessed but little knowledge of the arts, and to have made little progress in the art of building until the commencement of the Ommiad dynasty. They would appear to have acquired a great portion of their knowledge of the arts from the various nations they subdued, during the reign of Omar, who died A. D. 644. It was this prince who founded a mosque, still called after his name, on the site of the ancient temple at Jerusalem, and which, by the additions and embellishments of succeeding kaliphs, has been reared into a large and magnificent pile. With the commencement of the Ommiad dynasty, was introduced a taste for the cultivation of the fine arts, and after the first kaliph of that house had removed the seat of empire from Medina to Damascus, the Moors began to assume the refined manners and the magnificence of the more polished Asiatic empires. During this and the following reigns, Damascus was adorned with numerous and splendid public buildings, amongst which the great mosque, founded by Alwalid I. is particularly celebrated. This prince was the first to introduce the minaret, an appendage which, although an innovation at the time, has now become a marked characteristic of Mohammedan buildings. He likewise made considerable additions to the mosque of Medina, and enlarged and adorned that built by Omar at Jerusalem to which we have referred above; in short, he expended a great portion of his revenues in the promotion of architecture, an example which was followed by his subjects generally.

The zeal of this race, however, in the promotion of the fine arts was surpassed by the house of El Abbas. The second kaliph of the Abassides removed the seat of empire from Damascus to Bagdad, which was founded by Almansur, A. D. 762, and continued in affluence and splendour for the space of five hundred years. "In the structure and decoration of this city, neither labour nor expense were spared, and the details of the gorgeous magnificence of the kaliph's palace would almost exceed the ordinary limits of belief, were they not authenticated by contemporary and ocular testimony."

Egypt and Africa were at an early period in possession of the Arabs, and the seat of empire was placed at Cairo, which was founded by the victorious general, Akbah, and flourished chiefly under the Fatimite line of kaliphs, who in the tenth century founded the new city of Cairo, and affected to rival the kaliphs of Asia in the splendour and magnificence of their buildings. Numerous vestiges of their edifices still remain, and amongst the most stately must be enumerated the great mosque, which is accounted the most magnificent in Barbary, and is said to be supported by five hundred columns of granite, porphyry, and Numidian marble.

But of all the Moors, those of Spain were surpassed by none in the magnificence and grandeur of their buildings, which rivalled, if they did not excel, those of Damascus, Bagdad, and Cairo, even in their most palmy days. The exceeding splendour of the mosque at Cordova, and of the palaces of the Alhamra and El Genaraliffe, places those buildings on an equal footing with the most celebrated cities of antiquity; and as the remains here are more numerous, and withal better known and more readily accessible, than those of Asia or Africa, they are usually made to form the groundwork of an examination of the general style, and to afford examples of its application;—a practice which we shall adopt in the present article.

It is remarkable that while the Arabs were diffused so widely over the earth's surface, the style of architecture adopted by them retained in every place a striking identity. It is true that differences of detail may be found in different places, as well as variety of application, yet in every country their buildings retain a very close general resemblance. This similarity is to be accounted for probably by the peculiarity of their religious creed, which, wherever it is professed, diffuses a close uniformity of habits, manners, and opinions. Notwithstanding, however, this general resemblance, which is amply sufficient to identify all buildings of this race as belonging to the same style, it must not be understood that, as a style, the Moorish was at any given period exactly the same in different countries under their dominion, or in one country at different periods, or even at the same period, for such was not the case. Indeed, if we may judge from the remains of some edifices in Asia and Egypt, of apparently the same date, we shall perceive many distinctions not only in the minutiæ of the ornamental and apparently characteristic ornaments, but also in their distribution. It is to be regretted that we have but little knowledge of the Asiatic and African remains of this style, for we are thereby prevented instituting a satisfactory comparison between the example of different localities and dates. The edifices of Spain, of which we have no inconsiderable information, must suffice as a type of the style, for which purpose they will probably serve better than those of any other country.

Various opinions as to the merits of this style have been entertained by various writers, some speaking of it in a very disparaging manner, as fanciful and capricious, whilst others extol it as elegant and poetical. It is in truth eminently fanciful, but this we judge to be rather to its praise than otherwise, as evidencing a lively and fertile imagination on the part of their architects: their buildings are indeed the embodiment of a luxuriant fancy, tempered, however, in most cases with taste and judgment. It is true that this style may not rank amongst the higher examples of the art, for it is notably deficient in constructive science; and in this feature it falls immeasurably below its rival in variety and luxuriance—the Gothic or Pointed style. In the latter the construction is paramount; in the former it is made entirely subservient to ornamentation.

Nevertheless, although Arabian architecture does not present that appearance of strength and security which is to be looked for in the perfection of the art, it never fails to gratify the eye as well as the imagination, by the richness of its picturesque and fantastic decoration; for all its parts are perfectly symmetrical, and never degenerate into heaviness or incoherence. Neither do we mean to assert that the Arabians erected their buildings without any reference to the principles of construction, for we know that they had attained great proficiency in the mathematics, and we can scarcely suppose that they neglected to apply them to such a purpose; indeed, we have very satisfactory proof to the contrary in the durability of their buildings. We are equally unacquainted with the rules by which they were guided, or the proportions which they observed in the art, and yet we know that they worked by well-defined rules, and that numerous treatises were written upon the subject, as we learn from the Arabian MSS. in the Escurial. Their ideas of design in this art must have been borrowed from a great variety of sources, amongst which may be enumerated the edifices of Egypt, Syria, India, Greece, Rome, and Byzantium, and out of all these they eliminated a style which is perfectly distinct from every one of them. All these styles, diverse as they are, were blended together with such taste and skill, and the borrowed forms so moulded and adapted, as to form one harmonious and perfect whole. The style, which is eminently peculiar, would seem to have been a development of their religious creed; it breathes the very spirit of Islamism; it is sensual and voluptuous, and appeals to the gratification of the senses rather than to the higher and nobler faculties of the mind: the Egyptian awes by its grandeur; the Grecian elevates by its purity; the Gothic humbles by its solemnity; but the Moorish gratifies only by its luxury. Of all the Mohammedans, the Turks seem to have deviated most widely from the general character of this style, by giving a preponderance to the Byzantine peculiarities by which they were surrounded in their chief city, Constantinople.

Amongst the characteristics of Moorish architecture the *horse-shoe* arch stands conspicuous. This is sometimes called the *crescent* arch, a name which may probably give us some clue to the reasons for the adoption of this form, which is indeed that of a crescent, the peculiar symbol of the Mohammedan faith; in imitation of which, it is reasonable to suppose it was introduced in a prominent position in their buildings. We shall the more readily concur in this suggestion, when we consider that such a form could not have been dictated by any principles of construction; against which it offends not a little. We must therefore look for some other reason, and that not a weak one, which could induce the Arabians to disregard the ordinary and simple axioms of construction; and we think we find a sufficient one in the idea just broached, that it was to symbolize their religious faith. The fact that it was named by the Mohammedans, the sacred arch, will tend to corroborate this statement. The shape was first introduced into architecture by Muavia, the first of the Ommiad dynasty, who adopted it in all the buildings he erected, and it afterwards became common in all countries into which the Moors had penetrated. The same outline is found in the bulbous dome, which is so peculiar a feature of the Mohammedan mosque; and there can be no doubt but that this dome was suggested by the crescent arch, no more indeed than that the semicircular or segmental domes were derived from the corresponding arches. We might say that the probability in the former case is the stronger, inasmuch as that form of dome is scarcely natural, and not to be accounted for by requirements of construction. The profile of the bulbous dome is precisely that of the horse-shoe arch. Another instance in which the crescent-shape appears, is the cusping or scalloping of the soffit, or sometimes of both outlines of the arch, which is a common practice, and may have given rise to the use of cusps in Gothic architecture.

The profile of the horse-shoe arch is that of a segment of a circle greater than a semicircle, or, in other words, it is a circular segmental arch, which is struck from a centre above the springing line. A modification of the same form is used, which may be termed the *pointed-crescent* or *horse-shoe* arch. This form consists of two segments meeting in a point at the apex, and is struck from two centres, both, as before, above the springing line.

The *semicircular* arch was borrowed by them, and used occasionally in conjunction with the others. The *pointed* arch is by some supposed to be invented by the Arabians, and to have been copied from them by the Gothic architects; be this, however, as it may, it is certain that it was extensively in use amongst them, and is found in Persia, Egypt, and Arabia, but was most prevalent at Bagdad and in the East. It is said to have been introduced by the house of El Abbas, who adopted it in opposition to the crescent form which had been employed by the rival house of the Ommiades; but even by them the old form was not entirely discarded, being retained in the principal entrances, and also in the form of the domes.

Another variety of arch is the *stilted*, which is of semicircular form, the centre from which it is struck being taken, as in the case of the horse-shoe arch, somewhat above the springing line; but instead of the circle being continued downwards, and contracted in width towards the impost line, the ends of the semicircle are carried down straight or perpendicularly, so as to give an appearance of elevation and lightness to the arch, which it would not otherwise possess.

The last form which we shall notice is the *cusped* or *scalloped* arch, the outline of which is similar to the polyfoil-headed compartments in Gothic apertures, being produced by three or more intersecting semicircles. There is this difference, however, that whereas the Gothic examples are merely ornamental accessories, the Moorish form main parts of the construction; the scallops are large and form the outline of their main arches, the extrados as well as the intrados following the same profile.

All the above forms of arches are treated in various ways, both as to their impost and decoration. Sometimes the arch springs directly from the solid wall, at other times it is made to rest upon columns. In the case of the horse-shoe arch, when the former arrangement takes place, the whole of the arch rests upon the wall, or, in other words, the wall projects as far as the most prominent part of the arch, so that the arch does not overhang the impost; but in the other arrangement, the columns are recessed back so as to range with the extremity of the diameter with which the arch is struck, thus leaving a space between the columns as wide as the diameter or extreme width of the arch; the capital of the column, or an impost moulding above it, projects forward so as to sustain the extremities of the arch. Sometimes, but more especially when *stilted*, the arch is supported by corbels projecting from the walls, and serving as imposts. This practice of corbelling is very prevalent. In some cases the face of the arch, that is, the width between the intrados and extrados, is continued down the impost-jambs, but in others it stops at the springing. This face again varies considerably in breadth, and sometimes is not shown at all on the face of the wall; it is generally, however, a wide band or archivolt following the outline of the arch, sometimes plain, showing only the joints, sometimes plain with the addition of a moulding round the extrados, and at others both moulded and otherwise decorated. The decoration is usually in compartments formed by the joints, and frequently the alternate voussoirs are contrasted by a difference of ornamentation. The depth of the archivolt was sometimes so great as to equal the radius. Cusping in the direction of the outline of the arch is a common mode of decoration, being sometimes applied in the shape of a moulding round the extrados, and sometimes the intrados or soffit only being so cut or serrated. Occasionally the arches of apertures are left blank, being filled up with walling, and having a square-headed aperture underneath: this is especially the case with the crescent arch. Arches of whatever kind are generally placed within a square-headed panel or compartment, which is frequently surrounded by a border or plat-band, somewhat similar to the square hood-mould of the perpendicular period of Gothic architecture. This band, as well as the spandrels intercepted between it and the arch, are usually covered with ornamentation of various descriptions. Sometimes two plat-bands are introduced, with a space between them, which is commonly filled up with inscriptions or other decoration. This last method, however, is not common except in large apertures, or in principal entrances.

The columns are of slender proportions, and remarkable for extraordinary lightness and variety of form. Their shafts are sometimes plain, but often ornamented with carving, being sometimes surrounded with a spiral groove twisting round the shaft, at others grooved perpendicularly. The capitals are of various forms, usually carved into clustered foliage, being sometimes imitations of the classic orders, and sometimes designs of their own; the cap is covered with a plain abacus. Columns were very frequent in Arabian edifices, disposed in clusters or rows, and supporting low arcades; they add considerably to the light appearance of their buildings.

Corbelling, which consists in the projection of stones or bricks at regular distances from the main wall, is of extensive use in Arabian architecture, and was probably introduced into Europe by them. The practice seems to have originated in the East, for it is seen in Eastern edifices of very early date, and prevails to a great extent in the architecture both of India and China. The Arabians employed corbels in all their structures, but more especially in their fortresses, to throw out the parapets for machicolations.

Amongst the many peculiarities of Arabian art, perhaps none is more worthy of mention than that method of ornamentation which has been designated under the title of *arabesques*, although the term, as applied by the moderns, does not exactly describe the peculiar ornament alluded to; with us, the term includes a wider range of decoration. The law of the Mohammedan faith prohibited all representations of human or animal figures, as bordering too closely on the practices of Christianity and paganism, and this precept was at first very strictly adhered to. Their arabesques therefore, excluding all forms of animal life, consisted entirely of representations of fanciful plants, stalks, and foliage, treated in an artistic manner, and gracefully entwined in an endless variety of form; these were introduced on the walls, sometimes in colour only, but very often in stucco, the pattern standing out from the wall in high relief.

Another style of decoration, very similar to the last, consists of panels or compartments filled with lines or bands, disposed in an infinite diversity of geometrical figures, and interlacing one with another in such a manner as to form a sort of labyrinth, whose arrangement and combination was unintelligible, except by close observation. Of this method of decoration, a writer on the subject very justly observes—"Their geometrical patterns exhibit singular beauty and complexity, inexhaustible variety of combinations, and a wonderful degree of harmonious intricacy, arising out of very simple elements; to which must be added the variety produced by colour also, whereby the same arrangements of lines and figures could be greatly diversified. Hence, though apparently quite unmeaning, and intended only to gratify the eye, such embellishment must have powerfully recommended itself to a people both imaginative and contemplative, and whose fancy would find occupation in patiently tracing and unravelling the manifold intricacies and involvements, the mazes of what at first sight looks like a mere labyrinth, until its scheme unfolds itself; but merely momentarily, as it were, being again lost when attention is diverted from it to particular parts.

Another method of decoration, which was very prevalent, and is to some extent a characteristic, consists in the application of inscriptions as a means of enrichment. This custom was in all probability borrowed from the Egyptian practice of inscribing hieroglyphics on their walls; although the idea is somewhat differently applied. A nearer approach to the Arabian system, is seen in that adopted by the Gothic architects, the application in both instances being almost identical. The most usual position for such inscriptions was round their doors and windows, or on the surface of bands, architraves, and friezes; they were usually raised in relief from the surface of the wall, and oftentimes inlaid similarly to mosaic work, and richly illuminated with precious stones; in almost all cases, they were enriched with gilding and colour, and the characters rendered as calligraphic as possible. The inscriptions which mostly prevailed, were sentences from the Koran, sometimes other moral and religious precepts, and occasionally passages of Oriental poetry, the nature of the inscription varying in accordance with the requirements of the place or building they enriched.

Another addition to the decorative character of the style, is seen in the open trellis-work employed to close apertures—a happy contrivance for excluding the rays of the sun at the same time that it admitted freely both light and air; a matter of great importance in a warm climate. The idea is supposed to have been derived from network, suspended before apertures for the same purposes, as well as for the exclusion of insects; it is decidedly of Oriental origin. This fret-work is composed of bands interlaced, and forming an infinite variety of figures, and is very similar to the geometrical patterns we alluded to above.

The designs are often very elegant; and although they appear somewhat intricate at first, upon closer examination it will be found that they are composed of simple parts as simply put together, and yet they produce a great variety of tasteful patterns, in which the star is not unfrequently a prominent figure. The same eulogy will apply to this lattice-work, as to the geometrical arabesques. A similar method of interlaced work, is not unfrequently to be seen in their pierced parapets, which were common in the edifices of the East.

The floors, and sometimes a portion of their walls, were inlaid with mosaic work, disposed in various patterns, in which the interlacing band again makes its appearance, and with like success. The roofs are often coffered or recessed in panels in a very peculiar manner, which gives to them very much the appearance of a honeycomb; sometimes also they are covered with pendants, in such a way as to realize the idea of stalactite caverns. A very beautiful method of lighting their baths from the roof, has been noticed and extolled by almost every traveller; small star-shaped apertures are cut in a sloping direction through the roof, and while their form delights by its beauty and propriety, they admit only a subdued degree of light.

On the whole, when we consider the fantastic form of the arches, the slender proportions of their columns, the infinite variety and profuseness of their decorations, and remember that the entire edifice was enriched with the most brilliant colouring, it must be confessed that it would be difficult to picture a more vivid realization of our notions of fairy-land, than is presented to us by such a description.

Notwithstanding, however, the gorgeousness of their interiors, the Arabs, of Spain especially, paid little attention to external decoration. The exterior of their edifices is decidedly plain, sometimes approaching to rudeness, frequently composed of irregular masses of scattered buildings, without symmetry, or any attempt at ornament, and to be admired only for their bold outline and picturesque effect. One circumstance which adds to their heavy, massive appearance, arises from their custom of lighting their halls from the interior courts, so as to escape as much as possible the heat of the sun.

Their mosques and other buildings in the East presented a less rude exterior, the outline being broken up and varied by the numerous domes and minarets, the lofty and slender forms of the latter forming a picturesque contrast with the swelling curves of the former. These minarets are light circular towers, elevated above the rest of the building, with projecting galleries round the upper part, whence the imaum called to prayer; they are usually enriched with a profusion of delicate fret-work. Many mosques were covered with a multitude of domes, one principal one being larger than the others which surrounded it. The walls too are more enriched than those of the buildings in the West, and altogether the exteriors were of a much lighter and elegant description. *See* Mosque.

M. Laborde, in his voyage "Pittoresque de l'Espagne," divides Arabian architecture of Spain into three distinct chronological periods: the first of which dates from the establishment of Islamism to the ninth century; the second from the ninth to the thirteenth century; and the last, from that period to the decline of Mohammedan influence in Spain. The mosque of Cordova has been selected as the most apt type of the first period: a building which bears a close resemblance to the later works of the Romans, the plan corresponding in many respects with the oldest churches in Rome, and the materials being either procured or coarsely imitated from the Baselaine, which had been previously erected in Spain by the Romans.

In the second period, we see a considerable advance in elegance, of which the palace of the Alhambra presents a favourable example. In this period, most of the traces of the Byzantine style disappear, and the new style is seen in a state of perfect development; indeed, the examples of this date are of greater beauty, and more correct taste, than those either preceding or following it.

The third period shows a decline in art, and its examples exhibit a mixture with the style then prevalent in Italy, and which was spreading itself throughout Europe. M. Laborde found specimens of this style in the fortresses of Benevente, Pennafiel, Cordesillas, Segovia, and Seville. At this date the plans continued much the same as before, but Greek ornaments began to be employed, and Corinthian columns are frequently seen supporting Moorish arches. The restrictions also respecting the representation of living figures began to be less strictly adhered to.

We forthwith proceed to give a description of some of the more noted Spanish structures of this style, at the head of which in point of date, if not of importance, stands the mosque of Cordova.

This place is stated to have contained no less than 600 mosques, 900 baths, and 2,000 houses. Of these buildings the mosque to which we allude was one of the most important; it was commenced by Abdurrahman in the eighth century, and completed by his son and successor, Hisham, in the same century, since which period it has been frequently enlarged and enriched by subsequent kaliphs. The plan of the building is a rectangle or oblong, whose longest side from north to south is 620 feet, and that from east to west 440 feet; the whole space being enclosed by a wall with counterforts, both of which are embattled, and surrounded by four streets, which renders it isolated from all other buildings. The wall is 8 feet thick, and varies in height from 35 to 60 feet. The entire space enclosed by it, is divided into two parts, the first of which, at the northern extremity, was the court in which the Moslems performed the requisite ablutions ere entering the mosque. This quadrangle measured 210 feet in depth, and was surrounded by a colonnade of 72 columns enclosing three fountains. The remaining space is occupied by the mosque, which is divided internally into 19 naves, running from north to south, and extending in length about 400 feet, and into 32 from east to west. Each of the naves from south to north is about 16 feet wide, and those in the cross direction somewhat less, and are separated from each other in both directions by rows of columns, whose number amounted in all to 850, to which, if we add the 72 in the external colonnade, we shall have a total of 922 columns. They were composed of jasper and the richest marbles, measuring 18 inches in diameter, and on an average 15 feet in height: their capitals are of various designs, but all approaching the Corinthian or Composite in form, and upon these spring the arches. There were no less than 21 entrances, the doors of which were all covered with the best Andalusian brass. The cupola was 72 cubits, or 108 feet in height, and was surmounted by three apples, two of which were of pure gold, and the central one of silver, each measuring three spans and a half in circumference. The ceilings were of wood painted, each range forming on the exterior a small-roof, separated from the adjoining one by a gutter. The chief entrance that led into the Maksura or sanctuary, is said to have been formed of gold, as were also the walls of the Mibhra or chancel: the floor of the Maksura was of pure silver, and in it, on a throne of wood of aloes, with nails of pure gold, was preserved, in a case of the same metal set with pearls and rubies, the principal copy of the koran. The pulpit was formed of the most precious woods, such as ebony, sandal, brazil, citron, and wood of aloes, and occupied a period of seven years in its manufacture. The interior of the edifice was lighted by 280 chandeliers of brass and silver, containing 11,000 lamps.

Cordova once possessed a palace, which, according to the accounts of Mohammedan writers, was of the greatest magnificence; of this, however, although of more recent erection than the mosque by two centuries, we have no remains: it is said to have been adorned with 4,000 pillars of marble, and to have had floors of the same material.

The Alhambra is the most perfect and beautiful building of this style with which we are acquainted, and one of which we have more detailed information than of any other. It is situated on the northern brow of one of the steep hills of Granada, and is approached from the city through a narrow street, which leads to the entrance, called the Gate of Judgment, so named from the ancient practice of holding the courts of justice at the entrance of cities. This gate is a square tower, with an entrance under a large horse-shoe arch, which reaches half-way up the tower, and has an open hand sculptured on the key-stone, emblematical of the omnipotence of the Deity. The gate is of white marble, which, however, has become much discoloured through age and exposure; it is decorated above with mosaic tiling, about 3 feet 4 inches in height, beneath which is an inscription in Cufic characters, of the motto "There is no conqueror but God," and beneath this again on the keystone of the arch is sculptured a key, one of the principal symbols of the followers of Mohammed.

The entire plan of the building measures 2,300 feet, by 600 feet, and is divided into several courts, all upon the same plane. The first of these is the court of cisterns, so named from the cisterns which it contains, and which supplied the palace with water. The largest cistern is 102 feet long, and 56 feet wide, the whole being enclosed by a wall 6 feet thick, and covered over with an arch 47 feet 6 inches in the centre, and 17 feet 6 inches below the surface of the ground. There are two circular apertures 25 feet 6 inches apart, and 3 feet 6 inches in diameter, strongly built, and carried up 3 feet 6 inches above the level of the ground. The water is by this means kept in a constant state of coolness; in warm climates, a matter of some importance.

On the north side of the Court of Cisterns, is the Mesuar, or common bathing-court, which is an oblong of 150 feet by 56 feet. This hall is more enriched than the last, which leads us to notice a common practice of the Moors, that of increasing the luxury and magnificence of their decorations towards the interior of their buildings. In this hall there is an arcade springing from very light marble columns, of which material the floor also is composed; the walls are covered with mosaic tiling up to the ceiling, in which are small apertures in the shape of stars, lined with green-glazed tiles, to assist ventilation, and diffuse a refreshing coolness throughout the building. The bath-rooms of the kaliph and sultana are very richly finished, ornamented with gilding and porcelain: the basins are of white marble, and the walls are covered to the height of the cornices with black and white mosaics. The roof is of stone, vaulted, and is perforated for ventilation, as above.

At the lower end of the Mesuar is the Court of Lions, which is considered one of the most splendid examples of Moorish architecture still existing. It is, like the others, an oblong court, measuring 100 feet in length by 50 in breadth, and is surrounded with a corridor or arcade, supported by 128 columns of white marble, 9 feet high, and 8½ inches in circumference. The capitals vary in design; each design being frequently repeated, but similar designs being placed without any regard to regularity. The columns also are disposed irregularly, sometimes singly, at others coupled, and occasionally in groups of three.

The arches are of different sizes, the larger being 4 feet 2 inches wide, the smaller about 3 feet. They are enriched with a profusion of highly finished arabesques, and surmounted with an inscription; a rich cornice runs round the entire court. The floor of the colonnade is laid with white marble, and the dado of the walls is formed of a lining 5 feet high, of brilliant yellow and blue mosaic tiling, with a border containing the inscription. "There is no conqueror but God," in blue and gold. At each end of this court projects a kind of portico, supported, like the colonnade, with light marble columns and arches, and having a fine stuccoed ceiling. In the centre of the court stands the celebrated Fountain of Lions, which consists of an alabaster basin, richly decorated, supported on the backs of twelve lions, and carrying another smaller basin above. from which the water fell into the larger one, and thence through the lions' mouths into a large reservoir of black marble.

From the right-hand side of the Court of Lions, is a passage to the Hall of the Two Sisters, so named, from the two beautiful slabs of white marble forming part of the pavement on each side of the fountain, and which measure 15 feet by $7\frac{1}{2}$ feet, the entire surface being perfectly free from crack or stain. "The walls are decorated from the pavement to the rise of the arches, with the usual elegant mosaics; the panels between them are filled with a delicate ornament, which, at a little distance, has the appearance of a plain face; the ceiling is composed of stalactites, in stucco, and finished in a style of great elegance. The four balconies of this sumptuous apartment were appropriated to musicians; the women of the harem sat below, and a jet d'eau in the middle diffused a refreshing coolness through the hall. The windows look into a little myrtle garden."

On the other side of the Court of Lions, and opposite that of the Two Sisters, is the Hall of the Abencerrages, said to be so called, from the circumstance of some noble Arabs having been put to death there by one of the kings of Granada. "It appears to have been a central saloon, opening a communication to the other parts of the palace. Every possible variety of combination which can be devised by ingenuity and patience, are formed on the walls and ceiling; the lines regularly cross each other in a variety of directions, and return again to the point from which they were first projected. The extraordinary designs are thought to have been produced by pouring prepared gypsum into moulds, and, after it was applied to the walls, painting them with gold, azure, and purple.

"The concert-room of the baths is a lofty saloon, in which the royal family listened to the concerts of musicians, stationed in an elevated tribune, while the audience sat below on rich carpets. The columns are of white marble, and the mosaics between the columns are black, green, yellow, and white, set in a green border; the roof is covered with tiles, and the woodwork richly ornamented, especially the three lattices or windows."

The Hall of the Ambassadors is a square court, the sides of which measure 36 feet, and the height 64 feet. It is entered through an arched door, decorated profusely with arabesques in stucco, coloured in blue and gold. The walls are covered with mosaics of various patterns, interspersed with inscriptions formed in porcelain, and made to form a most harmonious combination with the stucco arabesques; the cornices are enriched with the same inscription as in the other halls. The ceiling is arched and decorated with great variety of chiligon mosaics, knots, and other ornaments; and gold, silver, and azure purple, are the colours covering the coloured facets; the floor is inlaid with mosaics. The walls of this hall are of an immense thickness, no less than 15 feet on three sides, and 9 feet thick on the fourth; they are composed of a mixture of pebbles and red clay. "The ceiling is composed of strong pieces of larch, in admirable preservation, which are keyed and fastened together in such a manner, that, on pressing the feet on the centre of the ceiling, the whole vibrates like a tight rope. The roof is formed of a scantling of 10 inches square deal, and laid close together, with cross-braces at the angles. Bricks are laid on these rafters, and upon them is a coating of lime; on these are placed the bricks and tiles forming the exterior covering of the roof.

"The walls of this splendid building are formed throughout of a sort of rubble-work mixed with clay, and were, on an average, 7 feet in thickness, flanked with solid towers 18 feet thick; bond-timbers of pine were inserted in the walls, and at other times, strands or twists made of rush were inserted for the same purpose; nails were driven into the walls to receive the plaster, being first coated with gypsum to prevent corrosion, but when timbers were to be plastered, they twisted Esparta cords round them to bind the plaster. The bricks with which the open courts are paved. are 14 inches long by $7\frac{1}{2}$ wide, and 3 inches deep; the underside had a groove sunk in it about $2\frac{1}{2}$ inches wide and 1 inch deep, and extending the length of the brick, for the purpose of forming a good bond with the cement. When these bricks were laid over boarding, a layer of potters' clay, or of bricks laid dry, was placed between the timber and the paving.

"The durability of the woodwork throughout this building is surprising, it is mostly of pine, and has withstood the attacks of dry-rot, worm, and every other insect, without injury; it seems now perfectly sound, and free from every sign of decay, and it is even stated, that, in the Court of Lions, the ancient woodwork is perfect, whilst that of later date is rapidly decaying." The Spaniards attribute this durability to the timber being coated with a composition consisting of Safne glue and garlic well pounded in a mortar; these being mixed together, with the addition of vermilion, are boiled over a gentle fire, until the glue becomes as thin as water; too much or too little boiling deprives it of its viscous property. Planks cemented with this composition are said to adhere so firmly, as to break at any other part except at the joint. Garlic being noxious to worms, the Moors evidently mixed it with their cement, in order to prevent their depredations; it is not improbable that it was mixed with the gypsum used in the Alhambra, which may account for the stucco work remaining uninjured either by spiders or insects. Some suppose that this durability arises from the trees having been lanced or deprived of their sap when felled.

The durability of the Arabian buildings of Spain will appear more marvellous when contrasted with other buildings. The wooden gate of Cyprus, belonging to the celebrated temple of Diana, is said to have existed for four centuries, and that of the old church of S. Peter at Rome, which was composed of the same material lined with sheets of silver, continued undecayed for 550 years, but the beams employed in the construction of the roof of the mosque of Cordova manifest no symptoms of decay after a lapse of 1,000 years.

The arabesques, paintings, and mosaics, which give so great a charm to this building, are very highly and carefully preserved. The former appear to have been cast in moulds, and fixed to the walls in pieces so accurately connected, that no sign of juncture is visible. The ornaments which recede from the eye are coloured in gold, pink, light blue, and dusky purple, the first colour being nearest to the eye, and the last farthest from it, the general surface being white, which is remarkably pure and splendid. All the colours are fresh and bright, and, if the dust be removed, appear in all their pristine beauty.

The domes and arcades are formed of artificial casts, which are almost as light as wood, and as hard as marble, having endured the test of ten centuries.

A house built during the third period still exists at Seville, which was the residence of a Moorish Arab chieftain; the whole is most voluptuously contrived for a warm climate, and is in the most perfect state of preservation, though upwards of 500 years old; one of the apartments is almost perfect of its kind. The form resembles a double cube, the one placed above the other, its height about 60, and its length and breadth about 30 feet. The ornaments begin at about 10 feet from the floor, and are continued to the top of the room: they consist of a kind of variegated network of stucco, designed with the most perfect regularity, and yet most admirable variety in the patterns and the interlacings of each. This edifice has often been adduced as an instance of the wonderful superiority of the Arabs over the modern Spaniards in the art of building.

There is one very ancient and remarkable building which we have not here described, but which may not be passed over without notice; we allude to the CAABA, of which a description will be found under that head.

For further and more detailed descriptions of this style of building, we refer the reader to the elaborate works of Jones and Murphy.

MOOR-STONE, a very remarkable stone, found in Cornwall, and some other parts of England, used in the coarser works of modern builders. It is, in fact, a white granite, and is a very valuable stone. It is very coarse and rude, but has beautiful congeries of variously constructed and differently figured particles, not diffused among, or running into one another, but each pure and distinct, though firmly cohering with whatever it comes in contact. Its colours are principally black and white: the white are of a soft marble texture, and opaque, formed into larger congeries, and emulating a sort of tabulated structure; among these are many of a pure crystalline splendour and transparence; and in some are lodged, in different directions, many small flaky masses of pure talcs, of several colours; some are wholly pellucid, others of an opaque white, others of the colour of brown crystal, and a vast number perfectly black. It is found in immense strata in some parts of Ireland, but is disregarded there.

It is found with us in Devonshire, Cornwall and some other counties; and brought thence in vast quantities, to London. It never forms any whole strata there, but is found on the surface of the earth, in immense and unmanageable masses; to separate these, and render them portable, a hole is dug in some part of the mass, which being surrounded with a ridge of clay, is filled up with water; this by degrees soaks in, and finding its way into the imperceptible cracks, so far loosens the cohesion of the particles, that the day after, on driving a large wedge into the hole, the stone breaks into two or more pieces. It is used in London for the steps of public buildings, and on other occasions, where great strength and hardness are required.

MOOT-HALL. MOOT-HOUSE, a town-hall; hall of judgment. In the *moot-halls*, formerly connected with the inns of court, imaginary or moot-cases were argued by the students at law.

MORESK, or MORESQUE, (from the Spanish *morisco*,) a kind of painting, carving, &c., done after the manner of the Moors, consisting of several grotesque pieces and compartments promiscuously intermingled, not containing any perfect figure of a man or other animal, but a wild resemblance of birds, beasts, trees, &c.

They are also called *arabesques*, and are particularly used in embroideries, damask-work, &c.

MORTAR (from the Dutch *morter*, cement) in architecture, a composition of lime, sand, &c. mixed with water.

In the construction of works in masonry, some kinds of cementitious matter is generally employed for connecting the stones together, and rendering them firm and compact. When the works are to be exposed to the action of water immediately after being built, this cementitious matter must be of such a nature, that it will harden under water. Hence it is, that we have occasion for two kinds of mortar, one that will set and harden under water, called by Smeaton a *water-mortar*, or cement; and *common mortar*, for ordinary buildings. *See* MORTAR, HYDRAULIC.

Common mortar is the substance placed between the stones or bricks of a building, to cement them together, and thus cause them to retain their places, and give strength and stability to the edifice. Mortar is essentially composed of lime and silicious sand, the first being in the state of hydrate or slacked lime: the sand is used of different degrees of fineness. The hardness of mortar is owing to the gradual conversion of the hydrate of lime into carbonate of lime, which takes place very slowly by the absorption of carbonic acid gas from the atmosphere; in this state it adheres very firmly to the particles of silica diffused through it, and both are strongly united with the material employed in the building.

In order that this change may occur with advantage, certain conditions are requisite: if the mortar dries too quickly, the carbonate formed will remain much divided, and will not acquire the necessary adhesive property; if on the other hand, the mortar be placed under water, a portion of the lime will gradually dissolve, what remains will become carbonate with great difficulty, and the particles of sand will be isolated. If, on the contrary, the mortar be long kept moist and exposed to the air, the carbonic acid gas acts slowly but incessantly on the lime, the water of which becomes gradually saturated with it, and this being transferred to the lime, it is converted into almost a crystalline carbonate, in successive portions or layers, and these adhere with great force to the particles of sand. It follows, from what has been stated, that buildings erected when the weather is too hot are less stable than those which are constructed later in the year; but it is to be observed, that during frost, owing to the freezing of the water, the absorption of carbonic acid is not only stopped, but the solidity of the mortar is destroyed by the freezing or crystallization of the water.

Much has been said as to the extreme hardness of ancient mortar, and it is supposed that some secret method was adopted in its preparation; but the fact may probably be accounted for by merely referring to the circumstance, that the long exposure which it has undergone in considerable masses has given it the opportunity of slowly acquiring the carbonic acid from the air, upon which its hardness and durability depend. It is to be observed, that lime which is not sufficiently burnt, or lime which has been slacked by the moisture which it has acquired by exposure to the atmosphere, cannot form good mortar: the first has not been deprived of the carbonic acid which it is requisite to regain slowly from the air; and the latter has re-acquired it under circumstances which diminish instead of increase the solidity of the mortar.

Other materials, such as limestone, marble, chalk or shells, may be used to burn for lime or common mortar, all these substances being composed chiefly of lime and carbonic acid; and if a piece of one of them be slowly burnt or calcined, so as to expel the whole, or nearly the whole, of its carbonic acid, it loses about 44 per cent. of its weight; and when a small quantity of water is added to the calcined matter, it swells, gives out heat, and falls into a finely-divided powder called *slack lime*. The bulk of the powder is about double that of limestone. If this powder be rapidly formed into a stiff paste with water, it sets or solidifies as a hydrate of lime, and ultimately hardens by the absorption of carbonic acid from the air. This constitutes common building-mortar. Hydrate of lime consists of 100 parts of lime, and 31 parts of water. Common limestone consists of carbonate of lime, with very little of any other substance; it produces a white lime, which slakes freely when well burnt; it dissolves in diluted muriatic acid, with only a small portion of residue, and never contains more than a trace of iron. It differs much in external characters, as chalk, marble, common compact limestone, &c.

These limestones do not form cements to set in water, without the addition of other kinds of cementing matter; hence they are usually employed only for common mortar. The hardest marble and the softest chalk make equally good lime when well burnt; but chalk-lime will slake when not perfectly burnt, and therefore seldom has a sufficient quantity of fire; whereas stone-lime does not re-absorb carbonic acid so rapidly as chalk-lime.

Lime made from common limestone, sustains very little injury from being kept after it has been formed into mortar, provided the air be effectually excluded; indeed, Alberti mentions an instance of some which had been covered up in a ditch for a very long time, and yet was found to be of an excellent quality.

To employ lime alone in the composition of mortar would render it expensive; besides, it would be of inferior quality. The material commonly used to mix with lime is sand, and this sand should be of a hard nature, not very fine, but angular; also, the more irregular it is in size, the better. It should be free from any mixture of soft or earthy matter, if it can be procured without. The reason is obvious; for mortar, composed of soft sand, cannot be harder than that sand. Sea-sand makes good mortar, particularly water-mortar. Very hard-burnt brick, or tile, reduced to a coarse powder, also makes an excellent substance to mix with lime, for many purposes. It may be observed, although generally supposed otherwise, that there is really no chemical affinity between lime and sand, it is only a mechanical mixture.

De Lorme observes, that the best mortar is made of puzzolana instead of sand; adding, that this penetrates black flints, and turns them white. Mr. Worledge observes, that fine sand makes weak mortar, and that the larger the sand the stronger the mortar. He therefore advises, that the sand be washed before it is mixed; and adds, that dirty water weakens the mortar considerably. Wolfius recommends that the sand be dry and sharp, so as to prick the hands when rubbed; yet not so earthy as to foul the water in which it is washed.

Vitruvius observes, that fossil sands dry sooner than those taken out of rivers. Whence, he adds, the latter is fitted for the insides, the former for the outsides of a building. But fossil sand lying long in the air, becomes earthy.

Palladio takes notice, that of all sands the white are the worst, from their want of asperity.

The proportion of lime and sand in our common mortar is extremely variable: Vitruvius prescribes three parts of pit-sand, and two of river-sand, to one of lime; but the quantity of sand here seems to be too great.

The best proportion of sand for common mortar, is easily ascertained by trial; enough should be added to render the mortar rather short than tough under the trowel. The proportion varies from 4 parts of sand to 1 of lime, or $1\frac{1}{4}$ parts of sand to 1 of lime, by measure, the proportion differing according to the coarseness of the sand, the nature of the limestone, and the precautions used in burning it; all set proportions being universally adhered to only by those who are utterly ignorant of the subject. In many situations, it is impossible to procure good sand, except at an enormous expense.

Mr. Dossie, in the second volume of the *Memoirs of Agriculture*, p. 20, &c., gives the following method of making mortar—impenetrable to moisture, acquiring great hardness, and exceedingly durable—discovered by a gentleman of Neufchatel: Take of unslaked lime and of fine sand, in the proportion of one part of the lime to three parts of the sand, as much as a labourer can well manage at once; and then adding water gradually, mix the whole well together with a trowel, till it is reduced to the consistence of mortar. Apply it, while hot, to the purpose, either of mortar, as a cement to brick or stone, or of plaster to the surface of any building. It will then ferment for some days in dry places, and afterwards gradually concrete or set, and become hard; but in a moist place it will continue soft for three weeks or more; though it will, at length, attain a firm consistence, even if water have such access to it as to keep the surface wet the whole time. The lime for this mortar must be made of lime-stone, shells, or marl; and the stronger it is, the better the mortar will be. It is proper also to exclude the sun and wind from the mortar, for some days after it is applied; that the drying too fast may not prevent the due continuance of the fermentation, which is necessary for the action of the lime on the sand. When a very great hardness and firmness are required in this mortar, the using of skimmed milk instead of water, either wholly or in part, will produce the desired effect, and render the mortar extremely tenacious and durable.

Dr. Higgins, who made a variety of experiments for the purpose of improving mortar, says, the perfection of lime, prepared for the purpose of making mortar, consists chiefly in its being deprived of its fixed air. On examining several specimens of the lime commonly used in building, he found that it is seldom or never sufficiently burned; for they all effervesced, and yielded more or less fixed air, on the addition of an acid, and slaked slowly, in comparison with well-burned lime. He also recommends that, as lime owes its excellence to the expulsion of fixed air from it in the burning, it should be used as soon as possible after it is made, and guarded from exposure to the air, as much as possible, before it is used.

From other experiments, made with the view of ascertaining the best relative proportions of lime, sand, and water, in the making of mortar, it appeared that those specimens were the best which contained one part of lime in seven of the sand. Also, that mortar, which is to be used where it must dry quickly, ought to be made as stiff as the purpose will admit, or, with the smallest practicable quantity of water; and that mortar will not crack, although the lime be used in excessive quantity, provided it be made stiffer, or to a thicker consistence, than mortar usually is.

In order to the greatest induration of mortar, it must be suffered to dry gently, and set; the exsiccation must be effected by temperate air, and not accelerated by the heat of the sun or fire; it must not be wetted soon after it sets; and afterwards it ought to be protected from wet as much as possible, until it is completely indurated; the entry of acidulous gas must be prevented as much as possible, until the mortar is finally placed and quiescent; and then it must be as freely exposed to the open air as the work will admit, in order to supply acidulous gas, and enable it sooner to sustain the trials to which mortar is exposed in cementitious buildings, and incrustations.

Dr. Higgins also inquired into the nature of the best sand or gravel for mortar, and into the effects produced by bone ashes, plaster-powder, charcoal, sulphur, &c., and he deduces great advantages from the addition of bone-ashes, in various proportions, according to the nature of the work for which the composition is intended.

This author describes an invention of his own for a superior kind of mortar, or stucco, applicable to ornamental work in imitation of stone. As the same general principles ought to be followed in making even the commonest kinds of mortar, we shall insert here the instructions given by Dr. Higgins.

Of sand, the following kinds are to be preferred; first, *drift-sand*, or *pit-sand*, which consists chiefly of hard quartose flat-faced grains, with sharp angles; secondly, that which is the freest, or may be most easily freed by washing, from clay, salts, and calcareous, gypseous, or other grains less hard and durable than quartz; thirdly, that which contains the smallest quantity of pyrites, or heavy metallic matter, inseparable by washing; and fourthly, that which suffers the smallest diminution of its bulk in washing. Where a coarse and fine sand of this kind, and corresponding in the size of their grains with the coarse and fine sands hereafter described, cannot be easily procured, let such sand of the foregoing quality be chosen, as may be sorted and cleansed in the following manner:—

Let the sand be sifted in streaming, clear water, through a sieve which shall give passage to all such grains as do not exceed one-sixteenth of an inch in diameter; and let the stream of water, and the sifting, be regulated so that all the sand which is much finer than the Lynn-sand, commonly used in the London glass-houses, together with clay, and every matter specifically lighter than sand, may be washed away with the stream; whilst the purer and coarser sand, which passes through the sieve, subsides in a convenient receptacle, and the coarse rubbish and rubble remain on the sieve to be rejected.

Let the sand which thus subsides in the receptacle, be washed in clean streaming water through a fine sieve, so as to be further cleansed, and sorted into two parcels; a coarser, which will remain in the sieve which is to give passage to such grains of sand only, as are less than one-thirteenth of an inch in diameter, and which is to be saved apart under the name of *coarse sand*, and a finer, which will pass through the sieve, and subside in the water, and which is to be saved apart under the name of *fine sand*. Let the coarse and the fine sand be dried separately, either in the sun, or on a clean iron-plate, set on a convenient surface, in the manner of a sand-heat.

Let the *stone lime* be chosen, which heats the most in slaking, and slakes the quickest when duly watered; that which is the freshest made and closest kept; that which dissolves in distilled vinegar with the least effervescence, and leaves the smallest residue insoluble, and in the residue the smallest quantity of clay, gypsum, or material matter. Let the lime, chosen according to these rules, be put in a brass wired sieve, to the quantity of fourteen pounds. Let the sieve be finer than either of the foregoing; the finer the better it will be; let the lime be slaked, by plunging it into a butt filled with soft water, and raising it out quickly, and suffering it to heat and fume; and by repeating this plunging and raising alternately, and agitating the lime until it be made to pass through the sieve into the water; and let the part of the lime which does not easily pass through the sieve be rejected; and let fresh portions of the lime be thus used, until as many ounces of lime have passed through the sieve as there are quarts of water in the butt.

Let the water thus impregnated stand in the butt, closely covered, until it becomes clear; and through wooden cocks, placed at different heights in the butt, let the clear liquor be drawn off, as fast and as low as the lime subsides, for use. This clear liquor is called *lime-water*. The freer the water is from saline matter, the better will be the cementing liquor made with it.

Let fifty-six pounds of the aforesaid chosen lime be slaked, by gradually sprinkling the lime-water on it, and especially on the unslacked pieces, in a close clean place. Let the slaked part be immediately sifted through the last-mentioned fine brass-wire sieve: let the lime which passes be used instantly, or kept in air-tight vessels; and let the part of the lime which does not pass through the sieve be rejected. This finer and richer part of the lime which passes through the sieve, may be called *purified-lime*. Let bone-ash be prepared in the usual manner, by grinding the whitest burnt bones; but let it be sifted, so as to be much finer than the bone-ash commonly sold for making cupels.

The best materials for making the cement being thus prepared, take fifty-six pounds of the coarse sand, and forty-two pounds of the fine sand; mix them on a large plank of hard wood placed horizontally, then spread the sand so that it may stand to the height of six inches with a flat surface on the plank, wet it with the lime-water, and let any superfluous quantity of the liquor, which the sand in the condition described cannot retain, flow away off the plank. To the wetted sand add fourteen pounds of the purified lime, in several successive portions; mixing and beating them up together, in the mean time, with the instruments generally used in making fine mortar; then add fourteen pounds of the bone-ash, in successive portions, mixing and beating all together.

The quicker and more perfectly these materials are mixed and beaten together, and the sooner the cement thus formed is used, the better it will be. This may be called *cross-grained cement*, which is to be applied in building, pointing, plastering, stuccoing, or other work, as mortar and stucco generally are; with this difference chiefly, that, as this cement is shorter than mortar, or common stucco, and dries sooner, it ought to be worked expeditiously in all cases; and, in stuccoing, it ought to be laid on by sliding the trowel upwards on it. The materials used along with this cement in building, or the ground on which it is to be laid in stuccoing, ought to be well wetted with the lime-water in the instant of laying on the cement. The lime-water is also to be used when it is necessary to moisten the cement, or when a liquid is required to facilitate the floating of the cement.

When such cement is required to be of a still finer texture, take 98 pounds of the fine sand, wet it with the lime-water, and mix it with the purified lime and the bone-ash, in the quantities and in the manner above described, with this difference only, that 15 pounds of lime, or thereabouts, are to be used instead of 14 pounds, if the greater part of the sand be as fine as Lynn sand. This may be called *fine-grained cement*. It is used in giving the last coating, or the finish, to any work intended to imitate the finer-grained stones or stucco. But it may be applied to all the uses of the *coarse-grained cement*, and in the same manner.

When, for any of the foregoing purposes of pointing, building, &c., a cement is required much cheaper and coarse-grained than either of the foregoing, then, much coarser clean sand than the foregoing coarse sand, or well washed fine rubble, is to be provided. Of this coarse sand, or rubble, take 56 pounds; of the foregoing coarse sand, 28 pounds; and of the fine sand, 14 pounds; and, after mixing these, and wetting them with the cementing liquor, in the foregoing manner, add 14 pounds, or somewhat less, of the bone-ash, mixing them together in the manner already described. When the cement is required to be white, white sand, white lime, and the whitest bone-ash, are to be chosen. Gray sand, and gray bone-ash formed of half-burnt bones, are to be chosen to make cement gray; and any other colour of the cement is obtained, either by choosing coloured sand, or by the admixture of the necessary quantity of coloured talc in powder; or of coloured, vitreous, or metallic powders, or other durable colouring ingredients, commonly used in paint.

This cement, whether the coarse or fine-grained, is applicable in forming artificial stone, by making alternate layers of the cement and of flint, hard stone, or bricks, in moulds of the figure of the intended stone, and by exposing the masses so formed to the open air, to harden.

When such cement is required for water-fences, two-thirds of the prescribed quantity of bone-ashes are to be omitted; and, in the place thereof, an equal measure of powdered terras is to be used; and, if the sand employed be not of the coarsest sort, more terras must be added, so that the terras shall be one-sixth part of the weight of the sand.

When such a cement is required of the finest grain, or in a fluid form, so that it may be applied with a brush; flint powder, or the powder of any quartzy or hard earthy substance, may be used in the place of sand; but in a quantity smaller, in proportion as the flint or other powder is finer; so that the flint-powder, or other such powder, shall not be more than six times the weight of the lime, nor less than four times its weight. The greater the quantity of lime within these limits, the more will the cement be liable to crack by quick drying, and vice-versâ.

Where the above described sand cannot be conveniently procured, or where the sand cannot be conveniently washed and sorted, that sand which most resembles the mixture of coarse and fine sand above prescribed, may be used as directed, provided due attention be paid to the quantity of the lime, which is to be greater as the quality is finer, and vice-versâ.

Where sand cannot be easily procured, any durable stony body, or baked earth, grossly powdered, and sorted nearly to the sizes above prescribed for sand, may be used in the place of sand, measure for measure, but not weight for weight, unless such gross powder be specifically as heavy as sand.

Sand may be cleansed from every softer, lighter, and less durable matter, and from that part of the sand which is too fine, by various methods, preferable in certain circumstances to that which has been already described.

Water may be found naturally free from fixable gas, selenite, or clay; such water may, without any great inconvenience, be used in the place of the lime-water; or a lime-water sufficiently useful, may be made by various methods of mixing lime and water in the described proportions, or nearly so.

When stone-lime cannot be procured, chalk lime, or shell lime, which best resembles stone-lime in the foregoing characters of lime, may be used in the manner described, excepting that fourteen pounds and a half of chalk-lime will be required in the place of fourteen pounds of stone-lime. The proportion of lime, as prescribed above, may be increased without inconvenience, when a cement or stucco is to be applied where it is not liable to dry quickly; and, in the contrary case, this proportion may be diminished. The defect of lime, in quantity or quality, may be very advantageously supplied, by causing a considerable quantity of lime-water to soak into the work, in successive portions, and at distant intervals of time; so that the calcareous matter of the lime-water, and the matter attracted from the open air, may fill and strengthen the work.

The powder of almost every well-dried or burnt animal substance, may be used instead of bone-ash; and several earthy powders, especially the micaceous and the metallic; and the elixated ashes of divers vegetables whose earth will not burn to lime, as well as the ashes of mineral fuel, which are of the calcareous kind, but will not burn to lime, will answer the ends of bone-ash in some degree.

The quantity of bone-ash described, may be lessened without injuring the cement; in those circumstances especially, which admit the quantity of lime to be lessened, and in those wherein the cement is not liable to dry quickly. The art of remedying the defects of lime, may be advantageously practised to supply the deficiency of bone-ash, especially in building, and in making artificial stone with this cement.

As the preceding method of making mortar differs, in many particulars, from the common process, it may be useful to inquire into the causes on which this difference is founded.

When the sand contains much clay, the workmen find that the best mortar they can make must contain about one-half lime; and hence they lay it down as certain, that the best mortar is made by the composition of half sand and half lime.

But with sand requiring so great a proportion of lime as this, it will be impossible to make good cement; for it is universally allowed, that the hardness of mortar depends on the crystallization of the lime round the other materials which are mixed with it; and thus uniting the whole mass into one solid substance. But if a portion of the materials used be clay, or any other friable substance, it must be evident that, as these friable substances are not changed in one single particular by the process of being mixed up with lime and water, the mortar, of which they form a proportion, will consequently be more or less of a friable nature, in proportion to the quantity of friable substances used in the composition of the mortar. On the other hand, if mortar be composed of lime and good sand only, as the sand is a stony substance, and not in the least friable, and as the lime by perfect crystallization, becomes likewise of a stony nature, it must follow that a mass of mortar, composed of these two stony substances, will itself be a hard, solid, unfriable substance. This may account for one of the essential variations in the preceding method from that in common use, and point out the necessity of never using, in the place of sand, which is a durable stone body, the scrapings of roads, old mortar, and other rubbish, from ancient buildings, which are frequently made use of; as all of them consist more or less of muddy, soft, and minutely divided particles.

Another essential point is the nature and quality of the lime. Now, experience proves that, when lime has been long kept in heaps, or untight casks, it is reduced to the state of chalk, and becomes every day less capable of being made into good mortar; because as the goodness and durability of the mortar depends on the crystallization of the lime, and, as experiments have proved, that lime, when reduced to this chalk-like state, is always incapable of perfect crystallization, it must follow, that, as lime in this state never becomes crystallized, the mortar, of which it forms the most indispensable part, will necessarily be very imperfect; that is to say, it will never become a solid stony substance; a circumstance absolutely required in the formation of good durable mortar. These are the two principal ingredients in the formation of mortar; but, as water is also necessary, it may be useful to point out that which is the fittest for this purpose; the best is rain-water, river-water the second, land-water the next, and spring-water last.

The ruins of the ancient Roman buildings are found to cohere so strongly, as to have caused an opinion, that their constructors were acquainted with some kind of mortar, which, in comparison with ours, might justly be called *cement:* and that, to our want of knowledge of the materials they used, is owing the great inferiority of modern buildings in their durability. But a proper attention to the above particulars would soon show, that the durability of the ancient edifices depended on the manner of preparing their mortar more than on the nature of the materials used. The following observations will, we think, prove this beyond a possibility of doubt.

Lime, which has been slaked and mixed with sand, becomes hard and consistent when dry, by a process similar to that which produces natural *stalactites* in caverns. These are always formed by water dropping from the roof. But, when the small drop of water comes to be exposed to the air, the calcareous matter contained in it begins to attract carbonic acid from the atmosphere. In proportion as it does so, it also begins to separate from the water, and to re-assume its native form of lime-stone or marble. When the calcareous matter is perfectly crystallized in this manner, it is to all intents and purposes lime-stone, or marble of the same consistence as before. If lime, in a caustic state, be mixed with water, part of the lime will be dissolved, and will also begin to crystallize. The water which parted with the crystallized lime will then begin to act upon the remainder, which it could not dissolve before; and thus the process will continue, either till the lime be all reduced to an *effete* or crystalline state, or something hinders the action of the water upon it. It is this crystallization which is observed by the workmen when a heap of lime is mixed with water, and left for some time to macerate. A hard crust is formed upon the surface, which is ignorantly called *frosting*, though it takes place in summer as well as in winter. If, therefore, the hardness of the lime, or its becoming a cement, depends entirely upon the formation of its crystals, it is evident that the perfection of the cement must depend upon the perfection of the crystals, and the hardness of the matters which are entangled among them.

The additional substances used in the making of mortar, such as sand, brick-dust, or the like, serve only for a purpose similar to what is answered by sticks put into a vessel full of any saline solution; namely, to afford the crystals an opportunity of fastening themselves upon a nucleus. If, therefore, the matter interposed between the crystals of the lime is of a friable, brittle nature, such as brick-dust or chalk, the mortar will be of a weak and imperfect kind; but, when the particles are hard, angular, and very difficult to be broken, such as those of river or pit sand, the mortar turns out exceedingly good and strong. That the crystallization may be the more perfect, a large quantity of water should be used, the ingredients be perfectly mixed together, and the drying be as slow as possible. An attention to these particulars, and to the quality of bricks and stones, would make the buildings of the moderns equally durable with those of the ancients. In the Roman works, the great thickness of the walls necessarily required a vast length of time to dry. The middle of them was composed of pebbles thrown in at random, and which evidently had thin mortar poured in among them. Thus a great quantity of the lime would be dissolved, and the crystallization performed in the most perfect manner. The indefatigable pains and perseverance for which the Romans were so remarkable in all their undertakings, leave no room to doubt that they would take care to have the ingredients mixed together as well as possible. The consequence of all this is, that the buildings formed in this manner are all as firm as if cut out of a solid rock; the mortar being equally hard, if not more so, than the stones themselves. See Cement, Concrete, Grout.

Mortar, Hydraulic, sometimes also called Roman cement is the composition used in walls under, or exposed to, the action of water, such as those of harbours, docks, &c. The material best adapted to the manufacture of hydraulic mortar is the poorer sorts of limestone, such as contain from 8 to 25 per cent. of foreign matter, in silica, magnesia, alumina, &c. These, when pulverized, absorb water without swelling up, or heating, as a richer lime does, and though calcined, do not slake when moistened, but makes a paste which hardens in a few days *under* water, though in the air it never acquires much solidity. These facts were discovered by Smeaton.

The following analyses of different hydraulic limestones, by Berthier, is given by Dr. Ure in his Dict. of Arts and Manufactures.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
A. *Analyses of limestones.*					
Carbonate of lime	97·0	98·5	74·5	76·5	80·0
Carbonate of magnesia	2·0	—	23·0	3·0	1·5
Carbonate of protoxide of iron	—	—	—	3·0	—
Carbonate of manganese	—	—	—	1·5	—
Silica and alumina				15.2	18.0
Oxide of iron	1·0	1·5	1·2		
	100·0	100·0	100·0	100·0	100·0
B. *Analyses of the burnt lime.*					
Lime	96·4	97·2	78·0	68·3	70·0
Magnesia	1·8	—	20·0	2·0	1·0
Alumina	1·8	2·8	2·0	24·0	29·0
Oxide of Iron	—	—	—	5·7	—
	100·0	100.0	100·0	100·0	100·0

"No. 1, is from the fresh-water lime formation of Chateau-Landon, near Nemours; No. 2, the large-grained limestone of Paris; both of these afford a fat lime when burnt. Delormite affords a pretty fat lime, though it contains 42 per cent. of carbonate of magnesia; No. 3, is a limestone from the neighbourhood of Paris, which yields a poor lime, possessing no hydraulic property; No 4, is the secondary limestone of Metz; No. 5, is the lime marl of Senonches, near Dreux; both the latter have the property of hardening under water, particularly the last, which is much used at Paris on this account."

All good hydraulic mortars must contain alumina and silica; the oxides of iron and manganese, at one time considered essential, are rather prejudicial ingredients. By adding silica and alumina, or merely the former, in certain circumstances, to fat lime, a water-cement may be artificially formed; as also adding to lime any of the following native productions, which contain silicates; puzzolana, trass or tarras, pumice-stone, basalt-tuff, slate-clay. Puzzolana is a volcanic product, which forms hills of considerable extent to the south-west of the Appenines, in the district of Rome, the Pontine marshes, Viterbo, Bolsena, and in the Neapolitan region of Puzzuola, whence the name. A similar volcanic tufar is found in many other parts of the world. According to Berthier, the Italian puzzolana consists of 44·5 silica; 15·0 alumina; 8·8 lime; 4·7 magnesia; 1·4 potash; 4·1 soda; 12 oxides of iron and titanium; 9·2 water; in 100 parts.

The tufa stone, which when ground forms trass, is composed of 57·0 silica, 16·0 clay, 2·6 lime, 1·0 magnesia, 7·0 potash, 1·0 soda, 5 oxides of iron and titanium, 9·6 water. This tuff is found abundantly filling up valleys in beds of 10 or 20 feet deep, in the north of Ireland, among the schistose formations upon the banks of the Rhine, and at Manheim in Bavaria.

The fatter the lime, the less of it must be added to the ground puzzolana or trass, to form an hydraulic mortar; the nixture should be made extemporaneously, and must at any ate be kept dry till about to be applied. Sometimes a pro-portion of common sand mortar instead of lime is mixed with he trass. When the hydraulic cement hardens too soon, as in 12 hours, it is apt to crack; it is better when it takes 8 days o concrete. Through the agency of water, silicates of lime, alumina, (magnesia,) and oxide of iron, are formed, which assume a stony hardness.

Beside the above two volcanic products, other native earthy compounds are used in making water cements. To his head belong all limestones which contain from 20 to 30 per cent. of clay and silica. By gentle calcination, a portion of the carbonic acid is expelled, and a little lime is combined with the clay, while a silicate of clay and lime results, asso-iated with lime in a subcarbonated state. A lime-marl con-aining less clay will bear a stronger calcining heat without rejudice to its qualities as a hydraulic cement; but much lso depends upon the proportions of silica present, and the hysical structure of all the constituents."

In England, what is commonly called *cement-stone*, is the ubstance generally used for making this kind of mortar. ; is found in great abundance on the coasts of Kent, in the sles of Sheppey and Thanet, and various other places. The tones vary in size from that of a fist to a man's head, are of yellow-gray or brown colour, interspersed with veins f talc spar. Their specific gravity is 2.59.

The following analyses of several cement-stones, and of ie cement made with them, is taken from the works f Berthier, Davy, and others—

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Constituents of the cement stones.					
arbonate of lime	65.7	61.6	—	82.9	63.8
— magnesia	0.5	—	—	—	1.5
— protoxide of iron	6.C	6.0	—	} 4.3	11.6
— manganese	1.6	—	—		
lica......................	18.0	15.0	—	13.0	14.0
lumina or clay	6.6	4.8	—	trace.	5.7
xide of iron...............	—	3.0	—	—	—
ater	1.2	6.6	—	—	3.4
B. *Constituents of the cement.*					
me	55.4	54.0	55.0	—	56.6
agnesia	—	—	—	—	1.1
umina or clay.............	36.0	31.0	38.0	—	21.0
xide of iron...............	8.6	15.0	13.0	—	13.7

The stones are in this country calcined in kilns, ground, ted, and packed in casks. The colour of the powder is a rk brown, with a tinge of red. It absorbs very little ater when made into paste, and soon hardens. Immediately fore using, it is mixed with sharp sand in various oportions.

This composition is employed in all marine and river-nbankments, in the footings of walls in damp situations, d in various other purposes to which common mortar is suited.

Mortar, *Mixing*, *Blending*, *and Beating of;* M. Felibien serves, that the ancient masons were so very scrupulous the process of properly mixing and blending the materials the making of mortar, that the Greeks kept ten men con-ntly employed, for a long space of time, to each bason; s rendered the mortar of such prodigious hardness, that truvius tells us the pieces of plaster falling off from old lls, served to make tables. Felibien adds, that it was a xim among old masons to their labourers, that they should ute it with the sweat of their brow, i. e., labour at it a long time instead of drowning it with water to have done the sooner.

In modern practice, when the buildings are of considerable magnitude, the mortar is usually ground in a mill; but which-ever way made, it may be laid down as a fixed rule, that the more labour there is bestowed on the mixing and thoroughly blending the mortar, the harder and better will it be, and, as a necessary consequence also, so much more perfect will be the work in which it is used.

The following excellent observations on the advantages of *beating* mortar, are taken from Mr. Weale's useful little work, "Dictionary of Terms of Arts."

"Mortar contained in a mould may be beaten or rammed in the manner of pisé, 'a mode of building formerly in use, whereby walls were formed by ramming and beating down earth, clay, &c., between upright planks,' and acquires by that means great compactness; but an increase of resistance does not always result from it.

"In order that any material be beaten with effect, it is necessary that it should possess a certain degree of consis-tency, which is a mean between complete pulverulence and that state of ductility which constitutes a firm paste. No compression is possible, when the material escapes from under the rammer; and this is still practised by the builders in pisé, who never employ any but earth slightly moistened. Mortar may always be prepared in this way, leaving it, after it has been worked in the ordinary manner, to undergo desiccation to a proper extent.

"The successive approximation of the particles of the compressed material to one another, necessarily determines a foliated structure, which, though it may not be perceived, is nevertheless real. Analogy will lead to the conclusion, that in every possible case, a body thus formed ought to oppose a greater resistance to a tractile force, in proportion as its direction forms a smaller angle with the plane of the laminæ; however, experience shows that this in general does not take place. The following has been determined in this respect:—

"1st. Beating has the effect of augmenting the absolute resistance of mortars of rich limes and pure sand in every case, but in an unequal manner. The greatest resistance assumes a direction perpendicular to the planes of the laminæ, when the mortars are buried in a damp soil immediately after their fabrication. It remains parallel to these same planes, when the mortars have been exposed to the atmospheric influence.

"2nd. The effect of beating is not constantly useful to mortars of hydraulic or eminently hydraulic limes, and cal-careous or quartose sands or powders, except in the case when these mortars are used under a damp soil. The greatest resistance is then in a direction perpendicular to the planes of these laminæ, as with the mortars of rich limes; but in the air the superiority of the mortars which have been beaten, over those which have not, is only exhibited in one direction, and that is parallel to the plane of the laminæ.

"3rd. Beating becomes injurious in every case, when the hydrates of the hydraulic or eminently hydraulic limes are employed without admixture, and subjected to the influence of a damp soil; and is favourable to it only in the direction parallel to the laminæ, when the stuff dries in the air."

Mortar, White, used in plastering the walls and ceilings, is made of ox or cow's hair mixed with lime and water, without any sand. The common method of making this mortar, is one bushel of hair to six bushels of lime.

Mortar, used in making water-courses, cisterns, &c., is made of lime and hogs' grease, sometimes mixed with the juice of figs, and sometimes with liquid pitch; after application, it is washed over with linseed oil.

For this purpose, mortar made of terras, puzzolana, tile-dust, or cinders, is mixed and prepared in the same manner as common mortar: only that these ingredients are mixed with lime instead of sand, in a due proportion, which is about half and half. The lime should be made of shells, or marble; and in works which are sometimes dry and sometimes wet, instead of terras, which is very dear, tile-dust or cinder-dust may be used.

MORTAR, for sun-dials on walls, or for tablets to write on, may be made of lime and sand, tempered with linseed oil; or, for want of that, with skimmed milk. This will grow to the hardness of stone. For buildings, one part of washed soap-ashes, mixed with another of lime and sand make a very durable mortar.

MORTAR MILL, a machine contrived by Mr. Supple, but since much improved by others, for the purpose of saving labour, and more effectually mixing the ingredients in making mortar.

MORTISE, or MORTICE, (from the French, *mortoise*, perhaps derived from *mordeo*, to bite, or pinch,) in carpentry and joinery, an excavation recessed within the surface of a piece of timber, to receive a projection called *a tenon*, left on the end of another piece, in order to fix the two together at a given angle. The sides of the mortise are generally four planes at right angles to each other, and to the surface whence the excavation is made. *See* CARPENTRY and JOINERY.

MORTISE LOCK, a lock made to fit into a mortise cut in the style and rail to receive it.

MORTUARY, a term sometimes used to signify a burial-place.

MOSAIC, or MOSAIC-WORK, (from *mosaicum*, a corruption of *musaicum*, as that is of *musivum*, as it was called among the Romans: but Scaliger derives it from the Greek, *μουσα*, and imagines the name was given to this sort of work, as being very fine and ingenious; and Nebricensis is of opinion it was so called, because *ex illis picturis ornabanter musea*.) an assemblage of little pieces of glass, marble, shells, precious stones, woods, or the like, of various colours, cut square, and cemented on a ground of stucco, &c., imitating the natural colours and gradations of painting. In this sense, mosaic work includes marquetry, or inlaid work, veneering, &c. But, in its more proper and restrained sense, mosaic only takes in works of stone, metals, and glass; those of wood being distinguished by the name of *marquetry* or *inlaying*. (*See* those words.)

Others distinguish differently between mosaic and marquetry. In that properly called *mosaic*, they say the several stones are all of the same colour; and the changes and diminutions of colours and shades are made by applying different stones, one on another, but all of the same colour. Marquetry, on the contrary, consists of stones of different colours; and by these the several colours, shades, gradations, &c., are expressed.

Mosaic seems to have taken its origin from paving: the fine effect and use of pavements composed of pieces of marble of different colours,—so well joined together, as that, when dried, they might be polished, and the whole make a very beautiful and solid body, which, continually trodden upon, and washed with water, was not at all damaged,—gave the painter the hint, who soon carried the art to a much greater perfection, so as to represent foliages, masques, and other grotesque pieces, of various colours, on a ground of black or white marble. But nature not producing variety of colours enough for them in marbles, to paint all kinds of objects, they thought of counterfeiting them with glass and metals coloured.

This kind of work is supposed to have originated in the East, to have been brought from Phenicia to Greece, and thence to Rome, where it was used more especially for pavements. These pavements consisted for the most part of patterns forming borders round a central figure or device, and sometimes a group or subject; others consisted solely of patterns worked out in two or three colours, usually black, white, and red. Of all places, however, the artists of Byzantium carried this art into most extensive practice, covering both walls, pavements, and ceilings with such decoration; mosaics became indeed a very common method of enrichment in Christian churches, both in Asia and Italy. They form the most characteristic decoration of the Basilica. As a style of art, as well as a manufacture, *musive* work may be said to have arisen wholly in the era of Christianity. The material of which the mediæval mosaics are formed being chiefly glass, distinguishes them completely from the tessellated pavements of the Romans. Perhaps the nearest approach to the manufacture, is the rude inlaid work of the columns and fountains in some of the Pompeii gardens: at all events, their application is entirely peculiar to Christianity. The apex of the apse was usually reserved for this species of decoration, which still constitutes the peculiar charm of the ancient Italian churches. The solemn gigantic figures and the mysterious imagery of the mosaics, dimly seen in the darkness of the sanctuary, produce an effect denied to more elaborate specimens of art. In one most important respect they are infinitely preferable to paintings, because, both from their position and their character, they never became the objects of adoration. Usually speaking, the main figure is the Saviour in the act of judging the world; on either side, St. Peter and St. Paul: other saints are added, usually with reference to the peculiar locality. Portraits of popes or emperors connect the sacred imagery with the annals of the age. Although not governed by any definite system, yet there is a uniform course in the adaptation of the ornaments.

Mosaic work is also common in Arabian edifices, so much so indeed as to become a feature of the style. Their mosaics were principally of porcelain, and were used in the decoration of the lower part of the walls, and also for pavements. *See* MOORISH ARCHITECTURE.

A kind of mosaic work was common on the exteriors of some of the mediæval churches of Italy, as the Duomo at Pisa, where the walls of the façade are decorated with a sor of pattern in black and white colours, brilliant reds and blue being interspersed occasionally. Another instance of externa decoration in mosaic is to be seen in the façade of St. Mark's Venice.

Pictures in mosaic, properly so termed, and which are o comparatively recent introduction, differ from the above i being merely copies or fac-similes of paintings, approaching i appearance as nearly to pictures as possible. This style o mosaic work dates only from the commencement of th seventeenth century. The tints are graduated off from ligh to darker shades by using an indefinite number of very sma pieces of glass of various intensities of colour, so placed tha those pieces which are contiguous exhibit scarcely any pe ceptible difference to the eye. In the more ancient mosai the tints are not blended one into the other, but kept qui distinct, the outlines being hard, and the joints between th tesseræ plainly visible. In these examples there is n attempt at making pictures; they are treated in a co ventional manner, so that such features are to be consider as characteristic proprieties rather than defects.

Florentine work may also be added to the list of mosaic it is employed principally in the inlaying of marble slabs for furniture, and decorative work upon a moderate scale.

One description of mosaic work is that of introducing, along with the finest marbles, the richest of precious stones, as lapis lazuli, agates, cornelians, emeralds, turquoises, &c. The practice of making mosaics with coloured glass and metals is now little in use, though of surprising lustre and durability; but that of marbles alone is in common use; the mosaic in precious stones being so very dear, that the few workmen who apply themselves to it, make little else but petty works, as ornaments for altar-pieces, tables for rich cabinets, &c.

MOSQUE, (from the Arabic, *Maschiad*, or *Medsched*, and intermediately the Spanish and Portuguese *Mezquita* and *Masqueta*,) a Mohammedan place of worship, the distinctive marks of which are generally cupolas and minarets. Internally they exhibit nothing remarkable as to plan or accommodation, forming merely a large hall or apartment, without any seats or other fittings-up, and with no other decoration than that of pavements and carpets, or arabesques and mosaics on the walls. In regard to these latter, some of the mosques at Cairo are highly embellished. Although more famed than any other, the mosque at Santa Sophia at Constantinople exhibits nothing of Mohammedan or Arabian architecture, but was originally built as a church, and is in the Byzantine style.

All mosques are square buildings, generally constructed of stone. Before the chief gate there is a square court paved with white marble; and low galleries round it, whose roof is supported by marble pillars. In these galleries the Turks wash themselves before they go into the mosque. In each mosque there is a great number of lamps; and between these hang many crystal rings, ostriches eggs, and other curiosities, which, when the lamps are lighted, make a fine show. As it is not lawful to enter the mosque with stockings on, the pavements are covered with pieces of stuff sewed together, each being wide enough to hold a row of men kneeling, sitting, or prostrate. The women are not allowed to enter the mosque, but stay in the porches without. About every mosque there are six high towers, called *minarets*, each of which has three little open galleries, one above another: these towers, as well as the mosques, are covered with lead, and adorned with gilding and other ornaments, and from thence, instead of a bell, the people are called to prayers by certain officers appointed for that purpose. Most of the mosques have a kind of hospital belonging to them, in which travellers of what religion soever, are entertained three days. Each mosque has also a place called *tarbe*, which is the burying-place of its founders; within which is a tomb six or seven feet long, covered with green velvet or satin; at the ends of which are two tapers, and round it several seats for those who read the koran and pray for the souls of the deceased. *See* Moorish Architecture.

MOTION, *Local*, a continued or successive change of place.

Motion, *Absolute*, the change of place in a moving body, independent of any other motion.

MOVEMENT, (from the French,) in architecture, a term used by some writers to express the rise and fall, the advance and recess, with other diversities of form, in the different parts of a building.

MOULD, *Glaziers'*. The glaziers have two kinds of moulds: in one they cast the lead into long rods, or canes, fit to be drawn through the vice, in which the grooves are formed; this they sometimes call *ingot-mould*. In the other, they mould those little pieces of lead, a line thick, and two lines broad, which are fastened to the iron bars of casements, &c.

Mould, among masons, a piece of hard wood, or iron, hollowed on the edge, answerable to the contours of the mouldings or cornices, &c., to be formed. It is otherwise called *a caliber;* and is made to a section of the stone intended to be cut. The ends, or heading-joints, being formed as in a cornice by means of the mould, the intermediate parts are wrought down by straight-edges, or circular templets, according as the work is straight or circular upon the plan.

When the intended surface is required to be very exact, a reverse mould is used, in order to prove the work, by applying the mould in a transverse direction to the arrises.

MOULDS, among plumbers, the tables on which they cast their sheets of lead; sometimes called simply *tables*. Besides these, they have others, in which they cast pipes, without soldering.

MOULDINGS, in architecture, prismatic or annular solids, formed by plane and curved surfaces, and employed as ornaments.

All parallel sections of straight mouldings, all the sections of annular mouldings, made by a plane at the same inclination to the axis, and, in general, all sections of mouldings made by a plane perpendicular to any one of the arrises, are similar figures. Mouldings are divided into two classes, or kinds; Grecian and Roman.

Grecian mouldings are formed of some conic section, as a portion of the ellipsis or hyperbola; and sometimes even of a straight line, in the form of a chamfer.

Roman mouldings have their sections composed of the arcs of circles, the same moulding having the same curvature throughout.

In both Grecian and Roman mouldings, their species is determined by the position of their extremities, or the circumstance of their being concave or convex: if the section be a semicircle projecting from a vertical diameter, the moulding is called an *astragal*, *bead*, or *torus*.

If the moulding be convex, and its section the quarter of a circle, or less, and if one extremity project beyond the other, that is, approach nearer to the eye than the other, it is termed a *Roman ovolo;* and if this Roman ovolo project equal to its height, and the portion employed be the quadrant of a circle, it is then called a *quarter-round*. If the section of a moulding be concave, but in all other respects the same as the last, it is denominated a *cavetto*.

If the section of a moulding be partly concave and partly straight, the straight part being vertical and a tangent to the concave part, and the concavity equal to, or less than the quadrant of a circle, the moulding is denominated an *apophygé*, *scape*, *spring*, or *congé:* this is used in the Ionic and Corinthian orders for joining the bottom of the shaft to the base, as well as to connect the top of the fillet to the shaft under the astragal.

If the section be one part concave and the other convex, and so joined as to have the same tangent, the moulding is named a *cymatium;* but Vitruvius calls all crowning or upper members cymatiums, whether they resemble the one now described or not.

If the upper projecting part of the cymatium be a concave, it is called a *sima-recta;* this is generally the crowning member of cornices, but is seldom found in other situations except on pedestals or altars.

If the upper projecting part of the cymatium be convex, it is called a *sima-reversa*, and is the smallest in any composition of mouldings, its office being to separate the larger members. Though seldom used as a crowning member of cornices, it is frequently employed with a small fillet over it, as the upper member of architraves, capitals, and imposts.

If the convex part of a moulding recede and meet a horizontal surface, the recess formed by the convexity and the horizontal surface is termed a *quirk.*

If the section of the moulding be a convex conic section, the intermediate part of the curve projecting only a small distance from the greatest projecting extremity, and the tangent to the curve at the receding extremity meeting a horizontal line, produced forward without the curve at the upper extremity, the moulding is called an *ovolo.* This is generally employed above the eye, as a crowning member in the Grecian Doric. Ovolos may be used in the same composition of different sizes; it is sometimes cut into egg-and-tongue, or egg-and-dart, when it is termed *echinus.* It is employed instead of a torus in the base of the monument of Lysicrates, at Athens. The contours of ovolos are generally elliptical or hyperbolical curves. These curves can be regulated to any degree of quickness or flatness; the parabola can also be drawn under these conditions, but its curvature, being of the intermediate species, does not afford the variety of change admitted by the other two.

If the section be a concave semi-ellipsis, having its conjugate diameter such that the one may unite the extremities of its projections, and the other diameter parallel to the horizon, the moulding is termed a *scotia.* This is always employed below the level of the eye, between two tori. One extremity has generally a greater projection than the other, the greater projection being nearest to the level of the eye.

If the section of the moulding be the two sides of a right angle, the one vertical, and the other, of course, horizontal, it is termed a *fillet, band,* or *corona.* A fillet is the smallest rectangular member in any composition of mouldings. Its altitude is generally equal to its projection; its purpose is to separate two principal members, and it is used in all situations under such circumstances. The corona is the principal member of a cornice. The facia is a principal member in an architrave as to height, but its projection is not more than that of a fillet, unless it be the lower facia, where the soffit is the whole breadth of the top, or sometimes even of the bottom of the shaft. Mouldings are either plain, or enriched with eggs, and with foliage displayed in a variety of forms; some enrichments are peculiar to certain forms, as egg-and-anchors, or egg-and-tongue, to the ovolo.

Mouldings in assemblage are used in the formation of cornices, architraves, bases, capitals, &c. *See* Apophyge, Cavetto, Cymatium, Echinus, Ovolo, Quarter-Round, Scape, Scotia, Sima-Recta, Sima-Reversa.

Plate I.—*Figure* 1, a quarter-round.

Figure 2, a cavetto, being exactly the reverse of the last figure; both being the quarter of a circle.

Figure 3, the sima-reversa, composed of two quadrants of a circle.

Figure 4, the sima-recta, being the reverse of the sima-reversa.

Figure 5, a torus, which is a semicircle described upon a vertical diameter.

Figure 6, a scotia, which, projecting equally at each extremity, occasions the contour to be exactly the reverse of the torus.

The following are the methods of describing Roman mouldings, where the projections and heights are unequal; the extremities of the moulding being given.

Figure 7.—*To describe the Roman ovolo.* Let A be the upper extremity, and B the lower; take the vertical line or height; from B, with that radius, describe an arc; from A, with the same radius, describe another arc, cutting the former at *c;* then from *c*, with the same radius, describe the arc A B, which will be the contour required.

Figure 8.—*To describe the cavetto.* With a radius equal to the height of the moulding, from the points A and B describe arcs, cutting each other in *c;* then from *c*, with the same radius, describe the arc A B, which will give the contour of the cavetto required.

Figure 9.—*To describe a sima-reversa, that shall touch a straight line at the points of contrary flexure.* Join the projections A and B by the straight line A B; bisect A B in D; draw the tangent E D, parallel to a line given in position; through D draw *c c*, perpendicular to E D; bisect A D by a perpendicular, *g c;* from the intersection *c*, describe the arc A *g* D; make D *c* equal to *c′;* from the lower point *c′*, describe the arc D B: then the curve of contrary flexure, A D B, will be the sima-reversa required.

Figure 10.—*To describe a sima-recta to touch a straight line at the points of contrary flexure, parallel to a line given in position.* Join the points of projection A and B; bisect A B in D, and draw the line D E parallel to the line given in position; bisect A D by the perpendicular *c g*; from *c*, with the radius *c* D, describe the arc A D; make D *c′* equal to D *c*, and from the other point *c′* within, describe D B: then A D B is the sima-recta required.

Figure 11.—*To describe the Grecian ovolo, two tangents being given, as also their points of contact.* Let A E and E B be the tangents; A and B the points of contact; complete the parallelogram B E A *d;* produce B *d* to *c*, and make *d c* equal to *d* B; divide E A and *d* A each into the same number of equal parts; through the points of division in E A, draw lines to B; draw lines to *c* through the corresponding points in *d* A, to meet the corresponding lines drawn to B; and the intersections will be in the curve of an ellipsis. The upper part, A Q, is a continuation of the same curve.

The same directions extend to *Figures* 12, 13, 14: but the following difference may be observed:

In *Figure* 11, the tangent B E is regulated by taking the point E in the middle of A D. In *Figure* 12, the point E is one-third of A D from the bottom. In *Figure* 13, in the middle of A D, as in *Figure* 11. In *Figure* 14, the point E is one-third of A D, from A. Then, according as the tangent is lower or higher, the curve will be quicker or flatter at the same projection: so that, among these curves, *Figure* 12 is the boldest, and *Figure* 14 the flattest.

When E B and A E are nearly equal, the moulding is the boldest of any, taking D E at the same height; but when the projection is very great, or very small, the moulding is extremely flat.

Figure 15.—*The same data being given, to describe the Grecian ovolo; supposing the point of contact,* B, *to be the extremity of one of the axes.* Draw B K perpendicular to E B; also P *c* perpendicular to B K, for the other axis, so that the point P may be above A; then E B and P *c* will be parallel. To find the major axis: from A, with the distance B *c*, describe an arc, cutting P *c* at F; draw A F, and produce it to meet B K in I; make *c* P equal to A I; then with *c* P, half the major axis, and *c* B, half the minor axis, describe the curve B A P Q, which will be the moulding required.

This method forms the most beautiful moulding of any, the curvature being continually increased from the point B to [illegible]

The same description applies to *Figures* 16 and 17. With regard to the quirk at the point Q, it will be more or less, [illegible] the point A is more or less distant from Q.

The quantity of curvature depends upon the angle E B [illegible] so that when the angle E B D is less, the curvature w[illegible] be greater.

For a description of mouldings employed in Norman a[nd] Gothic Architecture, we must refer the reader to t[he] subjects treated of under these respective titles.

MOULDINGS.

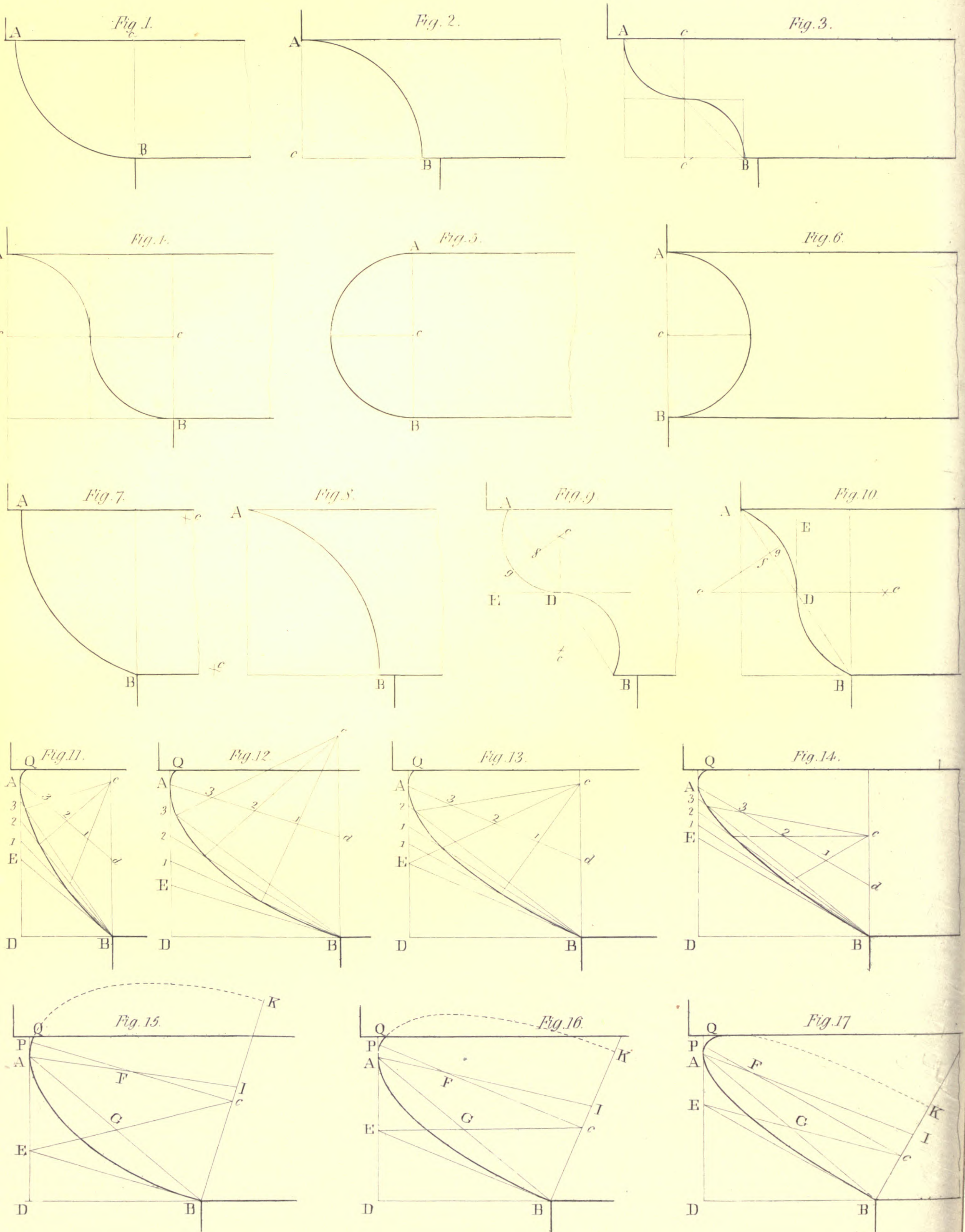


Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
Fig. 12.
Fig. 13.
Fig. 14.
Fig. 15.
Fig. 16.
Fig. 17.

MOULDING-PLANE. *See* Plane, and Tools.

Mouldings, *Raking*. *See* Raking Mouldings.

MOUTH, in the courts of princes, an apartment consisting f several rooms, as offices, kitchens, &c., where the meat ntended for the first tables is dressed by itself.

MULLIONS, in pointed architecture, all those parts of vindows which divide the light into compartments, and are ither curved or straight.

Vertical mullions are called *munnions;* and those which un horizontally are called *transoms*. The whole of the nullions of a window above the springing of the arch are alled the *head-work*.

MULTILATERAL, (from the Latin, *multus*, many, and *atera*, sides) in geometry, a term applied to figures which ave more than four sides or angles, more usually called *olygons*.

MULTIPLICATION, (from the Latin, *multiplicatio*) the ct of multiplying, or increasing a number. Accurately peaking, in every multiplication, the multiplier must always e considered as a number; and it is easy to conceive a quanty of any kind multiplied by a number. But to talk of a ound multiplied by a pound, a debt by a debt, or a line by line, &c., is unintelligible. However, by analogy, in the pplication of algebra to geometry, we meet with such expresions, and nothing is more common than to find A B × B C, ɔ denote the rectangle A B C D, the length of which is A B, nd the breadth B C. But this is only to be understood by nalogy; because, if the number expressing the measure of he side A B were multiplied by the number expressing the neasure of B C, the product would express the measure of B C D.

The sign of multiplication mostly used among algebraists, s ×. But the Germans, after Leibnitz, only make use of point placed between the quantities multiplying each other, hus: $a \cdot b$ is the same as $a \times b$; and A B . B C, the same s A B × B C, or the rectangle of A B into B C.

MUNIMENT-HOUSE, a small strong apartment in athedral and collegiate churches, castles, colleges, or the ke, destined for keeping the seal, evidences, charters, &c., f such church, colleges, &c., called *muniments*, or *miniments*.

MUNNIONS, see Mullions.

MURAL, (from the Latin *murus*) something belonging to wall. Thus mural monument, arch, and columns, *i. e.* ttached to the wall.

Mural Arch, a wall, or walled arch, placed exactly in ıe plane of the meridian, *i. e.* upon the meridian line, for ıe fixing of a large quadrant, sextant, or other instrument, ɔ observe the meridian altitudes, &c., of the heavenly odies. Tycho Brahe was the first who used a mural arch . his observations; after him, Helvelius, Flamsteed, De la Iire, &c., used the same means.

MUSES, (from the Greek μουσαι) fabulous divinities of ıe ancient heathens, who were supposed to preside over the rts and sciences.

The ancients admitted of nine Muses, and made them the aughters of Jupiter and Mnemosyne, or Memory. At first, ideed, their number was but three; *viz.*, Melete, Mneme, ıd Aœde; Greek words, signifying *meditation*, *memory*, ıd *singing:* but a certain sculptor of Sicyon, according to 'arro, having orders to make three statues of the three Iuses for the temple of Apollo, and mistaking his instructions, made three several statues of each Muse: these however, were found so beautiful, that they were all set up in the temple; and from that time they began to reckon nine Muses; to whom Hesiod afterward gave names; *viz.* Calliope, Clio, Erato, Thalia, Melpomene, Terpsichore, Euterpe, Polyhymnia, and Urania.

Each of these was to preside over her respective art; Calliope over heroic poetry; Clio over history; Melpomene over tragedy; Thalia over comedy; Euterpe over wind-music; Urania over astronomy; Terpsichore over the harp; Erato, the lute; Polyhymnia, rhetoric.

They are painted as young, handsome, and modest; agreeably dressed, and crowned with flowers. Their usual abodes were about mount Helicon, in Bœotia, and mount Parnassus, in Phocis. Their business was to celebrate the victories of the gods, and to inspire and assist the poets; and hence the custom of invoking their aid at the beginning of a poem.

MUSEUM, (from the Greek μουσειον) originally signified a palace of Alexandria, which occupied at least a fourth part of the city; and was so called from its being set apart to the Muses and the sciences.

Here were lodged and entertained a great number of learned men, who were divided into companies or colleges, according to the sciences or sects of which they were professors. And to each house or college was allotted a handsome revenue. This establishment is attributed to Ptolemy Philadelphus, who fixed his library in it.

Hence the word has passed into a general denomination, and is now applied to any place set apart as a repository for things that have some immediate relation to the arts, or to the Muses.

MUTILATED CORNICE, one that is broken or discontinued.

Mutilated Roof, see Roof.

MUTILATION, (from the Latin *mutilatio*, maiming) the retrenching or cutting away any part of a regular body. The word is extended to statues and buildings where any part is wanting, or the projection of any member discontinued.

MUTULE, in architecture, a part of the Doric cornice, appearing to support the corona and the superior members, formed by three vertical parallelograms at right angles, and an inclined plane which descends towards the front of the cornice, until it meets the rectangular vertical plane, the inclined plane being the soffit, and the two vertical parallel planes being at right angles to the surface of the frieze, and the vertical plane on the front parallel thereto.

Mutules had their origin from the ends of rafters in the original wooden structures, and are, therefore, properly represented with a declination towards the front of the corona; though represented by an architect of the last century with a level soffit. See Doric Order.

MYLASSENSE MARMOR, in the works of the ancients, a species of marble dug near the city of Mylassense in Caria. It was of a black colour, but with an admixture of purple, not disposed in veins, but diffused through the whole mass. It was much used in building among the Romans.

MYNCHERY, the same as Nunnery, which see.

MYRON, a celebrated statuary of Greece. He made a cow of brass, of admirable workmanship, much lauded by writers of that period.

N.

NAILS (from the Saxon *nægl*) in building, &c. small metalline-spikes, serving to bind or fasten the parts together, &c.

The several kinds of nails are very numerous; as *back-nails*, made with flat shanks to hold fast, and not open the wood. *Clamp-nails*, proper to fasten the clamps in buildings, &c. *Clasp-nails*. or *brads*, whose heads being flatted, clasp and stick into the wood, rendering the work smooth, so as to admit a plane over it: the most common in building are distinguished by the names *ten-penny*, *twenty-penny*, *two-shilling*, &c. *Clench-nails*, used by boat, barge, &c. builders, with boves or nuts, and often without: for fine work, they are made with clasp heads, or with the head beat flat on two sides. *Clout-nails*, ordinarily used for nailing on of clouts to axle-trees, are flat-headed, and iron-work is usually fixed with them. *Deck-nails* are for fastening of decks in ships, doubling of shipping, and floors laid with planks. *Dog-nails*, or *jobent-nails*, proper for fastening of hinges to doors, &c. *Flat-points* are of two kinds, *viz. long*, much used in shipping, and proper where there is occasion to draw and hold fast, yet no necessity of clenching; and *short*, which are fortified with points, to drive into oak, or other hard wood. *Lead-nails* used to nail lead, leather, and canvass, to hard wood, are the same as *clout-nails*, dipped in lead or solder. *Port-nails*, commonly used for nailing hinges to the ports of ships. *Ribbing-nails*, used to fasten the ribbing, to keep the ribs of ships in their place in building. *Rose-nails* are drawn square in the shank, and commonly in a round tool. *Rother-nails*, chiefly used to fasten rother-irons to ships. *Scupper-nails*, much used to fasten leather and canvass to wood. *Sharp-nails*, much used, especially in the West Indies, with sharp points and flat shanks. *Sheathing-nails*, used to fasten sheathing-boards to ships: the rule for their length is, to have them full three times as long as the board is thick. *Square-nails*, of the same shape as *sharp-nails;* chiefly used for hard wood. *Brads*, long and slender, without heads, used for thin deal work, to prevent splitting. To these may be added *tacks;* the *smallest* serving to fasten paper to wood; *middling*, for wool-cards and oars; and *larger*, for upholsterers and pumps. They are distinguished by the names of *white-tacks*, *two-penny*, *three-penny*, and *four-penny*, *tacks*.

NAIL-HEAD MOULDING, a Norman moulding, so named from its appearance, which is that of a surface studded with nails or nail heads.

NAKED FLOORING, the whole assemblage, or contignation of timber-work, for supporting the boarding of a floor on which to walk. Naked flooring consists of a row of parallel joists, called *floor-joists*.

When naked flooring consists of two rows of joists, of which the upper is supported by the under row, all the joists of the upper row crossing every one of the under at right angles, the supporting or lower row are called *binding-joists;* while the joists supported, or those of the upper row, are denominated *bridging-joists*. When the ends of binding-joists are framed into each side of a strong beam, such beam is called a *girder*. There are many curious methods of joining timbers in short lengths; for which the reader whose curiosity inclines to investigations of this nature, may consult the subsequent part of this article, from Wallis's *Opera Mathematica*, vol. I. prop. x. chap. vi., where he will find the demonstrations relating to the strength of timbers, according to their dispositions and bearings, and where several very ingenious methods of combining timbers in the forms of squares, oblongs, equilateral triangles, and pentagons, are shown by that renowned author. Of this species of flooring, Serlio has exhibited a design. Godfrey Richards, in his *Palladio*, exhibits the diagrams of two floors of this description, executed in Somerset House, which, he says, "was a novelty in England." Notwithstanding the ingenuity of this method of construction, it has been long out of use, probably, from the general introduction of foreign timber, which furnishes any lengths requisite for the purpose of building.

All the joists in the same floor, to which the boarding is attached, should be disposed in one direction, as the heading-joints of one set of boards should never meet the edges of another: the strength of the work, however, is by no means to be sacrificed, by a wrong disposition of the joisting, in order to make the joints of the boarding parallel to each other; symmetry of appearance being but a trifle compared to the strength of the work. Indeed the ends of the boards may be made to meet the edges of others under the bottom edge of the door in each apartment, should such a disposition be necessary.

In double naked flooring, when the binding-joists run parallel to the chimney side of the room, the joist nearest to such side ought to be placed at a distance from the breast of the chimney, equal to the breadth of the hearth, with an allowance for the brick trimmer by which the hearth is supported.

Floors are constructed by different methods, according to the bearing of the timber. When the rooms have small dimensions, the floor generally consists of single joists; when large, the framing for the support of the floor consists of two rows of beams, the lower supporting the higher: when the extent is so great, that the lower rows of beams would be too much weakened to support the upper rows and the floor for walking upon, a strong beam, called a *girder*, is introduced, so as to divide the length of the apartment; or two, three, &c., are introduced, so as to divide the length into three or four equal parts, as may be required for bearing the timber. The girders thus introduced should always be placed in the breadth or least dimension of the rectangle, or floor. The lower row of parallel beams are called *binding-joists*, and the transverse beams, which are supported by them, *bridgings* or *bridging-joists*. The binding-joists are framed into the girder, or girders, and the bridgings are notched upon the binding-joists.

Plate I. *Figure* 1.—A section of naked flooring, without binding-joists, but with a girder, into which the joists that support the flooring are framed, and the ceiling-joists into deep joists, which also support the boarding. The end of the girder is shown in No. 1, as also the sections of the ceiling joists. No. 2 is the transverse section of the floor, showing the sections of the boarding-joists, as also the sections of the strong joists, and the sides or longitudinal directions of the ceiling-joists.

Figure 2.—A section of a double floor. No. 1, shows the longitudinal section of the binding joists, a section of the girder, and the sections of the bridging and ceiling-joists. No. 2 shows the sections of the binding-joists, and the longitudinal directions of the bridging and ceiling-joists.

When girders are extended beyond a certain length, the

NAKED FLOORING.

PLATE I.

Fig. 1. No 1.

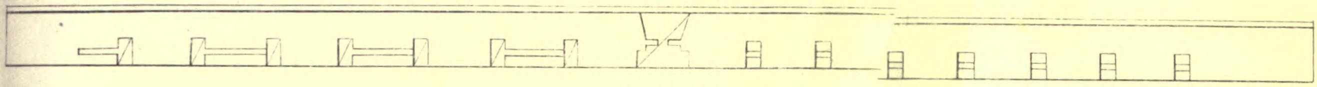


Fig. 1. No 2.

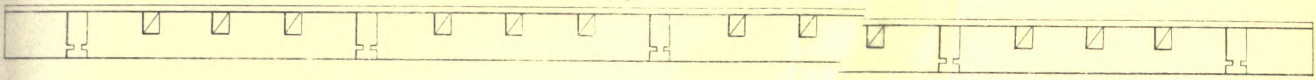


Fig. 2. No 1.

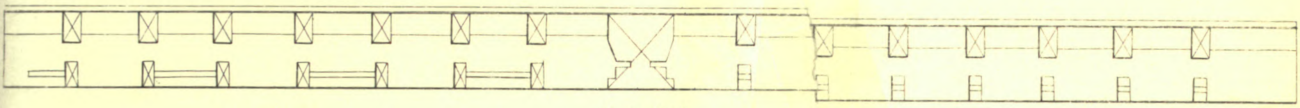


Fig. 2. No 2.

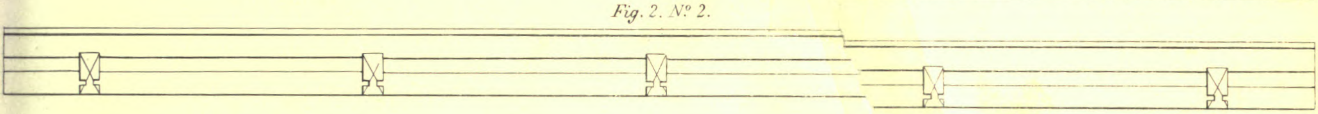


Fig. 5.

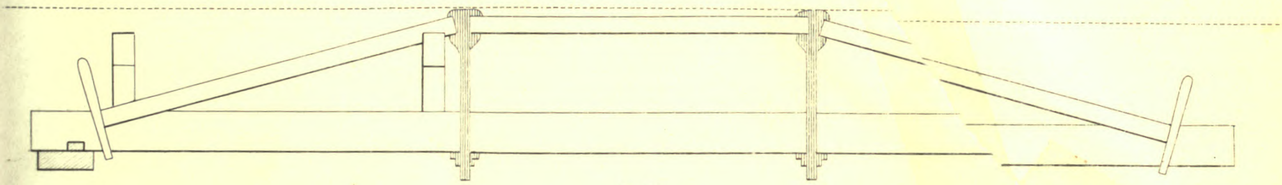


Fig. 3.

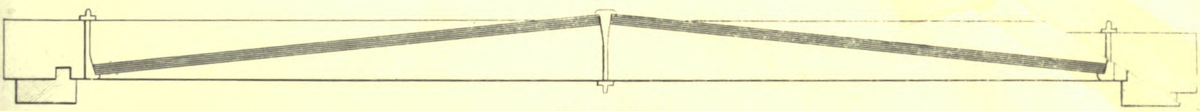


Fig. 4. No 1.

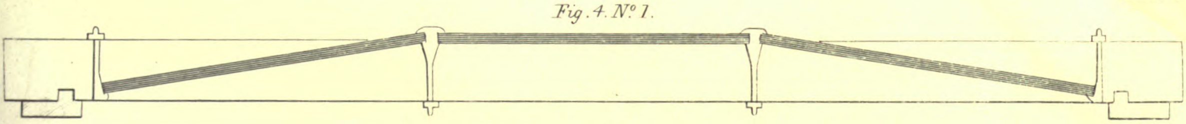
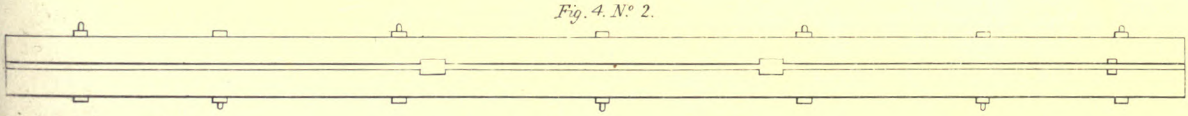


Fig. 4. No 2.



No 1. No 2

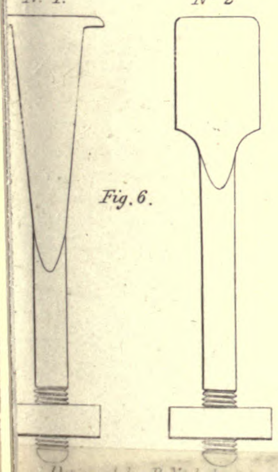


Fig. 6.

No 1. No 2.

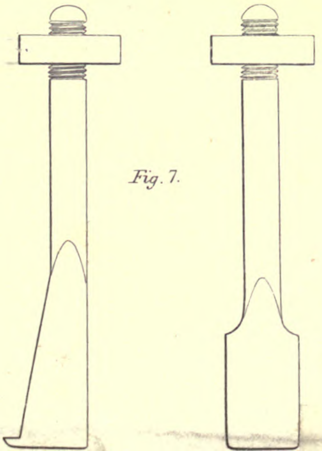
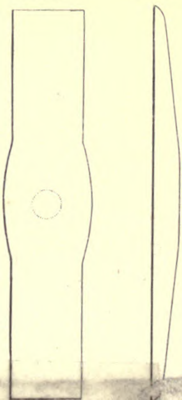


Fig. 7.

Fig. 8

No 1. No 2



acquire a degree of curvature from their weight, which in time reduces them to a concavity on the upper side, called *sagging*. To prevent this disagreeable consequence, without any intermediate support from the floor below, a strong truss, in the form of a low roof, is introduced between two equal beams, so as to make the whole discharge the weight at each extremity. To prevent the bad effects resulting from the shrinking of the timber, the truss-posts are generally constructed of iron, screwed and nutted at the ends; and to give a firmer abutment, the braces are let into a groove in each fitch or side. The abutment at each end is also made of iron, and is either screwed, nutted, and bolted through the thickness of both halves, that the braces may abut the whole dimensions of their section; or otherwise the two abutments are made in the form of an inverted wedge, where they are screwed and nutted. These modes may either be constructed with one truss-bolt in the middle, or with two, dividing the whole length into three equal parts: a straining-piece being placed in the middle, shortens the braces, and elevates them at a higher angle, so that the truss may give a more powerful resistance to the superincumbent weight. The braces may be constructed of oak, or of cast-iron; the bolts, from their nature, must be of wrought-iron.

As iron is subject to contraction and expansion, it is less eligible for the braces than wood, which is almost invariable in any degree of temperature, as to heat or cold; oak is therefore generally employed for this purpose.

Figure 3.—A longitudinal section of a truss-girder, consisting of two braces, meeting the truss-bolt in the middle.

Figure 4.—A longitudinal section of a truss-girder, divided into three parts; consisting of two braces, with a straining piece in the middle. No. 1. A longitudinal vertical section. No. 2. The upper side.

When the bearing is very great, the truss would require to be deep, to enable it to resist with greater efficacy: this construction may be as in *Figure* 5.

Figure 6.—Middle bolt.

Figure 7.—Abutment, as shown in *Figures* 3 and 4.

Figure 8.—Washers, to prevent a partial sinking of the nuts.

"*To construct the plain raftering for a floor, by joining together rafters that otherwise would not extend across the given space, so that the whole extent of the area may be perfectly level; and to estimate, by calculation, the pressure upon the whole, and upon the parts separately.*

"I. *The construction of the raftering.*—Plate II. Let *Figure* 1 exhibit the square area, any side of which is about quadruple the length of the longest rafter: the rafters are so fitted into each other as reciprocally to support themselves. The rafters that are dovetailed into the beams laid on the wall, are cut the whole depth of the timber, into the tenon of the dovetail; the mortise for this tenon is therefore in the wall-beam. The other ends of these rafters, each of which is fitted into the wall-beams, is formed into a tenon of about half the depth of the rafter; the mortise for this tenon is therefore, in another rafter, notched to a correspondent depth, so that the upper parts of both may be flush with each other, as will also happen to the lower sides. And because the tenon is but half the depth of the wood, the rafter to which it belongs is supported by half the depth of the rafter in which is the mortise, every rafter carrying the one that is fitted into it; as this is the case throughout the whole extent of the area, they must necessarily support each other over all parts of the area: and the parts towards the middle of the area, where, from the natural flexibility of the timber, the only fear is to be apprehended, lest, by the weight above, the interior of the floor should sink down, have this disadvantage provided against, by the excavations not extending precisely to the middle of the timber, but being a little deficient towards the middle. For, as by this method the raftering will rise progressively with each joint from the exterior to the centre of the area, any small depression that, from the weight above, might take place, will not be sufficient to reduce it below the fair level throughout; the curvature produced on the whole will compensate the weight, and prevent any hollow taking place.

"*Figure* 2, exhibits the side face of one of the longer timbers; where the end tenons and mortises, at one-third and two-thirds of the whole lengths, are sufficiently well exhibited: and *Figure* 3, shows one of the shorter timbers in that view which offers the end tenons and the single mortise. The upper face of all the rafters appears very plainly from *Figure* 2.

"But since they are disposed in so compact an order in this last-named Figure, the process may be much more easily understood from a close investigation of the diagrams than it can be from any explanation.

"It is very obvious, that the four great beams laid upon the wall are the first with which we ought to begin; for we would naturally proceed from these principal beams to the secondaries or rafters. Now, if we examine these principal beams, we shall find, that into each there are dovetailed five rafters or secondaries, and these have their other ends supported by other rafters parallel to the wall-beams; and those which carry the rafters dovetailed into the wall-beams, are themselves supported by others in a transverse direction; and so on, till they arrive at the opposite wall.

"For example, the rafter & s has one end dovetailed into the wall-beam, but the other end is supported by the rafter & z; this last rafter, & z, has one end dovetailed into another wall-beam, but the other end, z, is supported by the rafter P Q: and the rafter U Y has one end dovetailed into the wall-beam, but the other end, Y, is carried by P Q in the same manner as & Z: P Q is supported at P by I K, and at Q by R S: but I K and R S do also support the rafter O N, which in its turn supports the ends F, M, of the rafters F E, M L; H M L supports R X and V W; then we have determined the support of R, one end of the rafter S R; and V W supporting V, the end of the rafter V U, we come to V U supporting H G and I K: but the end, U, of the rafter V U, is supported by Y U; Y is supported by P Q, and P Q supports also & Z, and is itself supported by S R: but S R is supported by R X and S &: and thus we trace round the exterior framing, and discover the aid which these rafters reciprocally lend each other, to render the whole secure and compact. For if we follow the concatenation, we shall discover, from the slightest inspection of the diagram, the principle upon which, in regular succession, the parts conduce to give strength to the whole. In the same manner, when we begin to trace, from the centre of the framing, every rafter, A B and C D are supported by A B and E F; and also from these we trace L M, G H, and N O, reciprocally supported and giving their support; and following the others that are connected with those now named, we go on till we arrive at those which terminate, and are supported by the principal beams on the wall; as clearly appears from the plan.

"This method enables us to construct a floor scantling of this description with many, or even with few rafters; but in any other method, as in the case of an oblong differing but little from a square, we shall have to employ the following conditions:

"For example, in this same case the whole wall can be laid out, so that the rafters R S, U V, and & S brace, and are themselves braced; or, where the rafters & Z, M L, and P Q, are braced by others, or themselves are bracers; whence the area is extended less widely, as by the paucity of the rafters it extends from wall to wall by the rafters S &c, Q P, U V, L M, R S, and Z &c; but so long as there is occasion for only four rafters, the construction may be similar to *Figure* 4, or even of only three, as in *Figure* 5, which is the most simple form of any.

"But even if there were occasion (*Figure* 1) the rafters X R, W V, (and the remaining shorter ones that terminate in the wall) might be produced to an equal length with the others, and would support the corresponding rafters parallel to the principal beams, in which are fixed X R, V W, and Y U; and thus the ends of these, continued, would either be supported by the beams lying upon the wall, or even by others, as far as the area is extended, parallel to M L and P Q; and so on, to any distance that the work may require. For in the continued area, the number of the rafters being augmented, the weight may be increased to as much as the walls are able to sustain; for rafters may be found that will not give way, nor break under any weight the walls will carry.

"But although we are able to proceed safely in this regular proportion, it is from calculation that we must discover the weight which such a piece of framing will bear. For if it appears, from the quantity of weight laid on, that the rafters will everywhere bear it, then as much of the weight as any situation, or place of the area, has laid upon it, being in like proportion also laid on another, it becomes regularly and fairly distributed over the whole; and hence is the best judgment formed of what may safely be done. The calculation when the number of timbers is few, is pretty easy; but more laborious where there are many.

"But I shall show by what method this may be effected; each rafter of the continued framing, joined to its fellow, is subjected to this calculation; perplexed in a manner, it is true, from their number, but producing the result much more rapidly where there are few rafters.

"*Calculation accommodated to the raftering now explained.*

"That the calculation delivered in the following synopsis may be more clearly understood, it is to be observed, as is indeed sufficiently indicated to the eye, that some of the rafters are longer than others; and that the longer are about one and a half of the shorter ones. On this account we shall designate the weight of each of the longer rafters by T; and that of each of the shorter by $\frac{2}{3}$ T.

"But the weight upon every one of the joints of the rafters, will be indicated by the letter written on that joint in the diagram.

"Let it be moreover observed, since it may tend to elucidate our subject, that there are always four points which, on account of their similarity of situation in regard to the whole framing, equally determine the weight laid on them: these we shall always designate by the same marks, lest the number of the symbols should increase, and the calculation be thereby perplexed. Hence we shall have four A's, similarly situated and equally loaded, the same number of B's, and so on with the others. Whence it will be, for example (to No. 2, or the following equation) $B = \frac{1}{2}T + \frac{2}{3}C + \frac{1}{3}A$; in the same way, also, if the point, B, of the rafter, A B, thus subjected, be said to sustain as much weight as is laid upon it; besides that firmness which is necessary to prevent the wood giving way from the weight it carries, as this equation does not involve it; so much then is $\frac{1}{2}T$ (one half of the weight lying on A B, one of the longer rafters); then $\frac{2}{3}C$ (two-thirds of the weight of the same A B, situated on the point C; seeing that in C, A, it is understood to be cut in three different ways by the points); then $\frac{1}{3}A$ (one-third of the weight of the same rafter A B is placed in A.) Whence also there will be (to No. 21.) $W = \frac{1}{3}T + \frac{1}{2}V$: here we discover that in the point W of the rafter L M, the weight placed upon it is as much as is $\frac{1}{3}T$ (one-half of the weight of the short rafter, which is also a third of the longer one); then $\frac{1}{2}V$ (one-half of the weight, which is placed over the middle point, V, of the rafter so lying upon this one); which, by similarity, enables us to obtain 25 in the first equations.

"The equation 26, and those which follow, are derived from the preceding, which we have cited by numbers written for those equations; whence the manner of the whole process may be more clearly deduced. These partly serve for abbreviating fractions, as often as the numerators and denominators may be divided by the same common measure: but their most essential use is, to reduce and explain the preceding equations, by substituting the value of every individual symbol, and explaining it by other marks, on which account, as often as any symbols are expunged, the number of those which remain is sensibly lessened, till at last some one of the symbols unknown from the beginning, is expressed by the known quantity T, the weight of the longer rafters, considered simply by itself; and then, by examining every step of the preceding equations, the values of the remaining symbols are also found first of the unknown weights.

"For example, when there is (No. 1.) $A = \frac{1}{2}T + \frac{2}{3}A + \frac{1}{3}C$ (on account of A being found on both sides of the equation) it is manifest, that on taking away $\frac{2}{3}A$ on both sides, there will remain $\frac{1}{3}A = \frac{1}{2}T + \frac{1}{3}C$; that is (by multiplying both sides by 3) $A = \frac{3}{2}T + C$; and thus we have (No. 26.) this equation, as derived from the first equation (No. 1.) and which we have cited.

"By similarity, since it may be (No. 2.) $B = \frac{1}{2}T + \frac{2}{3}C + \frac{1}{3}A$; and (by No. 26) it may be $A = \frac{3}{2}T + C$; and so $\frac{1}{3}A = \frac{1}{2}T + \frac{1}{3}C$; B will be $(= \frac{1}{2}T + \frac{2}{3}C + \frac{1}{3}A = \frac{1}{2}T + \frac{2}{3}C + \frac{1}{2}T + \frac{1}{3}C) = T + C$. Whence we have this equation ($B = T + C$) No. 27, as derived from No. 2 and 26. And in like manner for the others.

"But, at no time, as we have said, is there more than the abbreviation of the fraction, as a reduction to less results by a common divisor. As when (No. 64) we have

$$H = \frac{6912\,T + 672\,G + 552\,I + 2790}{2907 = 3 \times 969};$$

and then all the members can be divided by 3; we have No. 65 (as derived from No. 64) the equation

$$H = \frac{2304\,T + 224\,G \times 184\,I + 930}{969};$$

and so for others.

"But as all these reductions and abbreviations of the equations are deduced singly, as we have deduced these few, we shall here briefly express them all in a continued synopsis; indicating those antecedent equations upon which the other depend.

"SYNOPSIS OF THIS CALCULATION.—*Figure* 1.

No.

1. $A = \frac{1}{2}T + \frac{2}{3}A + \frac{1}{3}C.$
2. $B = \frac{1}{2}T + \frac{2}{3}C + \frac{1}{3}A.$
3. $C = \frac{1}{2}T + \frac{2}{3}G + \frac{1}{3}I.$
4. $D = \frac{1}{2}T + \frac{2}{3}I + \frac{1}{3}G.$
5. $E = \frac{1}{2}T + \frac{2}{3}B + \frac{1}{3}D.$
6. $F = \frac{1}{2}T + \frac{2}{3}D + \frac{1}{3}B.$
7. $G = \frac{1}{2}T + \frac{2}{3}E + \frac{1}{3}L.$
8. $H = \frac{1}{2}T + \frac{2}{3}L + \frac{1}{3}E.$
9. $I = \frac{1}{2}T + \frac{2}{3}N + \frac{1}{3}P.$
10. $K = \frac{1}{2}T + \frac{2}{3}P + \frac{1}{3}N.$
11. $L = \frac{1}{2}T + \frac{2}{3}W + \frac{1}{3}X.$

NAKED FLOORING.

Fig 1

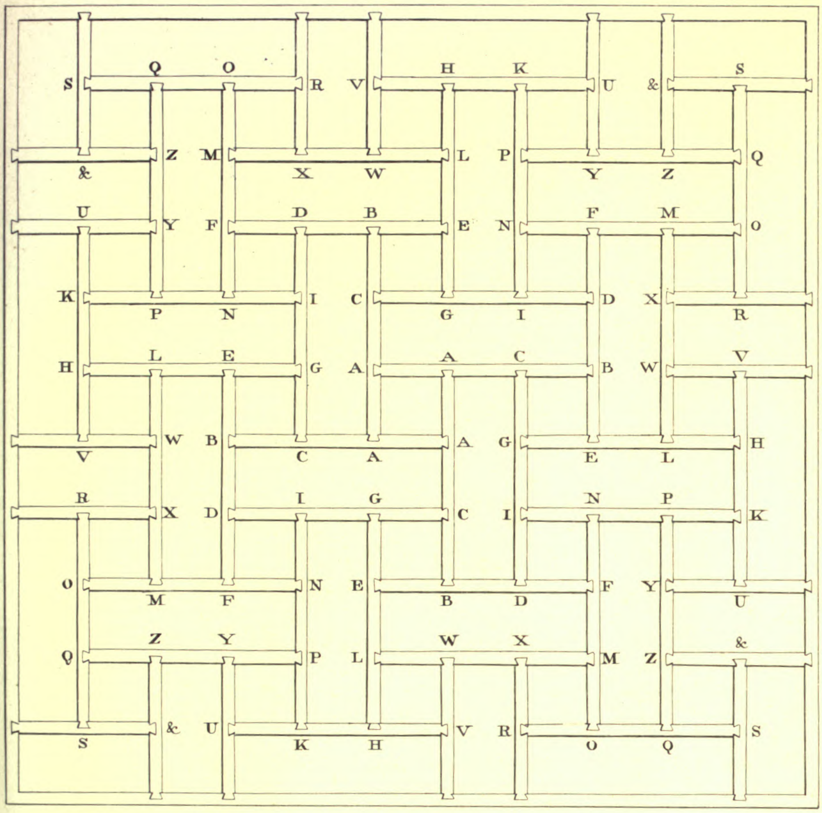


Fig. 4.

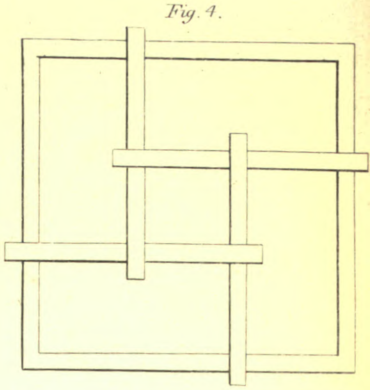


Fig. 5

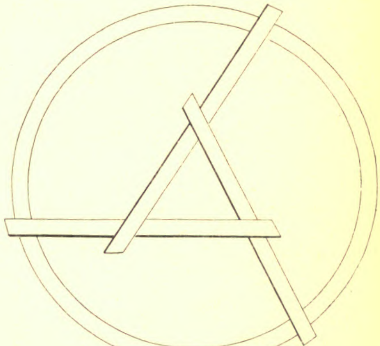


Fig. 6.

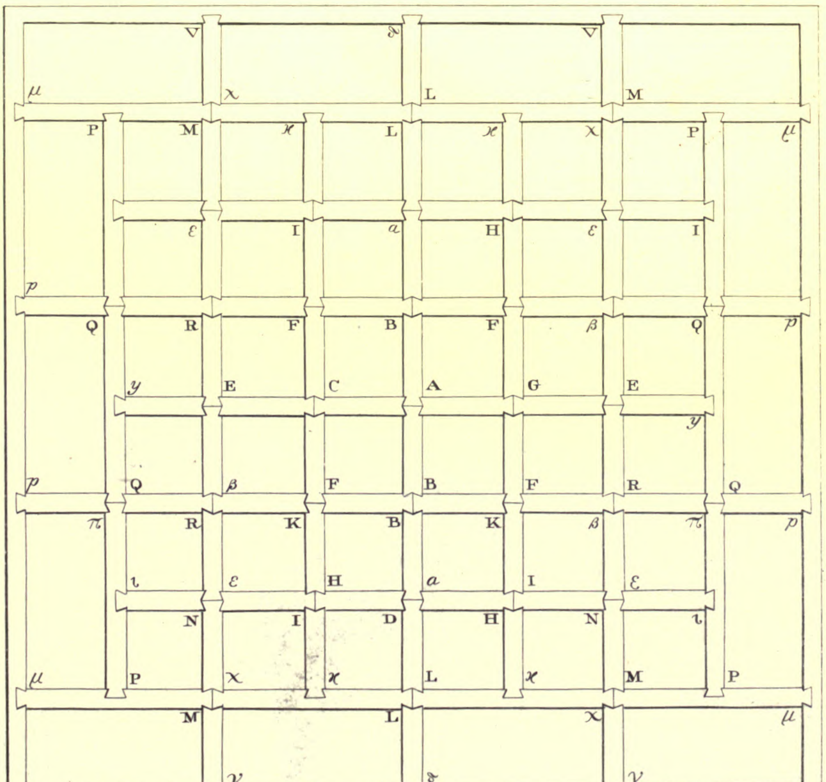


Fig. 2.

Fig. 3.

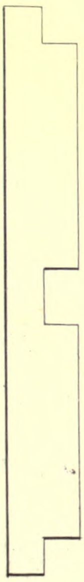


Fig. 7.

Drawn by M. A. Nicholson

Eng.d by R. Thew.

No.

12. $M = \frac{1}{2}T + \frac{2}{3}X + \frac{1}{3}W$.

13. $N = \frac{1}{2}T + \frac{2}{3}F + \frac{1}{3}M$.

14. $O = \frac{1}{2}T + \frac{2}{3}M + \frac{1}{3}F$.

15. $P = \frac{1}{2}T + \frac{2}{3}Y + \frac{1}{3}Z$.

16. $Q = \frac{1}{2}T + \frac{2}{3}Z + \frac{1}{3}Y$.

17. $R = \frac{1}{2}T + \frac{2}{3}O + \frac{1}{3}Q$.

18. $S = \frac{1}{2}T + \frac{2}{3}Q + \frac{1}{3}O$.

19. $V = \frac{1}{2}T + \frac{2}{3}H + \frac{1}{3}K$.

20. $U = \frac{1}{2}T + \frac{2}{3}K + \frac{1}{3}H$.

21. $W = \frac{1}{3}T + \frac{1}{2}V$.

22. $X = \frac{1}{3}T + \frac{1}{2}R$.

23. $Y = \frac{1}{3}T + \frac{1}{2}U$.

24. $Z = \frac{1}{3}T + \frac{1}{2}\&$

25. $\& = \frac{1}{3}T + \frac{1}{2}S$.

26. $A = \frac{3}{2}T + C$, by No. 1.

27. $B = T + C$, by 2, 26.

28. $C = \frac{3}{2}T + \frac{2}{3}O + \frac{1}{3}I$, by 27, 3.

29. $E = \frac{15T + 5G + 4I}{9}$, by 5, 28, 4.

30. $F = \frac{12T + 4O + 5I}{9}$, by 6, 4, 28.

31. $W = \frac{7T + 4H + 2K}{12}$, by 21, 19.

32. $X = \frac{7T + 4O + 2Q}{12}$, by 22, 17.

33. $Y = \frac{7T + 2H + 4K}{12}$, by 23, 20.

34. $\& = \frac{7T + 2O + 4Q}{12}$, by 25, 18.

35. $Z = \frac{7\frac{1}{2}T + O + 2Q}{12}$, by 24, 34.

36. $L = \frac{39T + 8H + 4K + 4O + 2Q}{36}$, by 11, 31, 32.

37. $M = \frac{39T + 4H + 2K + 8O + 4Q}{36}$, by 12, 31, 32.

38. $B = \frac{39\frac{1}{2}T + 4H + 8K + O + 2Q}{36}$, by 15, 33, 35.

39. $Q = \frac{20T + H + 2K + O + 2Q}{18}$, by 16, 33, 35.

40. $Q = \frac{20T + H + 2K + O}{16}$, by 39.

41. $N = \frac{94\frac{1}{2}T + 16G + 2H + 20I + K + 4O + 2Q}{54}$, by 13, 30, 37.

42. $O = \frac{45T + 4G + 2H + 5I + K + 4O + 2Q}{27}$, by 14, 30, 37.

43. $O = \frac{45T + 4G + 2H + 5I + K + 2Q}{23}$, by 42.

44. $G = \frac{213T + 40G + 8H + 32I + 4K + 4O + 2Q}{108}$, by 7, 29, 36.

45. $G = \frac{213T + 8H + 32I + 4K + 4O + 2Q}{68}$, by 44.

46. $H = \frac{48T + G + 4H + 4I + 2K + 2O + Q}{27}$, by 8, 29, 36.

47. $H = \frac{48T + 5G + 4I + 2K + 2O + Q}{23}$, by 46.

48. $I = \frac{658\frac{1}{2}T + 64G + 20H + 80I + 28K + 19O + 14Q}{324}$, by 9, 38, 41.

No.

49. $I = \frac{658\frac{1}{2}T + 64G + 20H + 28K + 19O + 14Q}{244}$, by 48.

50. $K = \frac{294T + 16G + 14H + 20I \times 25K + 7O + 8Q}{162}$, by 10, 38, 41.

51. $K = \frac{294T + 16G + 14H + 20I + 7O + 8Q}{137}$, by 50.

52. $G = \frac{1724T + 65H + 256I + 34K + 33O}{8 \times 68 = 544}$, by 45, 40.

53. $H = \frac{788T + 80G + H + 64I + 34K + 33O}{16 \times 23 = 368}$, by 47, 40.

54. $H = \frac{788T + 80G + 64I + 34K + 33O}{367}$, by 53.

55. $I = \frac{5408T + 512G + 167H + 238K + 159O}{244 \times 8 = 1952}$, by 49, 40.

56. $K = \frac{608T + 32G + 29H + 40I + 2K + 15O}{137 \times 2 = 274}$, by 51, 40.

57. $K = \frac{608T + 32G + 29H + 40I + 15O}{272 = 8 \times 34}$, by 56.

58. $O = \frac{380T + 32G + 17H + 40I + 10K + O}{23 \times 8 = 184}$, by 43, 40.

59. $O = \frac{380T + 32G + 17H + 40I + 10K}{183}$, by 58.

60. $G = \frac{14400T + 32O + 549H + 2088I + 279O}{544 \times 8 = 4352}$, by 52, 57.

61. $G = \frac{14400T + 549H + 2088I + 279O}{4320 = 9 \times 480}$, by 60.

62. $G = \frac{1600T + 61H + 232I + 31O}{480}$, by 61.

63. $H = \frac{6912T + 672G + 29H + 552I + 279O}{367 \times 8 = 2936}$, by 54, 57.

64. $H = \frac{6912T + 672G + 552I + 279O}{2907 = 3 \times 969}$, by 63.

65. $H = \frac{2304T + 224G + 184I + 93O}{969}$, by 64.

66. $I = \frac{47520T + 4320G + 1539H + 280I + 1377O}{1952 \times 8 = 15616}$ by 55, 57.

67. $I = \frac{47520T + 4320G + 1539H = 1377O}{15336 = 27 \times 568}$, by 66.

68. $I = \frac{1760T + 160G + 57H + 51O}{568}$, by 67.

69. $O = \frac{54720T + 4512G + 2457H + 5640I + 75O}{183 \times 136 = 24888}$, by 59, 57.

70. $O = \frac{54720T + 4512G + 2457H + 5640I}{24813 = 3 \times 8271}$, by 69.

71. $O = \frac{18240T + 1504G + 819H + 1880I}{8271 = 3 \times 2757}$, by 70.

72. $G = \frac{13799040T + 46624G + 529920H + 1977152I}{480 \times 8271 = 3970080}$, by, 62, 71

73. $G = \frac{13799040T + 529920H + 1977152I}{3923456 = 64 \times 61304}$, by 72.

74. $O = \frac{215610T + 8280H + 30893I}{61304}$, by 73.

75. $H = \frac{6917568T + 664192G + 25389H + 565568I}{969 \times 2757 = 2671533}$, by 65, 71.

No.

76. $\text{H} = \dfrac{6917568\,\text{T} + 664192\,\text{G} + 565568\,\text{I}}{2646144 = 64 \times 41346}$, by 75.

77. $\text{H} = \dfrac{108087\,\text{T} + 10378\,\text{G} + 8837\,\text{I}}{41346}$, by 76.

78. $\text{I} = \dfrac{15487200\text{T} + 1400064\text{G} + 513216\text{H} + 95880\text{I}}{568 \times 8271 = 4697928}$, by 68, 71

79. $\text{I} = \dfrac{15487200\,\text{T} + 1400064\,\text{G} + 513216\,\text{H}}{4602048 = 96 \times 47938}$, by 78.

80. $\text{I} = \dfrac{161325\,\text{T} + 14584\,\text{G} + 5346\,\text{H}}{47938}$, by 79.

81. $\text{G} = \dfrac{9809571420\text{T} + 85929840\text{G} + 1350472338\text{I}}{61304 \times 41346 = 2534675184}$; by 74, 77.

82. $\text{G} = \dfrac{9809571420\,\text{T} + 1350472338\,\text{I}}{2448745344 = 162 \times 919 \times 16448}$, by 81.

83. $\text{G} = \dfrac{65890\,\text{T} + 9071\,\text{I}}{16448}$, by 83.

84. $\text{I} = \dfrac{7247976552\text{T} + 658470852\text{G} + 47242602\text{I}}{47938 \times 41346 = 1982044548}$, by 80, 77.

85. $\text{I} = \dfrac{7247976552\,\text{T} + 658470852\,\text{G}}{1934801946 = 18 \times 919 \times 116963}$, by 84.

86. $\text{I} = \dfrac{438156\,\text{T} + 39806\,\text{G}}{116963}$, by 85.

87. $\text{I} = \dfrac{9829607228\,\text{T} + 361080226\,\text{I}}{116963 \times 16448 = 1923807424}$, by 86, 83.

88. $\text{I} = \dfrac{9829607228\,\text{T}}{1562727198 = 4594 \times 340167}$, by 87.

89. $\text{I} = \dfrac{2139662}{340167}$ T. by 88.

90. $\text{G} = \dfrac{2542309}{340167}$ T. by 83, 89.

91. $\text{C} = \dfrac{2578443\frac{1}{2}}{340167}$ T. by 3, 89, 90.

92. $\text{D} = \dfrac{2444094\frac{1}{2}}{340167}$ T. by 4, 89, 90.

93. $\text{B} = \dfrac{2918610\frac{1}{2}}{340167}$ T. by 27, 91.

94. $\text{A} = \dfrac{3088694}{340167}$ T. by 26, 91, 93.

95. $\text{E} = \dfrac{2930522}{340167}$ T. by 5, 92, 93.

96. $\text{F} = \dfrac{2772350}{340167}$ T. by 6, 92, 93.

97. $\text{H} = \dfrac{1984812\frac{1}{2}}{340167}$ T. by 77, 89, 90.

98. $\text{O} = \dfrac{1895418\frac{1}{2}}{340167}$ T. by 71, 89, 90, 97.

99. $\text{K} = \dfrac{1690314\frac{1}{2}}{340167}$ T. by 57, 89, 90, 97, 98.

100. $\text{V} = \dfrac{2056730}{340167}$ T. by 19, 97, 99.

101. $\text{U} = \dfrac{1958564}{340167}$ T. by 20, 97, 99.

102. $\text{W} = \dfrac{1141704}{340167}$ T. by 21, 100.

103. $\text{Y} = \dfrac{1092671}{340167}$ T. by 23, 101.

104. $\text{Q} = \dfrac{879012\frac{1}{2}}{340167}$ T. by 40, 97, 98, 99.

105. $\text{R} = \dfrac{1726700}{340167}$ T. by 17, 98, 104.

106. $\text{S} = \dfrac{1387898}{340167}$ T. by 18, 98, 104.

107. $\text{X} = \dfrac{976739}{340167}$ T. by 22, 105.

108. $\& = \dfrac{807338}{340167}$ T. by 25, 106.

109. $\text{Z} = \dfrac{517058}{340167}$ T. by 24, 108.

110. $\text{L} = \dfrac{1256832\frac{1}{2}}{340167}$ T. by 11, 102, 107.

111. $\text{M} = \dfrac{1201827\frac{1}{2}}{340167}$ T. by 12, 102, 107.

112. $\text{N} = \dfrac{2418926}{340167}$ T. by 13, 96, 111.

113. $\text{P} = \dfrac{1070883\frac{1}{2}}{340167}$ T. by 15, 103, 109.

" *Or thus, in Alphabetical Order.*

$\text{A} = 9\,\dfrac{27191}{340167}$ T.	$\text{O} = 5\,\dfrac{194583\frac{1}{2}}{340167}$ T.
$\text{B} = 8\,\dfrac{197274\frac{1}{2}}{340167}$ T.	$\text{P} = 3\,\dfrac{50382\frac{1}{2}}{340167}$ T.
$\text{C} = 7\,\dfrac{197274\frac{1}{2}}{340167}$ T.	$\text{Q} = 2\,\dfrac{198678\frac{1}{2}}{340167}$ T.
$\text{D} = 7\,\dfrac{62925\frac{1}{2}}{340167}$ T.	$\text{R} = 5\,\dfrac{25865}{340167}$ T.
$\text{E} = 8\,\dfrac{209186}{340167}$ T.	$\text{S} = 4\,\dfrac{27230}{340167}$ T.
$\text{F} = 8\,\dfrac{51014}{340167}$ T.	$\text{V} = 6\,\dfrac{15728}{340167}$ T.
$\text{G} = 7\,\dfrac{161540}{340167}$ T.	$\text{U} = 5\,\dfrac{257729}{340167}$ T.
$\text{H} = 5\,\dfrac{283077\frac{1}{2}}{340167}$ T.	$\text{W} = 3\,\dfrac{121253}{340167}$ T.
$\text{I} = 6\,\dfrac{98660}{340167}$ T.	$\text{X} = 2\,\dfrac{296405}{340167}$ T.
$\text{K} = 4\,\dfrac{329646\frac{1}{2}}{340167}$ T.	$\text{Y} = 3\,\dfrac{72170}{340167}$ T.
$\text{L} = 3\,\dfrac{236331\frac{1}{2}}{340167}$ T.	$\text{Z} = 1\,\dfrac{176891}{340167}$ T.
$\text{M} = 3\,\dfrac{181326\frac{1}{2}}{340167}$ T.	$\& = 2\,\dfrac{127004}{340167}$ T.
$\text{N} = 7\,\dfrac{37757}{340167}$ T.	

"All this weight lying on the building, or wall, is n necessarily distinguished by a distinct calculation; becaus those evidently correspond with others which are situated the ends of their respective rafters. For example, when th rafter X R does not rest exactly upon its middle, the fulcrum, whether it sustains one-half the weight of the rafter at X, and the other on the wall, then also the half of the burden is placed at R.

"It is obvious, from this calculation, that the joinings about A, toward the middle of the framing, press most of all. Since the particular weight of these is about nine of the longer rafters (but of the others, less by a ninth part of the wood) to each of which there will be added, half the weight of the rafter for firmness deducted, lest by its own weight it should break, and moreover one-half of the weight of the joint C lying upon it, being about four of the rafters. And so, by computing the whole, the strength requisite, lest a rafter should give way, will equal more than thirteen times the weight of the rafters, and be about fourteen times $9\frac{27191}{340167} + 4\frac{394549}{1360668} = 13\frac{503313}{1360668} = 13\frac{167771}{453556}$: the computation in weight of each rafter.

"No doubt can now remain that the rafters, even the longest, can be made of such firmness as shall enable them to sustain any weight that may be placed upon them individually to fourteen times the weight of the whole; neither can it be doubted, that raftering of this description is the safest that can possibly be applied to purposes where great weights are to be carried.

"Another form of this construction. *Figure* 6 exhibits another form, differing from the preceding in this, that where the ends of two of the rafters lie upon a third, they are jointed by two distinct dovetails; into these a third rafter is notched, and all are so placed as to be supported by those parts: hence to the middle part of each rafter are fastened two others, but to opposite parts.

"*Figure* 7 exhibits the lateral face: the upper face is sufficiently obvious from *Figure* 6. All these rafters are of an equal length, and similar among themselves.

"But here, as in the preceding construction, the work may be more or less extended, and the condition of the timber will be equally determined both as to the aid it gives and the weight it will carry. For, as in the protracted area, the number of the beams is augmented, so is also the weight. But this construction is attended with a disadvantage from both the beams' weight lying upon one, which having to endure the burden on an individual part of the beam, it is more strenuously pressed; that is, it has to sustain the entire weight of two ends, one entire beam; for, in this construction, equal to that of the half, which in the preceding was not borne, is here to be supported at one and the same point; on this account, also, the wood at that mortise is very much weakened, by being cut away to enable it to support the two beams, which rest their tenons in one place. This in some measure seems to be compensated by the resting timbers being placed towards opposite parts, which in the preceding construction lay towards the same parts; although, in this also it is not of much consequence, especially if the ends of the beams, resting on the others, are not extended toward the centre, but kept pretty close to the outer part of the framing, which is easily done by the judicious management of the architect.

"But this inconvenience forms no substantial objection to the plan, since the rafters are sufficiently strong and well joined to support any proportionate weight, as will be obvious from the subjoined investigation of their strength.

"In looking at what is before us, the former of these figures seems the stronger, because the timbers are so disposed that the workmanship is more obvious to the eye; while in the latter it is scarcely distinguishable, and the intervals are so varied as to give the work a distorted appearance: yet in both they are squares; and in the latter the spaces beyond the half-rafter from the wall-beams are also resolved into the same figure.

"The calculation in this construction, will result from the same principles as in the preceding; but here it will be much more expeditious, because, as all the timbers are of the same length, and they support the weight of the corresponding timbers about the centre, they are almost all pressed by an equality of weight about the same part: all which conduce to render the results more readily to be obtained.

"*Calculation adapted to this construction.*

"With respect to the facility of this calculation, it may be observed, that the points (whether five or four) which are similarly posited in respect of the scheme, and on that account support an equality of weight, are designated by the same symbol that was adopted in the preceding problem. But, here, on account of the individual pieces of wood supporting the same weight, and that too about the same part, the two ends of each rafter have to support the same weight; these ends we shall therefore express by the same symbols, the equal weight being denoted by a similar sign. Other methods of proof might be mentioned, but the foregoing will be sufficient for our purpose.

"SYNOPSIS OF THIS CALCULATION.

1. $\mathrm{A} = \alpha = \frac{1}{2}\mathrm{T} + \mathrm{B}$.
2. $\mathrm{B} = \beta = \frac{1}{2}\mathrm{T} + \frac{1}{2}\mathrm{K} + \frac{1}{2}\mathrm{F}$.
3. $\mathrm{C} = \frac{1}{2}\mathrm{T} + \mathrm{A}$.
4. $\mathrm{D} = \delta = \frac{1}{2}\mathrm{T} + \mathrm{L}$.
5. $\mathrm{E} = \varepsilon = \frac{1}{2}\mathrm{T} + \frac{1}{2}\beta + \frac{1}{2}\mathrm{R}$.
6. $\mathrm{F} = \frac{1}{2}\mathrm{T} + \frac{1}{2}\mathrm{C} + \frac{1}{2}\mathrm{G}$.
7. $\mathrm{G} = \gamma = \frac{1}{2}\mathrm{T} + \mathrm{E}$.
8. $\mathrm{H} = \frac{1}{2}\mathrm{T} + \frac{1}{2}\alpha + \frac{1}{2}\mathrm{D}$.
9. $\mathrm{I} = \iota = \frac{1}{2}\mathrm{T} + \frac{1}{2}\varepsilon + \frac{1}{2}\mathrm{N}$.
10. $\mathrm{K} = \kappa = \frac{1}{2}\mathrm{T} + \frac{1}{2}\mathrm{H} + \frac{1}{2}\mathrm{I}$.
11. $\mathrm{L} = \lambda = \frac{1}{2}\mathrm{T} + \frac{1}{2}\kappa$.
12. $\mathrm{M} = \mu = \frac{1}{2}\mathrm{T} + \frac{1}{2}\mathrm{P}$.
13. $\mathrm{N} = \nu = \frac{1}{2}\mathrm{T} + \frac{1}{2}\lambda + \frac{1}{2}\mathrm{M}$.
14. $\mathrm{P} = \pi = \frac{1}{2}\mathrm{T} + \frac{1}{2}\iota$.
15. $\mathrm{Q} = \frac{1}{2}\mathrm{T} + \frac{1}{2}\gamma$.
16. $\mathrm{R} = \rho = \frac{1}{2}\mathrm{T} + \frac{1}{2}\pi + \frac{1}{2}\mathrm{Q}$.
17. $\mathrm{C} = \mathrm{T} + \mathrm{B}$, by 3, 1.
18. $\mathrm{D} = \mathrm{T} + \frac{1}{2}\kappa$, by 4, 11.
19. $\mathrm{F} = \frac{5}{4}\mathrm{T} + \frac{1}{2}\mathrm{B} + \frac{1}{2}\mathrm{E}$, by 6, 7, 17.
20. $\mathrm{H} = \frac{5}{4}\mathrm{T} + \frac{1}{2}\mathrm{B} + \frac{1}{4}\kappa$, by 8, 1, 18.
21. $\mathrm{M} = \frac{3}{4}\mathrm{T} + \frac{1}{4}\iota$, by 12, 14.
22. $\mathrm{N} = \mathrm{T} + \frac{1}{4}\kappa + \frac{1}{4}\mathrm{P}$, by 13, 11, 12.
23. $\mathrm{N} = \frac{9}{8}\mathrm{T} + \frac{1}{4}\kappa + \frac{1}{8}\iota$, by 22, 14.
24. $\mathrm{Q} = \frac{3}{4}\mathrm{T} + \frac{1}{2}\mathrm{E}$, by 15, 7.
25. $\mathrm{R} = \frac{9}{8}\mathrm{T} + \frac{1}{4}\mathrm{E} + \frac{1}{4}\iota$, by 16, 14, 24.
26. $\mathrm{B} = \frac{9}{8}\mathrm{T} + \frac{1}{4}\mathrm{B} + \frac{1}{4}\mathrm{E} + \frac{1}{2}\mathrm{K}$, by 2, 19.
27. $\mathrm{B} = \frac{9\,\mathrm{T} + 2\,\mathrm{E} + 4\,\mathrm{K}}{6}$, by 26.
28. $\mathrm{E} = \frac{29}{16}\mathrm{T} + \frac{7}{24}\mathrm{E} + \frac{1}{8}\mathrm{I} + \frac{1}{3}\mathrm{K}$, by 5, 25, 27.
29. $\mathrm{E} = \frac{87\,\mathrm{T} + 6\,\mathrm{I} + 16\,\mathrm{K}}{34}$, by 28.
30. $\mathrm{H} = 2\,\mathrm{T} + \frac{1}{6}\mathrm{E} + \frac{1}{12}\mathrm{K}$, by 20, 27.
31. $\mathrm{I} = \frac{17}{16}\mathrm{T} + \frac{1}{2}\varepsilon + \frac{1}{16}\mathrm{I} + \frac{1}{8}\kappa$, by 9, 23.
32. $\mathrm{I} = \frac{17\,\mathrm{T} + 8\,\varepsilon + 2\,\kappa}{15}$, by 31.
33. $\mathrm{K} = \frac{31}{15}\mathrm{T} + \frac{7}{20}\mathrm{E} + \frac{43}{120}\mathrm{K}$, by 10, 30, 32.
34. $\mathrm{K} = \frac{248\,\mathrm{T} + 42\,\mathrm{E}}{77}$, by 33.

35. $I = \frac{361\,T + 140\,E}{3 \times 77 = 231}$, by 32, 34.

36. $E = \frac{11389\,T + 952\,E}{34 \times 77 = 2618}$, by 29, 34, 35.

37. $E = \frac{1627\,T + 136\,E}{34 \times 11 = 374}$, by 36.

38. $E = \frac{1627}{238}\,T$, by 37.

39. $G = \frac{1746}{238}\,T$, by 7, 38.

40. $Q = \frac{992}{238}\,T$, by 15, 39.

41. $K = \frac{1654}{238}\,T$, by 34, 38.

42. $L = \frac{946}{238}\,T$, by 11, 41.

43. $D = \frac{1065}{238}\,T$, by 4, 42.

44. $B = \frac{2002}{238}\,T$, by 27, 38, 41.

45. $A = \frac{2121}{238}\,T$, by 1, 44.

46. $C = \frac{2240}{238}\,T$, by 3, 45.

47. $F = \frac{2112}{238}\,T$, by 6, 39, 46.

48. $H = \frac{1712}{238}\,T$, by 8, 43, 45.

49. $I = \frac{1358}{238}\,T$, by 32, 38, 41.

50. $P = \frac{798}{238}\,T$, by 14, 49.

51. $M = \frac{518}{238}\,T$, by 12, 50.

52. $N = \frac{851}{238}\,T$, by 13, 42, 51.

53. $R = \frac{1014}{238}\,T$, by 16, 40, 50.

That is, in Alphabetical Order.

$A = 8\frac{217}{238}\,T.$	$I = 5\frac{168}{238}\,T.$
$B = 8\frac{98}{238}\,T.$	$K = 6\frac{226}{238}\,T.$
$C = 9\frac{98}{238}\,T.$	$L = 3\frac{232}{238}\,T.$
$D = 4\frac{113}{238}\,T.$	$M = 2\frac{42}{238}\,T.$
$E = 6\frac{199}{238}\,T.$	$N = 3\frac{137}{238}\,T.$
$F = 8\frac{208}{238}\,T.$	$P = 3\frac{84}{238}\,T.$
$G = 7\frac{80}{238}\,T.$	$Q = 4\frac{40}{238}\,T.$
$H = 7\frac{46}{238}\,T.$	$R = 4\frac{62}{238}\,T.$

It appears from this calculation that the greatest of the separate weights will be $A = 8\frac{217}{238}\,T$. When therefore upon this point (C C in the middle of the wood) there lie two A's (on both sides) it is $7\frac{196}{230}\,T$; and so on, in like manner, lest any rafter give way by its own weight. Whence one-half the weight of the timber is determined. The strength requisite there, is the same, lest that beam give way, which is equal to the weight of the respective beams $8\frac{217}{238} + 8\frac{217}{231} + \frac{1}{2} = 18\frac{77}{238} = 18\frac{11}{34}$. But indeed this weight is not so great as to occasion any apprehension for the strength of the timber; for even if the timbers be pretty long, they are sufficient to bear any weight that may be laid upon them, to eighteen or even to nineteen times their own weight.

"Here the weight is indeed heavier than in the preceding case; for there, the pressure amounted only to fourteen times the weight of the timber.

"In the mean time, the conditions of this construction dispense with a multiplicity of rafters, as the length of the area within the walls extends to twelve times the length of the whole, the length and breadth of the rafters remaining. For in this case the rafters being joined are equal to 49, but in the other the longer are 40 and the shorter 20."

Naked of a Column, or Pilaster, the surface of the shaft or trunk, when the mouldings are supposed to project. Thus we say, a pilaster ought to exceed the naked of the wall by so many inches, and that the foliages of capital ought to answer to the naked of the columns.

Naked of a Wall, the remote face whence the projectures take their rise. It is generally a plane surface, and when the plan is circular, the naked is the surface of a cylinder, with its axis perpendicular to the horizon.

NAOS or Nave (from the Greek *ναος*, *a temple*) the chamber or enclosed apartment of a temple. The part of the temple which stood before the naos, comprehended between the wall and the columns of the portico, was called the *pronaos*; while the corresponding part behind was called the *posticum*.

NAPIER'S BONES, or RODS, a contrivance of Napier to facilitate the performance of multiplication and division, explained by him, in his Rabdologia, published in 1617. The invention would perhaps have been more employed, but for his discovery of logarithms: but even yet it might be used with advantage by young arithmeticians in verification of their work.

These rods may be made of bone, ivory, horn, wood, pasteboard, or any other convenient material. There are five of them, and the face of each is divided into nine equal parts, each being subdivided by a diagonal line into two triangles. In these compartments or squares the numbers of the multiplication table are inserted, the units or right-hand figures being placed in the right hand triangle, and the tens in the left.

NARTHEX, the name of an enclosed space in the ancient Christian churches, and also of an ante-temple or vestibule without the church. To the Narthex the catechumens and penitents were admitted; and there appears to have been several such apartments in each church, but nothing certain is known of their position. Narthex is frequently used as synonymous with *porch* and *portico*.

NATTES, a name given to an ornament used in the decoration of surfaces in the architecture of the 12th century, from its resemblance to the interlaced widths of matting.

NATURAL BEDS, of a stone, the surfaces from which the laminæ were separated. It is of the utmost consequence to the duration of stone walls, that the laminæ should be placed perpendicular to the face of the work, and parallel to the horizon, as the connecting substance of these thin plates, or laminæ, is more friable than the laminæ themselves, and consequently liable to scale off in large flakes, and thus reduce the work to a state of rapid decay.

NAVE (from the Saxon *naf*) in architecture, the body of a church; or the place where the people are seated; reaching from the rail or baluster of the choir to the chief door. The ancient Greeks called the nave *pronaos*; the Latins frequently call it *cella*. *See* Naos.

The nave of the church belongs to the parishioners, who are bound to keep it in repair, &c.

NAUMACHIA, the representation of a sea-fight among the Romans, which was sometimes performed in the Circus Maximus or amphitheatre, water being introduced sufficient to float ships; but more frequently in places made especially for the purpose, which were called Naumachiæ. Julius Cæsar appears to have been the first who gave a representation of a sea-fight on an extensive scale. He dug a lake in the Campus Martius for the purpose, which, however, was filled up in his life-time. Augustus also dug a lake near the Tiber for the same purpose, which was afterwards turned into a park or plantation. Another lake was dug in the Campus Martius by Caligula; but Claudius exhibited a naumachia on the lake Fucinus, now Celano. The naumachia, in which Titus is said by Suetonius to have exhibited a sea-fight, has occasioned some dispute among the learned; some understanding it to be the Circus Maximus, and others the lake dug by order of Augustus. Domitian appears to have been the first who erected a building of stone around these artificial lakes. Previous to his time the spectators appear to have sat upon wooden benches, which might be easily made to rise gradually above one another with the earth which had been dug out of the artificial lake. In later times the naumachia were usually surrounded with buildings like the amphitheatre or circus.

The ships which were engaged in these sea-fights were divided into two parties, which were called respectively by the names of different maritime nations, as the Tyrian and Egyptian fleets, the Sicilian and Rhodian. The combatants, who were called Naumachiarii, were usually composed of captives or criminals, who fought to death, unless saved by the clemency of the emperor. These sea-fights were said to have been exhibited on such a scale of magnificence and splendour as almost to surpass our belief. In the naumachia exhibited by Nero, there were sea-monsters swimming about in the artificial lake, and Claudius caused a Triton, made of silver, to be placed in the middle of the lake Fucinus, who was made, by machinery, to give the signal of attack with a trumpet. In Domitian's naumachia the number of ships engaged was almost equal to two real fleets, and in the sea-fight on the lake Fucinus, there are said to have been no fewer than 19,000 combatants.

NEBULE (from the Latin *nebula*, a cloud) an ornament of the zig-zag form, but without angles. It is chiefly found in the remains of Saxon architecture, in the archivolts of doors and windows.

NECK, of a capital, the space between the channelures and the annulets of the Grecian Doric capital. In the Roman Doric, it is the space between the astragal and the annulet.

The rich Ionic capitals of Minerva Polias, and Erechtheus, at Athens, have neckings, but most other antique examples of the Ionic order are without them.

NEEFS, PETER, in biography, a painter of architecture, and a disciple of Henry Steenwick, born at Antwerp, in the year 1570. He was particularly skilful in perspective, and generally chose such subjects as required a considerable display of that science; such as the interior of churches, splendid halls, &c. These he drew with great neatness and effect, and painted very clear, gay, and agreeable, but he never equalled the truth of his master. His execution of the mouldings and masses of columns, in the various Gothic works which he chose as models, is too neat, and too much made up of lines, for real imitation; but that very defect gives them lightness; and the truth with which he drew the forms of the building, and proportioned his figures, which are very freely wrought, though not unfrequently by other artists, renders them very agreeable. Van Fulden, Teniers, and Breughel, were often called upon to assist Neefs, and by their skilful execution made amends for his want of knowledge of the human figure. He died at the age of 81, leaving a son, whose name also was Peter, and who is denominated *the Young*, in contradistinction to his father, whose excellence in the art of painting he never rivalled, although he had the advantage of his example and instruction, and practised in the same branch of the art.

NEGATIVE QUANTITIES, are those quantities which are preceded or effected with the negative sign.

Negative sign, in algebra, is that character or symbol, which denotes subtraction, being a short line preceding the quantity to be subtracted, and is read *minus*; thus, $a - b$ denotes that the quantity b is to be taken from the quantity a, and is read *a minus b*; like signs produce *plus*, and unlike signs *minus*, hence $-a \times b = +ab$. The introduction of this character has given rise to various controversies, with regard to the legality or illegality of certain conclusions depending upon it; some maintaining, that as a negative quantity is in itself totally imaginary, it ought not to be introduced into a science, the excellency of which depends upon the rigour and certainty of its conclusions; while others, running into the opposite extreme, have endeavoured to illustrate what will not admit of illustration, and thus, like other zealots, have been the greatest enemies of the cause they were endeavouring to defend.

It is in vain to attempt to define what can have no possible existence; a quantity less than nothing is totally incomprehensible; and to illustrate it, by reference to a debtor and creditor account, to say the least of it, says Barrow, is highly derogatory to this most extensive and comprehensive science.

NERVES, in architecture, the mouldings of the groined ribs of Gothic vaults.

NET, or RETE, (from the Saxon, *net*, derived from the Gothic, *nati*) the covering of a body or geometrical solid. *See* ENVELOPE and SOFFIT.

NET MEASURE, in building, is when no allowance is made for finishing; and in artificers' works, when no allowance is made for waste of materials.

NET MASONRY. *See* MASONRY and STONE WALLS.

NEWEL, in architecture, the upright post or central column, round which the steps of a circular staircase are made to wind; being that part of the staircase by which they are sustained.

The newel is, properly, a cylinder of stone, which bears on the ground, and is formed by the ends of the steps of the winding-stairs.

There are also newels of wood, which are pieces of timber placed perpendicularly, receiving the tenons of the steps of wooden stairs into their mortises, and wherein are fitted the shafts and rests of the staircase, and the flights of each story. In some of the Tudor and Elizabethan residences, some very fine examples may be seen of the newel richly ornamented, and adding much to the beauty of the staircase.

NICHE, (from the Italian, *niechia*, shell) in architecture, a cavity, or hollow place, in the thickness of a wall, to place a figure or statue in.

Niches are made to partake of all the segments under a semicircle. They are sometimes at an equal distance from the front, and parallel or square on the back with the front line; in which case they are called *square recesses*, or *square niches*. The larger niches serve for groups of figures, the smaller for single statues, and sometimes only for busts.

Great care must be taken to proportion the niches to the figures, and the pedestal of the figures to the niches.

Niches are sometimes made with rustic work.

Few niches are to be found in Grecian antiquity, but what may be supposed to have been erected under the dominion of the Romans.

In the Pantheon at Rome, the niches are all rectangular recesses, dressed in the same manner as the apertures of doors; the columns are insulated, and the entablatures crowned with triangular and circular pediments alternately. The large niches, or exedræ, on the sides, have cylindrical backs, but finish at top with the soffit of the architrave of the general entablature; these niches have each two columns placed in the aperture which supports the architrave. The entablature is continued without any break or interruption of recesses, except by the large cylindro-spherical niche opposite the entrance, and the side through which the entrance is made; but neither of these is supposed to have been in the original edifice, but to have been introduced at some later period. The large niches on the exterior side within the portico are cylindro-spherical, without any dressings. In the remains of the piazza of Nerva (see Desgodetz's *Antiquities of Rome*) a niche is exhibited upon a circular plan, with a rectangular front and cylindrical head in the middle of the attic, over the intercolumns; the axis of the cylinder, forming the head of the niche, is horizontal, and parallel to the naked of the wall. This niche is surrounded with an architrave, standing upon the base of the attic, which projects to receive it, and the head of the architrave supports the crowning of the attic.

The *Ruins of Palmyra*, by Wood, exhibit niches of various kinds, some of which are very fantastically dressed. The inside of the portico of the temple of the sun has two niches, one on each side of the doorway, with cylindrical backs, terminated at the head with spheroidal tops, which show an ellipsis on the face with its greater axis horizontal. These niches are decorated with four attached columns, whose axes are placed in the surface of a cylinder: the entablature over the columns terminates under the spheroidal head; the head is decorated with a shell, and surrounded on the front with an elliptic archivolt upon the face of the wall. *See Plates* VI. and IX. *of the Ruins of Palmyra.*

The inside of the portico of the court of the same edifice, shown in *Plate* XI. exhibits two niches on each side of the doorway, which terminate on the front in parallel lines, and with a semicircle at the head; they finish with a pilaster on each side: the capital, which is Corinthian, serving as an impost to the archivolt surrounding the head. Besides this dressing, a column is placed on each side, attached to the wall, so that the distance between the insides of the columns is greater than that between the outsides of the pilasters; the architrave of the entablature rests upon the archivolt of the head of the niche.

The inside of the court of the great temple of Balbec exhibits niches dressed in the most whimsical manner: the sides of the niches terminate with the wall in vertical lines, and the head with the said wall in a semicircle.

The sides finish with Corinthian pilasters; the entablature is horizontal over the pilasters; but the architrave and cornice are carried round the semicircular head of the niche, which appears to be spherical within, being decorated with a shell resting upon an impost, and corresponding in its situation to the height of the capital on each side. The inside of the temple of Jupiter, at Spalatra, is decorated with niches, one between every two columns; the one opposite the entrance, and those on each of the two sides, are rectangular below, but finish with cylindric heads: the axis of the cylinder, which forms the head, is parallel to the horizon, and in the direction of radii which belong to the cylindric wall, in which these niches are placed.

The other four niches are cylindro-spherical; that is, they have cylindrical backs, and are terminated with spherical heads. All these niches are decorated with an impost, continued from side to side, and the heads are furnished with archivolts.

In the pointed style of architecture, niches are sometimes highly decorated. The back very frequently consists of three sides of a hexagon, and the head is terminated with a rich canopy, forming a complete hexagon with the interior; the under part of each of the three projecting sides of the canopy has a Gothic arch, and the soffit represents a groined vault, decorated with tracery and ribs in the most beautiful manner.

The bottoms of these niches are formed by a table of the same shape as the head, and terminate below in the form of a pendant.

The ceiling of the canopy represents the groined roof of an hexagonal building in miniature, as some of the highly decorated chapter-houses exhibit; the top of the canopy finishes with battlements; and the vertical angles are sometimes finished with pendant buttresses, which are surmounted with pinnacles elaborately finished with crockets.

Niche, in carpentry, the wood-work to be lathed over for plastering.

The most usual construction of niches in carpentry, are those with cylindrical backs and spherical heads, called *cylindro-spheric niches;* the execution of which depends upon the principles of spheric sections.

As all the sections of a sphere are circles, and those passing through its centre are equal, and the greatest which can be formed by cutting the sphere; it is evident, that if the head of a niche is intended to form a spherical surface, the ribs may be all formed by one mould, whose curvature must be equal to that of a great circle of the sphere, viz., one passing through its centre: but the same spherical surface may be formed by ribs of wood moulded from the sections of lesser circles, in a variety of ways; though not so eligible for the purpose as those formed of great circles; because their disposition for sustaining the lath is not so good, and the trouble of moulding them to different circles, and of forming the edges according to different bevels, in order to range them in the spherical surface, is very great, compared with those made from great circles.

The regular dispositions for the head of a niche are the following:

The ribs of niches are generally disposed in a vertical plane, parallel to each other, or intersecting each other in a vertical line. When the line of intersection passes through the centre of the sphere, all the ribs are great circles; but if the line of intersection do not pass through the centre of the sphere, the circles which form the spherical surface are all of different radii.

When the ribs are fixed in parallel vertical planes, their disposition is either parallel to the face of the wall, or parallel to a vertical plane passing through the centre of the sphere perpendicular to the surface of the wall; and this will be understood whether the surface be a plane, or that of a cylinder, or that of a cylindroid.

Though these dispositions are the most common and most fit for the purpose, there is still another regular position of the ribs of a niche, which is easily constructed in practice, viz. by making all the ribs intersect in a line passing through the centre of the sphere perpendicular to the surface of the wall; but this method is not so eligible for lathing upon.

Another method is by making the planes of the ribs parallel to the horizon: this is not only attended with great labour in workmanship, but is incommodious for lathing upon.

The number of positions in which the ribs of a niche may be placed are almost infinite; as the ribs may have a common intersection in a line or axis obliquely situated to the horizon, or their position may be in parallel planes obliquely situated to the horizon: but the regular positions already enumerated, ought to be those to which the carpenter should direct his attention.

Plate I. *Figure* 1, No. 2, the elevation of a niche, where all the ribs intersect each other in a vertical line, coinciding with the inside of the front rib, as shown by the plan, No. 1.

To describe any one of the ribs, as $m\ n$, continue the inside circle of the plan round beyond the wall, as far as may b

Fig. 1. Nº 1.

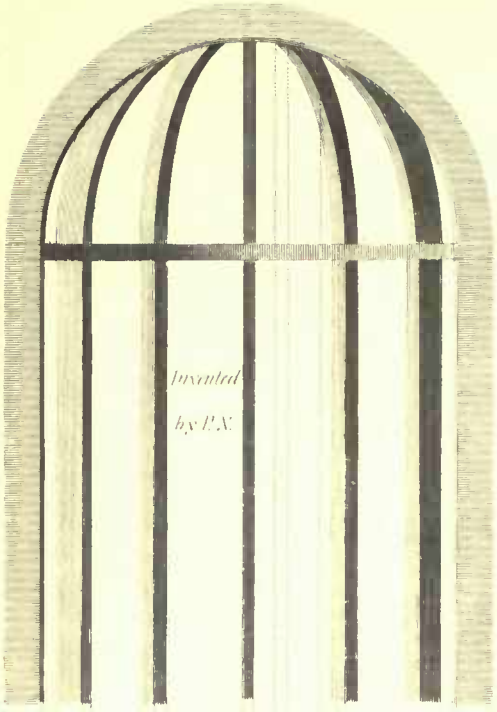
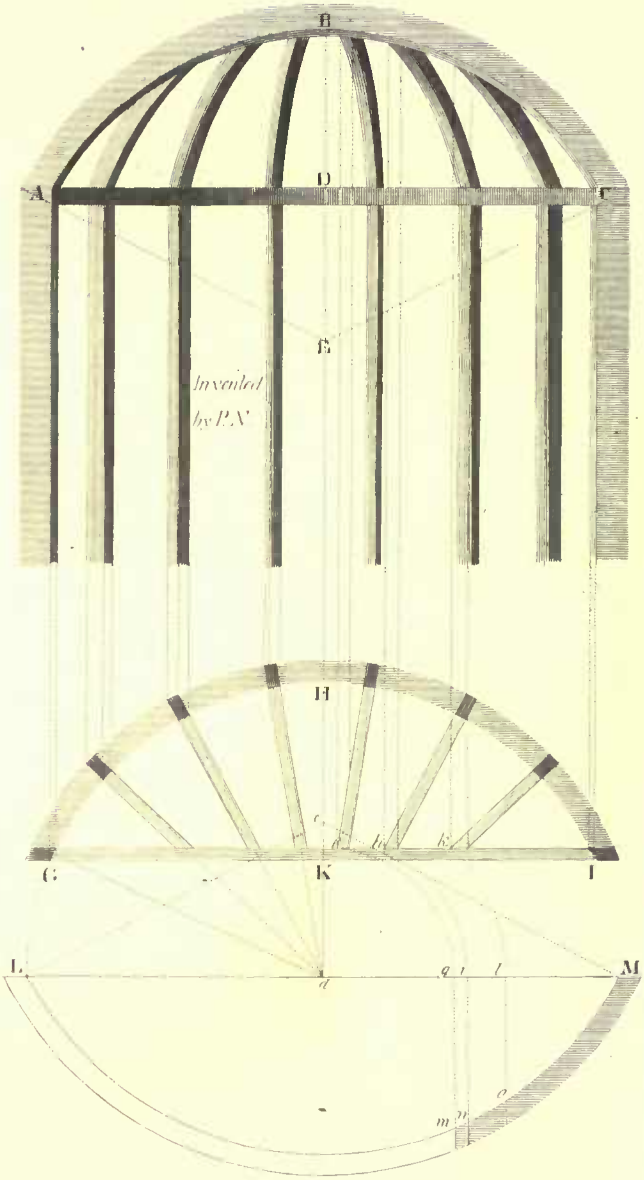


Fig. 2.



Nº 2

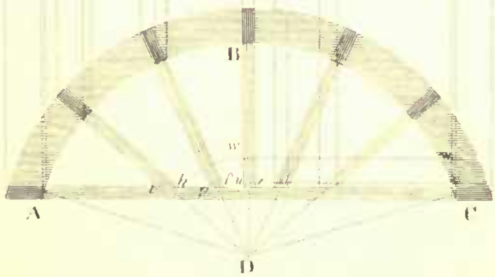


Fig. 1. Nº 3.

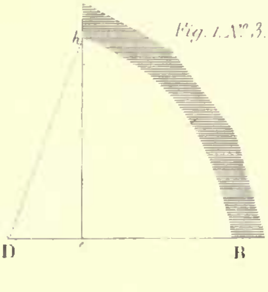


Fig. 1. Nº 4.

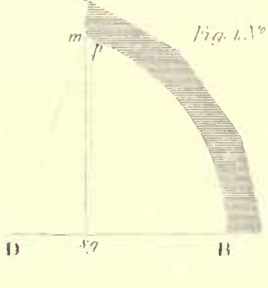
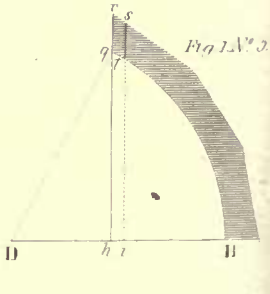


Fig. 1. Nº 5.



Drawn by M.A. Nicholson

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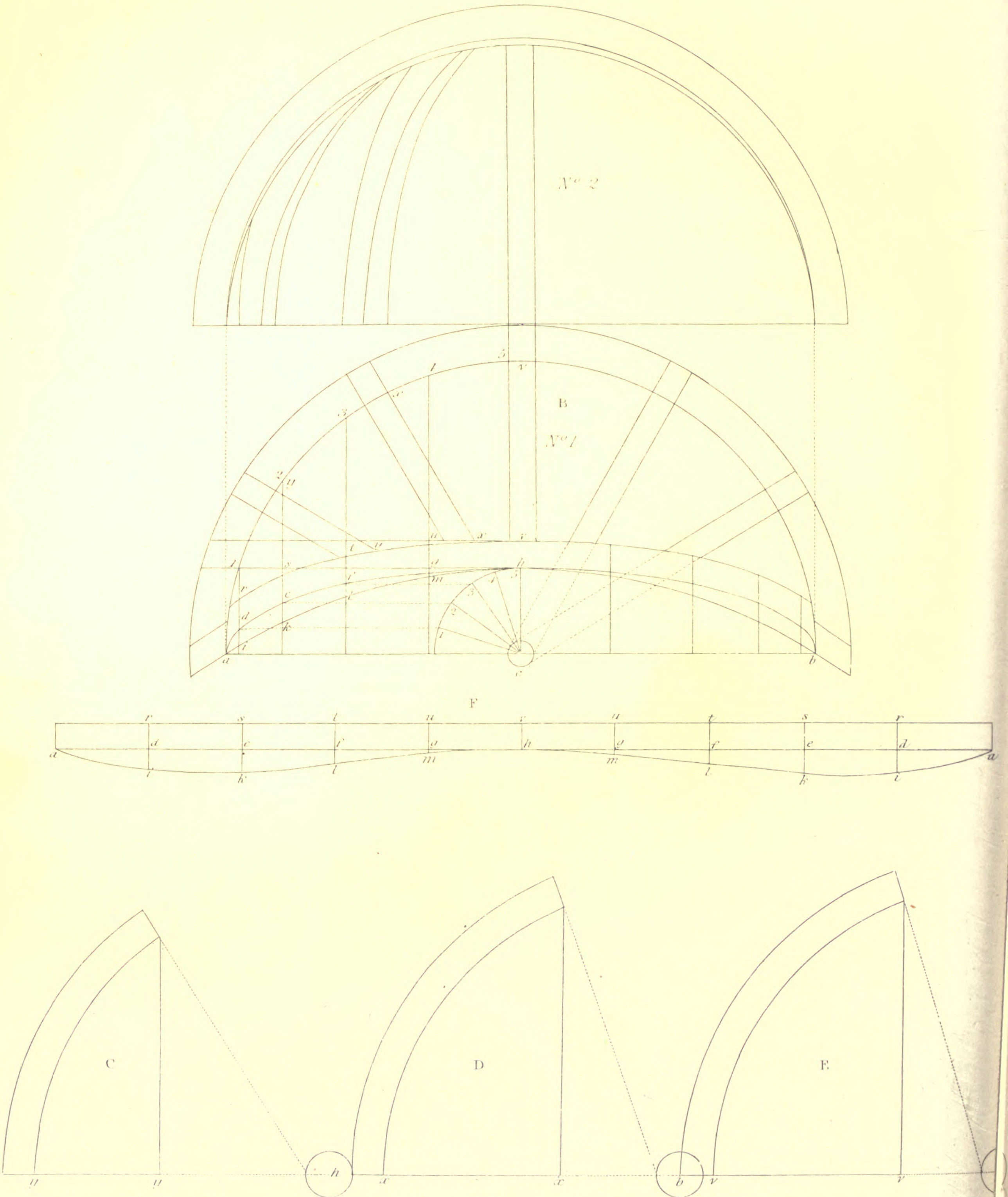
NICHES.

Fig. 1



Engraved by J.

found necessary: produce *f i*, the base of the rib, to meet the opposite circumference in *g*; bisect *g e* at *h*; from *h*, with the radius *h e*, describe the arc *e l*; draw *d f* perpendicular to the other side of the plan of the rib, cutting *g e* at *f*; from *h*, with the radius *h f*, describe the arc *f k*; from the centre draw *i n* perpendicular to *g e*, the base, cutting the other circles at *k* and *l*; from the same centre, *h*, draw *m n* at any convenient distance, so as to make the rib sufficiently strong: the two inner arcs *f k*, and *e l*, show the part to be taken from the side of the rib in order to range its inner edge. In the same manner every other rib may be described.

Figure 2, No. 2, the elevation of a niche, where the ribs are posited in parallel vertical places perpendicular to the face of the wall.

The method of describing the ribs is as follows: Draw a line through the centre of the circle which forms the plane, parallel to the face of the wall. Suppose it were required to describe the rib whose base is *f h*: produce *f h* to meet the line parallel to the face of the wall in *g*; from *g*, as a centre, with the distance *g f*, describe the arc *f k*; draw the short line *d e* perpendicular to *g f*, cutting *d f* in *e*: from *g*, with the radius *g e*, describe the arc *e i*, so that *e i* and *f k* may terminate upon the inside of the front rib, A C, in the points *i* and *k*: then *e i* and *f k* will show the bevelling of the edge in order to range in the spherical surface.

In the same manner may all the other ribs be described.

Figure 3, shows the method of forming the spherical head of a niche, when the planes of the ribs are parallel to the front rib, or to the face of the wall. No. 1, the plan; No. 2, the elevation. The figure is so obvious as hardly to require any description, the ribs being all semicircles of different diameters, as shown by the plan: the parts darkly shadowed, are the places where the ribs come in contact with the plate or sill on which they stand; and show the degree of bevelling requisite for the edges, in order that they may range with the spherical surface. This disposition of the ribs is very convenient for fixing the laths, which may be all directed towards the centre, the workmanship in bevelling is very considerable.

In order to strengthen the work, a vertical rib is made to pass through the centre of the sphere, perpendicular to the surface of the wall.

Figure 4, is a very convenient method of forming the head of a niche, by making the planes of all the ribs to intersect in a common axis, passing through the centre of the sphere, perpendicular to the surface of the wall; but it is not so convenient for fixing the laths.

Plate II. *Figure* 1, is the most convenient method of any for fixing the laths, and the ribs are all described from one mould: they need only be cut to different lengths in order to agree with their seats or plans.

No. 1, is the elevation; No. 2, the plan. The lengths of the ribs are shown below, at No. 3, 4, and 5. The bases of the different ribs are taken from their seats on the plan. The double lines show the bevel at the top, where they come in contact with the back of the front rib.

Figure 2, is a different construction from the foregoing methods, which all spring from a horizontal plane passing through the centre of the sphere, and consequently the cylindrical surface will be a tangent to the spherical surface, at their junction. Whereas, in the present instance, the head of the niche is still spherical, but the horizontal plane from which it springs is higher than the centre of the sphere: this occasions a little more difficulty in the formation of the ribs, of which the construction is as follows:

The plan, or springing rib, which forms the top of the cylindric back, and the front rib, which is the segment of a circle, being given; to form the moulds of the back ribs.

Through the centre, *d*, of the plan, draw L M parallel to G I, the seat of the front rib; from *d*, with the radius *d* G, or *d* I, describe the arcs G L and I M; draw *d e* perpendicular to L M; then find the centre, E of the front rib; and draw D E perpendicular to A C, cutting A C in D; make *d e* on the plan equal to D E; from *e*, as a centre, with the radius *e* L, or *e* M, describe the arc L *m n o* M, which will be the curve of all the ribs.

To find the length required for any rib.

Let *f*, *h*, and *k*, be the points where the back ribs join the back of the front rib: from *d*, as a centre, with the distance *d f*, describe the arc *f g*, cutting L M at *g*; draw *g m* perpendicular to L M: then the part *m* M is the length which will stand over the seat of the rib, which meets at *f*. In the same manner, the lengths of the other ribs, which meet at *h* and *k*, will be ascertained; and thus having obtained the ribs for one half, the other half is also found; they being duplicates of each other.

The method of bevelling the heads of these ribs is the same as in the preceding examples.

The plan of a niche in a circular wall being given, to find the front rib.

Plate III. *Figure* 1, *No.* 1, is the plan given, which is a semicircle, whose diameter is *a b*; and *a*, *i*, *k*, *l*, *m*, *h*, the front of the circular wall; suppose the semicircle to be turned round its diameter, *a b*, so the point *v* may stand perpendicular over *h* in the front of the wall, the seat of the semicircle standing in this position upon the plan will be an ellipsis; therefore divide half the interior arc of the plan into any number of equal parts, as five; draw the perpendiculars 1 *d*, 2 *e*, 3 *f*, 4 *g*, 5 *h*; upon the centre, *c*, with the radius *c h*, describe the quadrant of a smaller circle, which divide into the same number of equal parts as the interior of the plan; through the points 1, 2, 3, 4, 5, draw parallel lines to *a b*, to intersect the others at the points *d*, *e*, *f*, *g*, *h*; through these points draw a curve, and it will be an ellipsis; then take the stretch-out of the interior of the plan, round 1, 2, 3, 4, 5, and lay the divisions from the centre both ways at F, stretched out; take the same distances *d i*, *e k*, *f l*, *g m*, from the plan, and at F make *d i*, *e k*, *f l*, equal to them, which will give a mould to bend under the front rib, so that the edge of the front rib will be perpendicular to *a*, *i*, *k*, *l*, *m*.

Note, The curve of the front rib is a semicircle, the same as the ground-plan; and the back ribs at C, D, and E, are likewise of the same curve.

The reason of this is easily conceived, the niche being part of a sphere, the curvature must be everywhere the same, and consequently the ribs must fit upon that curvature.

Note, The curve of the mould F will not be exactly true, as the distances *d i*, *e k*, *f l*, &c. are rather too short for the same corresponding distance upon the soffit F; but in practice it will be sufficiently near for plaster-work.

In applying the mould F, when bent round the under edge of the front rib, the straight side of the mould, F, must be kept close to the back edge of the front rib; and the rib, being drawn by the other edge of the mould, will give its place over the plan.

C, D, E, are the back ribs shown separately.

The plan and elevation of an elliptic niche being given, to find the curve of the ribs.

PLATE IV. *Figure* 1.—Describe every rib with a trammel, by taking the extent of each base, from the plan whereon the ribs stand, to its centre, and the height of each rib to the height of the top of the niche; it will give the true sweep of each rib.

To range the ribs of the niche.—There will be no occasion for making any moulds for these ribs, but make the ribs themselves; then there will be two ribs of each kind: take the small distances 1 *c*, 2 *d*, from the plan at B, and put it to the bottom of the ribs D and E, from *d* to 2, and *e* to 1; then the ranging may be drawn off by the other corresponding rib, or with the trammel; as for example, at the rib E, by moving the centre of the trammel towards *e*, upon the line *e c*, from the centre, *e*, equal to the distance 1 *e*, the trammel-rod remaining the same as when the inside of the curve was struck.

Given one of the common ribs of the bracketing of a cove, to find the angle-bracket for a rectangular room.

Figure 2.—Let II be the common bracket, *b c* its base; draw *b a* perpendicular to *b c*, and equal to it draw the hypothenuse *a c*, which will be the place of the mitre; take any number of ordinates in II, perpendicular to *b c*, its base, and continue them to meet the mitre line, *a c*, that is, the base of the bracket, at I; draw the ordinates of I at right angles to its base; then the bracket at I, being pricked from II, as may be seen by the figures, will be the form of the angle-rib required.

Note.—The angle-rib must be ranged either externally or internally, according to the angle of the room.

NICHE, *Angular*, one formed in the corner of a building.

NICHE, *Cul de Four of a.* *See* CUL DE FOUR.

NICHE, *Ground*, that which instead of bearing on a massive base, or dado, has its rise from the ground; as the niches of the portico of the Pantheon at Rome. Their ordinary proportion is two diameters in height, and one in width.

NICHE, *Round*, one whose plan and circumference are circular.

NICHE, *Square*, a niche whose plan and circumference are square.

NICHED COLUMN. *See* COLUMN.

NICOMEDES, an ancient geometrician, celebrated for having been the inventor of the curve named the *conchoid*, which has been made to serve equally for the resolution of the two problems relating to the duplication of the cube, and the trisection of an angle. It was much used by the ancients, in the construction of solid problems. Sir Isaac Newton approved of it for trisecting angles, or finding two mean proportionals, and for constructing some other solid problems, as may be seen in his *Arithmetica Universalis*. It is not certain at what period Nicomedes flourished, but it was probably at no great distance from the time of Eratosthenes, who holds him up to ridicule on account of the mechanism of his *Mesolabe*, and also from the circumstance that Geminus, who lived in the second century before the Christian æra, wrote on conchoids, of which Nicomedes was then allowed to be the inventor.

NIDGED ASHLAR, a kind of ashlar used in Aberdeen, which is brought to the square by means of a cavil, or hammer, with a sharp point; whereby the asperities of the stone may be reduced in any degree proportioned to the time employed. As the species of stone found in that country is so very hard as to resist the mallet and chisel, this sort of operation becomes necessary.

NOGS, the same as WOOD-BRICKS, which see. The term is used in Liverpool, and perhaps in other parts of Lancashire.

NOGGING, a species of brickwork carried up in panels between quarters.

NOGGING-PIECES, horizontal boards placed in brick-nogging, nailed to the quarters, in order to strengthen the brickwork. They are disposed at equal altitudes in the brickwork.

NONAGON, (Greek,) a figure of nine sides, and consequently of as many angles.

NORMAL LINE, in geometry, a term used for a perpendicular line. *See* PERPENDICULAR and SUBNORMAL.

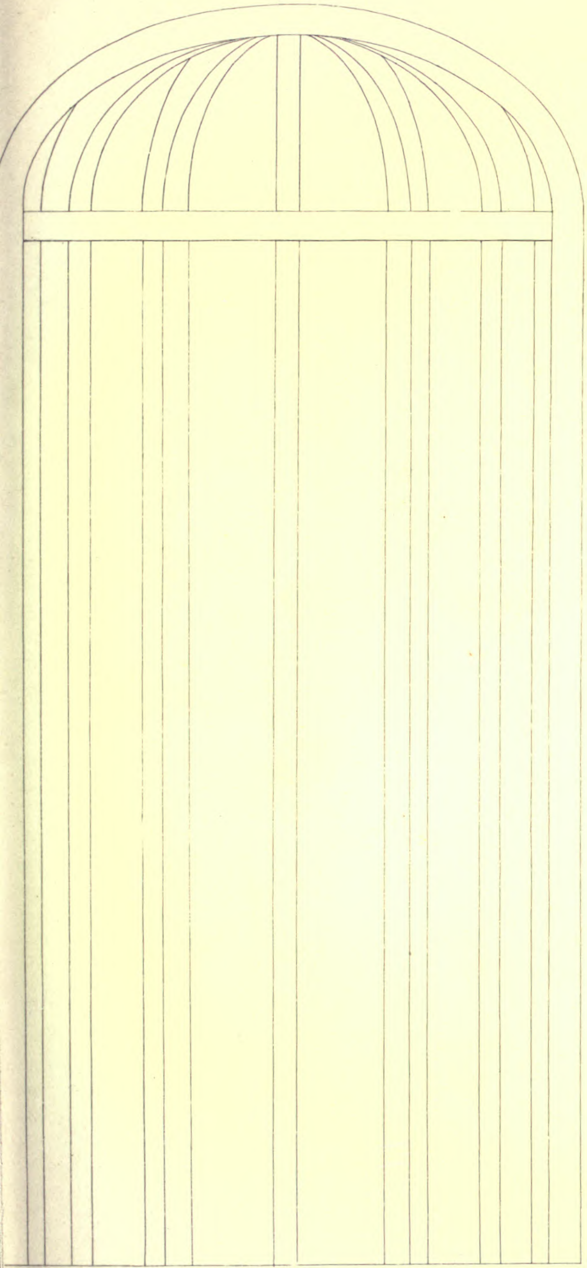
NORMAN ARCHITECTURE, a style of architecture closely allied to the debased Roman examples of the Eastern and Western empires, and with them may be conveniently included under the general title of Romanesque. It can scarcely, however, be ranked as a division of equal importance with either the Byzantine or Lombardic, of both of which it is a modification, approximating more closely to the latter, but maintaining a general resemblance with both. It may perhaps be correctly considered as a sub-division of the same style, viz., the Romanesque.

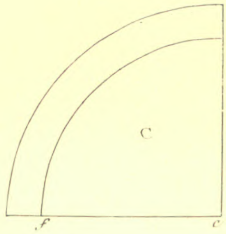
The Norman style flourished primarily and principally in Normandy, as its name implies, but became prevalent in many other places, wherever the Normans obtained influence or dominion; amongst others, in this country. When the style was first introduced into England, it is a matter of considerable difficulty to determine, some persons affirming that it was introduced by the Conqueror, others by Edward the Confessor, while a third party maintain that it was but a development of the Saxon, or style of building immediately preceding that under consideration, by whatever title it may be designated. Some writers entirely ignore the Saxon as a distinct style, including all the examples usually classified under that name, under the same designation as the latter, or Norman style, supposing the earlier examples to be but uncouth and unskilful imitations of the continental architecture. In favour of this assertion, it is argued, that it is very improbable that a method of building, practised on the continent, should have remained unknown in England for any length of time, notwithstanding the frequent intercourse of neighbouring nations, whereas we have good evidence that the Norman style was fully developed abroad at least a century before its general adoption in this island. The second statement, as to the introduction of the style by Edward, is founded, we believe on the authority of Matthew Paris, who says, that Edward rebuilt Westminster Abbey in a new style, from which others took the idea. This passage has led antiquaries to conclude, that the style referred to was the Norman, and that it was entirely unknown in England before that time; this, however, amounts to little better than conjecture.

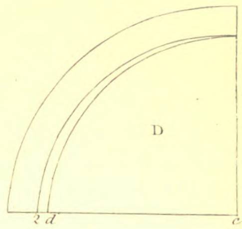
For our own part, we are inclined to consider the Saxon and Norman as, to a certain extent, distinct styles, although emanating from the same grand type, and, for that reason, in some sense modifications of each other. They are both derived from the Roman, and are both developments of the Romanesque or debased Roman, but here we imagine they part company, and take each its own course; they bear such a similarity to each other, as might be expected from descendants of a common stock, but of different branches of the same family. The Saxon style was reared on an uncultivated soil, and tended by rude hands, while the Norman was developed under more favourable circumstances. When the Romans invaded Britain, they naturally introduced the style of building then prevalent in their own country, as far, at least, as circumstances would permit. The want, however, of proper materials or tools, as well as the insufficiency of skilful workmen, must have put a limit to their success in this imitation, as we find to have been the case with their erections in this island, which were very rude in comparison with those of Rome. When the Romans were recalled, and the Britons left defenseless and unprotected against their formidable foes in the north, we may suppose that the art of building was

NICHES.

Fig. A.







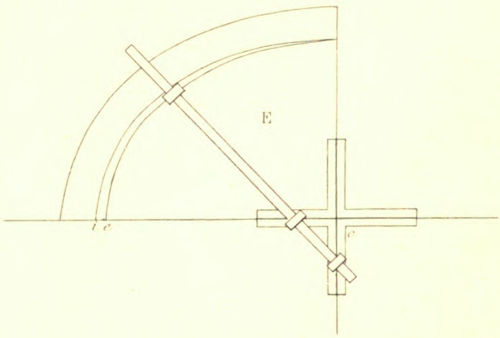
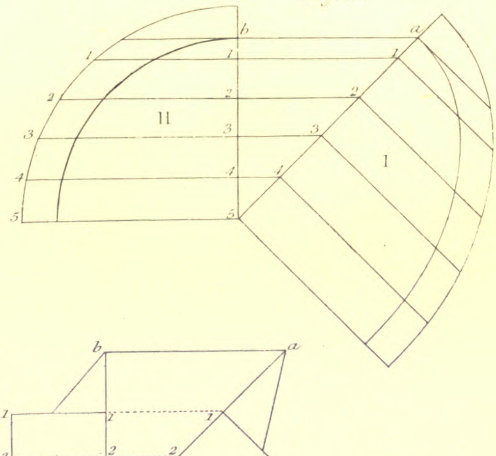
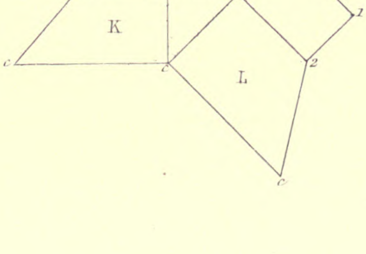
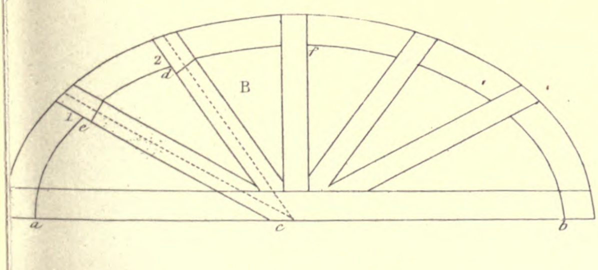


Fig. F.







but little practised; and whatever edifices were erected during that period, must have been of a still ruder character than those of a preceding age. The Saxons do not seem to have had any mode of building of their own, but followed the method which they found practised in the country; their buildings were for the most part composed of timber, but sometimes of stone, and Bede speaks of the monastery at Wearmouth being erected after the Roman manner, and states that workmen were procured from France for the purpose. The Roman manner is contrasted with the Scotch, which latter term was applied apparently to the wooden structures. From the fact of foreign workmen being employed, it would appear reasonable to suppose that some foreign peculiarities might have been introduced by them. The mere fact, however, of French workmen being sent for into England, would prove that they were considerably further advanced in the art than those who sent for them; and it is probable that such importations of foreign artisans led to the introduction of some peculiarities of continental architecture, which however was not introduced in an entire and complete form until after the Conquest.

Many writers apply the term Lombardic to this style; but although, as we before observed, there is a near resemblance in many points, yet, on the other hand, there are not a few distinctions between the Norman and Italian Lombardic, *e. g.*, the former is wanting in a feature which is very conspicuous in Lombardic churches, the dome or cupola, nor has it the low pedimental roof extending over the whole façade. The sloping arcade in the gable is absent, as are likewise the tiers of external galleries or arcades in the façades and sides of buildings. Circular windows are not so common or prominent as in Italian buildings, nor do we meet with the peculiar projecting porch, with its columns resting on the backs of animals. Some of the details of the style, such as mouldings, windows, &c., are similar to those of the Byzantine. It agrees also with the Saxon in its massive proportions, the shape of its arches and piers, and in general construction; in some matters of detail also, such as the zig-zag ornament; it differs from it, however, amongst other matters, in finish and general decoration, the Norman bearing a much greater share of enrichment than its predecessor, and being, in fact, a much more highly-cultivated style of building.

Having given this general and rapid sketch of the origin and nature of Norman architecture, as well as of the relation it bears to other cognate modes of building, we shall proceed to consider the subject somewhat more in detail, referring more especially to the character and peculiarities of the style. We must premise, that it is our intention to confine ourselves almost exclusively to the consideration of the style as it is developed in this country; the difference, however, between the English and Continental mode of treatment, is not very considerable.

The style may be said to have been fully developed in this country soon after the successful invasion, by Duke William of Normandy; whether it had arrived at any degree of perfection before that time, it is difficult to say; but it may be said to have flourished from the middle of the eleventh century, and prevailed to the latter part of the twelfth, or the close of the reign of Henry II. It is styled generally, the architecture of the twelfth century, and dates from 1066 to 1170, or, if the Transition or Semi-Norman be included, to 1200. The conqueror and his countrymen were great builders, and the monkish chronicles tell us, that after their arrival, churches were erected in almost every village, and monasteries were seen to arise in the towns and cities, designed in a new style of architecture. From Doomsday book, we learn that the number of churches had increased to such an extent, that at the time of its compilation, there were no less than seventeen hundred in existence.

The *plans* of the larger churches belonging to this style, such as those of cathedrals, and other ecclesiastical establishments, are usually cruciform; having a low massive tower at the intersection between the nave, choir, and transepts; the choir being frequently terminated with a semicircular apse. The aisles of the nave are frequently continued at the sides of the choir and round the apse, and in this case the high altar is situated between the easternmost piers, with a screen or reredos at its back, stretching between the piers. Thus a space was left clear behind the altar, which was named the retro-altar, and this allowed of processions passing entirely round the church. In some instances, the choir is surrounded with chapels, having likewise apsidal terminations. The aisles were extremely narrow, sometimes not more than from four to six feet in width. The western façades are occasionally flanked by towers, but more frequently by only turrets or buttresses.

The parish churches are generally of small dimensions, and consist of a nave usually without either porch or aisles, chancel and tower, the latter being sometimes at the west end, and at others between the nave and choir, as in cruciform churches. This last disposition is somewhat curious, but in some instances of the kind, arches of construction have been discovered in the north and south walls of the tower, a fact which gives every reason to suppose, that transepts formed a part of the original design, and were intended to be added at some subsequent period. The chancel in these smaller churches also, sometimes terminated in a semicircular apse. Not unfrequently, small churches consisted of nave and chancel only, without any tower or other appendage.

The *walls* of buildings of this period, were of immense thickness, but the masonry was not solid, being composed of two external walls, or facings of ashlar-work, having the intermediate space filled in with grouted rubble, gravel, flints, &c. Sometimes, however, the walls are made up of solid rubble-work, with quoins of ashlar. The joints of ashlaring in early work are extremely wide, being frequently as much as an inch in thickness. Many walls of the first description have failed, from the outward pressure of the core of loose material, and it is not an unfrequent occurrence to see a Norman wall considerably out of the perpendicular. The introduction of buttresses at a later period, led to a great improvement in the construction of walls, adding materially to their efficiency and strength; while at the same time it lessened the consumption of material.

Arches are almost invariably of the semicircular form, but occasionally stilted, and the only variety in the proportions of arcades, depends upon the height of the piers, the height of the opening averaging in general about twice its width. The earliest arches are simply semicircular apertures in the wall, with a plain or single soffit; but owing to the extreme thickness of the walls, the intrados was very soon broken into two surfaces, so as to form a concentric rib or sub-arch attached to the soffit of the outer or main arch; in the majority of instances, the sub-arch is placed in the centre of the main arch, so as to form a recess or angle on either side, but occasionally, the sub-arch is set back, so as to present a recess on one side only, the other side being flush with the face of the wall. Sometimes we find two sub-arches, one under the other, thus presenting three soffits, and two recessions on either side of the arch. The edges of these soffits are for the most part rectangular, but are sometimes chamfered or rounded, which is an indication of later work; still later in the style, we find round and other mouldings introduced, and the intradosses and faces of the arches enriched with the zig-zag and other mouldings and ornaments, characteristic of the style. Some chancel-arches are deeply recessed, and enriched with a number of decorative mouldings, as are also the arches of doorways, of which we shall speak more particularly presently.

The *piers* supporting the principal arches of construction, such as those separating the nave and aisles, are exceedingly massive, and frequently of stunted proportions. The simplest form presents a plain *shaft* on a square plan, which was afterwards recessed at the four angles with a rectangular nook, and this again was frequently filled up with a slender shaft. The same form is not unfrequently varied in appearance by the addition of a semicircular projection on two sides of the pier, so that we have a square pier recessed at the angles, into which recesses slender circular shafts are introduced, and having half a cylindrical column of massive proportions engaged to two opposite sides of the pier, the remaining sides being left plain: the former answer the purpose of supports to the sub-arches, while the latter range with the length of the building. This plain face was sometimes broken by a lofty shaft reaching from the ground to the springing of the vault, commonly termed a vaulting-shaft. Massive cylindrical shafts are very common, and are sometimes enriched with spiral or longitudinal flutings or bands, and sometimes with the zig-zag ornament disposed in a variety of ways. Octagonal shafts are also to be met with, though not nearly so frequently as the preceding, with which they sometimes alternate in a series of arches: sometimes, too, the shafts are made to appear as made up of a cluster of slender pillars. Cylindrical shafts, such as form principal supports in an edifice, are most frequently, as we have just observed, of massive proportions, but in one or two instances we find them approximating to classical proportions, as in Becket's Crown, Canterbury, in which example they bear in every respect a closer resemblance to the classical than probably in any other in England. Slender circular shafts, however, are very much employed as subordinate members and ornamental accessories, an example of which has been alluded to in the case of the square pier with nook-shafts at the angles; they are also much employed in the jambs of doorways and windows in a similar position, and as bearing shafts where an arch is subdivided into two or three apertures, as in two-light windows, and in the triforia and clere-stories of large churches. They are used very largely in the blank arcades which decorate the walls, and also as vaulting-shafts. In all such cases their proportions and treatment differ very considerably: some are much more slender than others, and some are plain, whilst others are enriched with carving of various patterns, amongst which the spiral groove or band of the zig-zag ornament are of constant occurrence: sometimes, too, spiral bands intersect each other so as to form diamond-shaped compartments throughout the surface; and at other times the shaft is ornamented with scroll-work, or diamond-shaped leaves, and such like enrichment. In principal piers we occasionally but rarely find clustered shafts.

The *capitals* partake of great variety of character, some assimilating more or less closely to the Corinthian and other classical examples. They are for the most part, however, rude and unskilful imitations, and have a heavy appearance when contrasted with the originals; the foliage is more crowded and irregular, and the capital itself much more squat, and therefore less elegant, than the classical examples. Many specimens of sculptured foliage exist which can scarcely be said to have been borrowed from such sources, some of which are not unworthy of praise. Some have interlaced bands or foliage in slight relief from the surface, and others are sculptured with grotesque representations of men and animals. Many capitals are quite plain, the most common of which is the cushion capital: this is of cubical form, being rounded at the lower end to meet the shaft, the profile of the curve presenting somewhat the appearance of the ovolo moulding; or it may be described as an inverted cone of convex contour spreading upwards, but intersected at about half its height by four vertical planes parallel to the four sides of the abacus, which produce as many flat surfaces rectilinear at the top and sides, but convex at the lower side where it intersects with the curve. Sometimes the side of the capital consists of many such figures of smaller dimensions placed side by side, the lower edge of the flat surface presenting a scalloped appearance, and beneath each of the scallops is a kind of inverted semi-cone, which meets the neck-mould of the shaft. The variety of capitals is, however, so great, that it would be useless to attempt to describe them all; they almost invariably terminate with a heavy square abacus, with a plain face chamfered only on the lower edge.

The *base* mouldings are set upon a shallow rectangular plinth, and consist either simply of a quirked ovolo reversed, or otherwise of some imitation or modification of the classic bases; the angles of the plinth are often ornamented with leaves or other ornaments, falling over from the base mouldings.

Piers and pillars are very greatly varied even in the same building, and in the same part of it; and this, too, not only in the minutiæ of decoration, but also in the entire form of the shaft and capitals, so that two very dissimilar designs are frequently seen in close proximity, forming supports to the same arcade.

Mural or blank arcades are a very common feature in this, as also in the Lombardic style; they sometimes cover the greater portion of both external and internal walls, but are more common on the exterior, especially on the façades, the clere-stories, and the upper stories of towers. The arches are mostly semicircular, resting upon slender pillars with capitals and bases, which, together with the shafts, bear various degrees of enrichment; sometimes, however, the arches intersect each other, producing at their intersection arches of the pointed form; pointed arches are employed alone, but only in late examples. The arcades are for the most part of small dimensions, but they vary in size, as also in proportions, some of them being exceedingly high in comparison to their width. In the interiors of larger churches, the space or width occupied by each arch in the lower story is frequently divided into two arches, enclosed within a larger one in the triforia, and into three arches in the clere-story, the central one being loftier than the others, and the whole contained within a larger one.

Doorways in this style are to be found in great variety, from the most simple to the most elaborate. The simplest form consists of merely a plain semicircular-headed aperture, with a hood-mould springing from plain square-edged jambs; the arches spring directly from an impost resting on the jambs, which is frequently a simple plat-band, with the under angle chamfered off. More frequently, however, the doorways are recessed, having a nook-shaft in the angle formed by the recession, from the capital of which an archivolt springs, so that the arch in this case presents two soffits and two faces besides the hood-mould. Sometimes we have a succession of such receding arches, with a nook-shaft in each recess, from which the arches spring alternately with the projecting square-edged jambs. The depth of the doorways is owing mainly to the great thickness of the walls, but in many cases, in addition to this, that portion of the wall in which the entrance is inserted, is made to project forward beyond the general face, the projection being finished above either with a plain horizontal capping, or with a highly-pitched gable; at St. Sepulchre's, Cambridge, the outermost arch finishes the projection, or rather the arch itself projects from the face of the wall, but this is not a common practice. With this additional thickness of walling we sometimes find as many as six or eight recessions, so that the aperture of the door occupies but a very small proportion of space, when compared with the entire surface taken up by the doorway, including the dressings. In some cases, too, the archivolt mouldings extend on each side considerably beyond the jambs. The soffits and faces of the arch, as well as those of the jambs, are sometimes left plain, but more frequently sculptured with the zig-zag, or some other ornament peculiar to the style, such as those described under *mouldings;* and to such an extent is this decoration carried, that sometimes there is not a single surface left uncovered with some ornamentation; even the shafts of the pillars are sometimes decorated in a similar manner, but this is not often the case, they are more frequently plain, and of not inelegant proportions, with capitals of various degrees of enrichment. Above the capitals is an abacus, which is often continued along the jambs from one capital to the other, but sometimes the mouldings of the archivolt are carried without interruption to the ground; occasionally, also, an enriched band is carried across the shafts and jambs, for the apparent purpose of tying them together. The hood-mould is mostly enriched, and springs from a continuation of the abacus, but if not, is either returned horizontally as a string-course, or terminates on either side in a grotesque head. The aperture often follows the form of the arch, having a semicircular head, but is very frequently square-headed, having a semicircular tympanum of masonry above, which is generally enriched with sculpture, sometimes in a sort of diaper pattern of reticulated or scalloped work, but more usually representing, in low relief, some portion of scriptural or traditionary history. Not unfrequently the head of the aperture is in the form of a square-headed trefoil, and sometimes of a segment of a circle larger than that of the external arch. Over some doorways is to be found a small niche containing a rudely sculptured figure, and sometimes a Vesica Piscis is substituted for the sculptured subject in the tympanum under the arch.

A great many examples of Norman doorways still remain, even in churches which present no other features of this style, for it seems to have been a practice with the architects of later periods to preserve this portion of an old church, even when they rebuilt the entire structure in a later style; many of them are certainly very rich and beautiful, and their preservation does credit to the taste and judgment of succeeding ages.

In this style, *windows* form but subordinate members of an edifice, and in the earlier examples are small and insignificant, being little better than slits or narrow oblong apertures, often not exceeding a few inches in breadth, and finished with a plain semicircular head; the glass was inserted close to the external wall, and the sides of the aperture were splayed towards the interior, the circular heads being generally concentric on both sides of the wall; the height of such windows was usually little more than twice their breadth, but occasionally they were much longer in proportion. In cathedral and the larger churches we sometimes find windows of much greater dimensions. After a time, a slight degree of enrichment came to be added in the shape of zig-zag and other mouldings round the arch; and at a still later period, an important improvement was made by inserting nook-shafts in the jambs, similar to those in doorways; but in this case they seldom exceeded two in number, that is to say, one on either side; in Normandy, we have examples of a greater number, which add considerable importance to the window, but we do not know of any such in this country. Such shafts were mostly slender, with plain caps and abacus, and in such examples the archivolt was either moulded or recessed, so as to form two soffits; the zig-zag moulding was very common in this position. Windows of this kind were usually larger than the earlier ones, though not always so; they are also frequently protected by a hood-mould, and the same decoration is sometimes observed in the interior.

A window of still more advanced character is very often found in the upper stories of towers; it consists of two lights with semicircular heads, separated by a central shaft, and having a jamb-shaft on either side; the two lights are enclosed under another larger semicircular arch, the spandrel of which, however, is very rarely, if ever, perforated; the larger arch is surrounded by a hood-mould. These windows bear a remarkable resemblance to those of the Byzantine and Lombardic styles, many of which exist in Italy. Sometimes, apertures for windows are pierced in a continuous arcade, running along the church; and in that case, the apertures usually occur in regular order, the intermediate arcades being left blank.

Plain circular windows, of small dimensions, are sometimes seen in clere-stories and other positions; and in churches of a late date, are to be found occasionally in gable walls, larger windows of the same form, with small shafts radiating from the centre, connected at the circumference by small semicircular or trefoiled arches; a fine example exists at Barfreston, Kent.

Of *mouldings*, such as are distinguished by their profile, the most usual combinations are composed of plain surfaces, or bands, chamfers, and quarter, half and three-quarter cylindrical mouldings, but of ornamental bands of sculpture, which are employed as mouldings in this style, there are a great variety; amongst the most common of which we may mention the following:—

The *zig-zag* is formed of a series of salient and re-entrant angles, recessed or otherwise carved on the surface of the stone, sometimes in a single line, but perhaps more frequently in two, three, or more lines, running parallel to each other, but sometimes we find them reversed. The name will probably give a better idea of the moulding than any definition; it is also termed the chevron-mould. It is used more than any other enrichment, and is found in all situations.

Similar to this is the *indented* or *trowel-point*, which presents such an appearance as a stuccoed wall which has been indented with a trowel-point before setting, the point having been pressed further into the mass, than the wider portion of the blade.

The *beak-head*, *bird's-head*, and *cat's-head* mouldings, are of a similar character, and consist of a series of grotesque heads, somewhat similar to those of the animals whose names they bear, each being furnished with a pointed beak; they are set in close proximity to each other, frequently over one or more plain mouldings, with the beaks all pointing downwards.

The *nail-head* is composed of a row of shallow pyramids, similar to nail-heads, set in contact with each other; they probably originated the idea of the dog-tooth moulding, so common in the succeeding style.

The *billet*-moulding, of which there are two kinds, the square and cylindrical, consists of cubes or semi-cylinders, placed at short intervals from each other, on a plain surface.

The alternate billet is formed of two or more rows of billets, the billets and spaces alternating in each row. The square billet is often used for supporting a blocking-course, and is termed also the *corbel-bole.*

The *double cone* is formed of a series of two cones set base to base, and point to point, in a hollow moulding.

The *embattled* is formed of a band or channel following the form of a battlement, with alternate merlons and embrasures. Similar to this is the *dove-tail*, but in this the angles are acute, instead of right. There are several varieties of frets, trellis, and interlacing bands employed as mouldings, some plain, and others more or less enriched.

The *nebule*-moulding presents a wavy outline, and the *scalloped* such as its name implies. The *pellet* or *stud*-moulding is enriched with flat and slightly projecting circular pellets in close proximity, or at short intervals; while the *chain*, *star*, *medallion*, and *lozenge* mouldings are of a similar description, varying only in the forms of their respective ornaments.

The *cable*-moulding bears the appearance of a cable placed in a concave moulding.

The above are some of the most usual forms, but there are altogether such a variety of shapes and combinations, that it is impossible to describe them all.

The *string-courses* are very simple, consisting most frequently of a sloping water-table at top, with a plain vertical face splayed off at the lower edge; sometimes the vertical face is enriched with the zig-zag, indented, or other ornament, and occasionally a round moulding is introduced.

The *parapets* are usually plain and slightly projecting, supported upon *corbel-tables*, which consist either of cubical blocks placed at regular intervals under the parapet, and carved into grotesque heads and other devices, or of a series of small arches resting on such blocks; the arches are either semicircular, interlacing, or trefoiled. Sometimes the arches are seen without the blocks, and at others the table consists of a projecting course, the soffit of which presents a nebulous or undulating outline.

Buttresses can scarcely be said to exist in buildings of this style, the thickness and solidity of the walls not requiring such supports; somewhat similar, however, in appearance, are those projections which are termed by Mr. Whewell, *pilaster-strips.* They are precisely of the same character as the projections in Lombardic buildings, and resemble a broad flat pilaster, standing out but slightly from the general face of the wall, and terminating under the cornice or parapet, sometimes with a slope, but frequently carried up square to the soffit of the parapet, the face of the buttress being flush with that of the corbel-table. The basement consists merely of a ground-table, and the pilaster is often divided into two or more stages by string-courses, which are frequently continued along the walls, and over the arches of apertures, sometimes, however, they stop at the buttresses, and in such cases, the latter are merely plain projecting strips, without any divisions; it is seldom that the lower stages project beyond the upper ones, as in the later styles. The string-courses are mostly plain, with the under edge chamfered, or of a semi-hexagonal projection, but they are occasionally hatched or chevroned. At a later period, the angles of the buttresses are ornamented with slender nook-shafts.

The *towers* of this period are low and massive, with but little ornamentation, especially in the smaller churches. In many examples, the lower stages are plain, but the upper ones enriched with blank arcades, or with an arcade, some of the arches of which are blind, and others pierced for windows. The windows in the lower stages were quite plain, but in the higher stories, besides the arrangement just alluded to, we often see windows of two lights with semicircular heads, both included under a larger arch; the lights were divided by a central shaft, and flanked by a nook-shaft on either side. The towers are often divided into stories by string-courses, and terminated at the top with a corbel-table supporting a plain horizontal parapet or blocking-course. Towers were probably roofed with low pyramidal caps of masonry, tiles or shingles, in the latter cases with projecting eaves; wooden spires covered with lead, would seem also to have been occasionally employed. Sometimes a pinnacle adorned each angle of the tower.

The plans were mostly square, having in some cases a square or circular stair-turret at one of the angles; round towers, however, of this date, are frequent in the counties of Norfolk and Suffolk. They are mostly constructed of flint, and batter externally from the base upwards; they are sometimes divided into stages by string-courses, and the upper story is more enriched than those below. The windows in the lower stories are small and narrow, and exceedingly plain.

The *pinnacles* were usually cylindrical in plan, and covered with a conical capping, but occasionally the capping was polygonal or square on the plan.

Porches, as we before stated, rarely occur in this style, some few however do remain, but mostly belonging to the larger churches. They are most frequently vaulted, and sometimes consist of two stories having a small apartment above the porch properly so called. There are sometimes benches on either side, and the walls on the interior are ornamented with blank arcades. The doorways are often deeply recessed and of an ornamental character.

The *Roofs* of this period in large buildings are highly pitched, but in the smaller churches they are somewhat more depressed, forming a rectangle at the apex. In the interior they are most frequently vaulted, although we have some examples still remaining of timber roofs: there is one at Peterborough cathedral, which is flat, and covered with paintings of figures, which have recently been restored. A greater number of roofs of this material in all probability existed, but, from their liability to decay and destruction by other means, very few examples still remain. All wide spans, such as the naves of churches, and especially of the larger ones, were probably covered with timber roofs, as the builders of the period do not seem to have been bold enough to attempt vaulting over wide intervals: this circumstance is supposed to account for the narrowness of the aisles, which, together with crypts, porches, and other places where the bearings were inconsiderable, were always vaulted. Many examples of stone vaulting still remain, the quadripartite, or that consisting of four cells, with diagonal groins, being the most common; the barrel vault, however, was also employed, a specimen of which is to be seen in the Tower of London. At first the groins were simple arrises without any projecting moulding, but afterwards a square moulding was added, and still later this simple form was enriched by cylindrical mouldings of various projections, and sometimes with the zig-zag and other ornamental mouldings.

The later portion of this style, which has been named by some the *transition*, and by others the *Semi-Norman* style may be said to have commenced a little before the middl[e] of the twelfth century, and forms the connecting link be[-]tween the Romanesque and Pointed styles. It is distinguishe[d] generally by its amalgamation of Norman details with th[e] pointed arch, or perhaps we should rather say by the intro[-]duction of the pointed arch into what would otherwise b[e] Norman work.

Pointed *arches* are found treated in all respects in the sam[e] manner as the older semicircular form, having only one [or] two recessions on the soffit, and these generally square at th[e] dges without chamfering; sometimes we see only one soffit vith plain chamfered edges, and not unfrequently the faces f the arch are adorned with zig-zag and other mouldings f purely Norman character. These are supported upon nassive Norman piers, either cylindrical or of other orm, sometimes square with attached circular shafts on the ides, but occasionally consisting of several shafts clustered ogether, and banded about midway between the base and apital: this last forms a near approach to the clustered illars of a later style. The abacus was in almost all cases, quare, and of Norman character, as also were the bases, but he capital frequently exhibits a more chaste and delicate rnamentation, consisting of foliage which bears some pproach in design to the Early English.

The *doorways* are recessed similar to Norman examples, ut have pointed arches, and the shafts with their capitals are nore delicate than in pure Norman work. The arches, howver, are decorated with mouldings which are purely Norman.

The *windows* generally retain the same character as before, ut occasionally the pointed arch is introduced here also. In hurches of this period, we frequently find a triforium with semicircular arcade, and a clere-story with purely Norman vindows ranging above an arcade composed of pointed arches; s also a lower tier of mural arcades with pointed arches surnounted by semicircular or intersecting arcades. In short, he architecture of this period is nothing more than a combination of the pointed arch with work which is otherwise Jorman: it is true, the character of the arch did, in some ases, affect some other members of the building, but not to ny great extent, for the main features of the style, with this xception of the arch, still remain strictly and unmistakably Jorman.

During the whole of the period we have been considering, rchitecture was making rapid progress in England, and a umber of churches and other edifices were erected.

The prelates in the early Norman reigns were men of conummate skill in architecture; they applied themselves to the ebuilding of cathedral churches, and also the rebuilding of he greater abbeys. No less than fifteen of the twenty-two nglish cathedrals retain considerable portions which are ndoubtedly Norman workmanship, and of which the several ates are ascertained. The Normans, who either were archiects themselves, or under whose auspices architecture floushed, are Gundulph, Bishop of Rochester, who flourished om A.D. 1077 to 1107; Mauritius, Bishop of London, who ourished from 1086 to 1108; Roger, Bishop of Salisbury, om 1107 to 1140; Ernulf, Bishop of Rochester, from 1115 1125; Alexander, Bishop of Lincoln, from 1123 to 1147; enry of Blois, Bishop of Winchester, from 1129 to 1169; d Roger, Archbishop of York.

The works of Gundulph may be seen at Rochester, Canrbury, and Peterborough. Mauritius, of London, built Old . Paul's cathedral; Roger, of Salisbury, the cathedral of d Sarum; Ernulf completed the work begun by Gundulph Rochester; Alexander, of Lincoln, rebuilt his own catheal: and Henry of Blois, Bishop of Winchester, a most ninent architect, built the conventual churches of St. Cross d Rumsey, in Hampshire; but with respect to Roger, rchbishop of York, none of his works remain.

By these architects, the Norman style of architecture was ogressively brought to perfection in England; and it will casily supposed, that the improvements made by any of em were only adopted in succession.

Many of the churches belonging to the greater abbeys re constructed in this æra; but of these, few, indeed, ve escaped the general demolition that took place at the formation.

With respect to the military structures of the Normans they knew they could not live in security without building strong places of defence; they therefore erected a castle upon every lordship, or assimilated with their own, what they found already erected to their hands.

The leading distinction in a Norman fortress, is a lofty mound of earth thrown up in the centre of the other works, from the excavations necessary in forming the ditch, fosse, or moat. A square or circular tower, consisting of several stories, rose from the upper ballium, or a low circular story of considerable diameter, which was usually approached by a very steep stone staircase on the outside.

The gateway, or tower of entrance, and the barbican, or watch-tower, had both of them a communication with the keep. Remarkable instances in the square form are those of the towers of London, Norwich, Rochester, Dover castle, Hedingham (Essex,) Bamborough (Northumberland,) Porchester, Colchester, Kenilworth, Knaresborough, Carisbrooke, and Oxford. Of the circular are Arundel, Pontefract, and Conisburgh (Yorkshire,) Lincoln, and Tunbridge in Kent. Besides the above-stated towers, an irregular form, of which the plan consists of several segments of circles, may be seen in Clifford tower, in York, and Berkeley castle, Gloucestershire. These keeps, or citadels, in subsequent æras underwent no alteration, whatever additions or improvements took place in architecture.

Bishop Gundolph seems to have considered the lofty artificial mound, originally of Danish usage, as unnecessary. His central towers are so lofty as to contain four stories, as was also the case with most other keep-towers. The basement was the dungeon, without light: the portal or grand entrance was raised many feet above the ground; but his great merit consisted in various architectural contrivances, by which as much security during a siege was given to his keeps by stratagem, as by real strength. The walls were not unfrequently from 12 to 20 feet thick at the base. In the souterrain of the vaulted stone, the military engines and stores were deposited. In the thickness of the walls were placed winding staircases, the well for water, the vast oven, enclosed galleries and chimneys, with an aperture open to the sky, and communicating with the dungeon, in which prisoners were confined, and to whom it gave all the light and air they could receive. There was also a kind of flue for conveying sound to every part, not more than eight inches in diameter. The state apartment occupied the whole third story, and the staircases leading to it were much more commodious than the others, and even so large as to admit of military engines. Adjoining to the great chamber was the oriel, lighted by a window embowed withinside. In Rochester castle the chief room was 32 feet high, including the whole space within the walls. The walls of the ground story had no light, the second had only loop-holes; but the third had large arched windows placed so high as not to be looked through, and so defended by an internal arcade that no missile weapon could enter or fall with effect. Each floor had its communication with the well. The chimneys were very capacious, projected considerably into the rooms, and rested upon small pillars; and the sinks were so contrived, in an oblique direction, that no weapons could be sent up them.

Gundulph is said to have introduced the architectural ornaments of the ecclesiastic style into fortresses, both withinside and without. Most of the Norman castles had a richly carved door-case or portal, as the remains of Arundel and Berkeley amply testify. The windows were decorated with mouldings, frequently sculptured. Castle-Rising, Norfolk, and Norwich abound in admirable specimens of Norman arcades and mouldings.

The great tower of entrance was built at the foot of the artificial mount, from which was a sally-port, with stone stairs leading to the keep. It contained the portcullis and drawbridge affixed to the archway, and several spacious chambers. In point both of the formation of the mount and keep, and their connection with the entrance-tower, the remains of Tunbridge, and the more perfect state of Arundel castle, exhibit a singular resemblance. The walls were protected by strong buttresses, and the round towers had a central space left open, to admit light and air. At Arundel, the corbel-stones, which supported the beams of timber, are still to be seen. See Castle.

The well-authenticated buildings of Norman construction, erected from before A. D. 1100 to 1150, are the abbeys of Abingdon, Reading, and Cirencester, destroyed; Malling, Kent; Tewkesbury, nave, aisles, transept, and west front; Malmsbury, nave and west front; Buildwas, Salop; St. Botolph, Colchester; Bolton, Yorkshire; Winborn minster, Dorsetshire; Castle-Acre, Norfolk; Dunstable, Bedfordshire; St. Cross, Hants; Romsey, Hants; Furness, Lancashire, the most ancient parts; Llindisfarne, Northumberland; Byland, Yorkshire; Lanercost, Cumberland; Sherbourn, Dorset; Southwell, Nottinghamshire; Kirkstall, Yorkshire, nave. Of those now named Tewkesbury, Malmsbury, Winborn minster, St. Cross, Romsey, and Sherbourn, are now used as parochial churches.

From A. D. 1155, the style of architecture practised by the Normans began to be mixed with new forms and decorations, and was at length superseded by that much more elegant and lofty style of building, improperly denominated *Gothic*.

The principal works that may be consulted in Norman architecture, are the *Archæologia*, Carter's *Ancient Architecture of England*, Britton's *Architectural Antiquities of Great Britain*, and Dalaway's *English Architecture*.

NOSINGS OF STEPS, the projecting parts of the tread-board or cover, which stand before the riser. The nosings of steps are generally rounded, so as to have a semicircular section, and, in good staircases, a hollow is placed under them.

NOTCH-BOARD, a board notched or grooved out, to receive and support the ends of the steps of a staircase.

NOTCHING, the cutting of an excavation throughout the whole breadth of a substance.

By this method timbers are fastened together; or their surfaces, when joined at angles, are made to coincide.

NUCLEUS (Latin) the internal part of the flooring of the ancients, consisting of a strong cement, over which they laid the pavement, bound with mortar.

NUEL, see Newel and Staircase.

NUISANCE, or Nusance, (from the French, *nuire*, to hurt) in law, is used not only for a thing done to the hurt or annoyance of another, in his free lands or tenements, but also for the assize, or writ lying for the same.

Nuisances are either *public* or *private*: a *public* or *common* nuisance is an offence against the public in general, either by doing what tends to the annoyance of all the king's subjects, or by neglecting to do what the common good requires. A *private* nuisance is when only one person or family is annoyed, by the doing of anything; as where a person stops up the light of another's house, or builds in such a manner, that the rain falls from his house upon his neighbour's; as likewise the turning or diverting water from running to a man's house, mill, meadow, &c., corrupting or poisoning a water-course, by erecting a dye-house, or a lime-pit, for the use of trade, in the upper part of the stream; stopping up a way that leads from houses to lands; suffering a house to decay, to the damage of the next house; erecting a brew-house in any place not convenient; or a privy, &c., so near another person's house as to offend him; or exercising any offensive trade; or setting up a fair or market, to the prejudice of another.

The continuation of a nuisance is by the law considered as a new nuisance, and therefore, where a person suffers a nuisance to be set up, and then alienates and lets the land, &c., without removing it, an action of the case lies against him who erected it; and also against the alienee or lessee, for continuing it.

Writs of nuisance are now properly termed *trespasses* and *actions upon the case*.

Nuisance, *Abatement of* denotes the removal of it, which the party aggrieved is allowed to do, so as he commits no riot in the doing of it.

"If a house or wall is erected so near to mine, that it stops my ancient lights, which is a *private* nuisance, I may enter my neighbour's land, and peaceably pull it down." *Salk.* 459. "Or if a new gate is erected across the public highway, which is a *common* nuisance, any of the king's subjects passing that way may cut it down, and destroy it." *Cro. Car.* 184. The reason why the law allows this private and summary method of doing one's self justice, is, because injuries of this kind, which obstruct or annoy such things as are of daily convenience and use, require an immediate remedy; and cannot wait for the slow progress of the ordinary forms of justice.

O.

OAK, the well-known tree, styled by way of eminence the "lord of the forest." The oak grows to an enormous size, attaining frequently a height of from 80 to 100 feet, with a trunk from 6 to 12 feet or more in circumference. Some of the parks attached to the mansions of our great nobles are adorned with magnificent specimens of these monarchs of the woods. In Amphill Park stands an oak of very large size. The circumference of its base is upwards of 40 feet; its middle girt is about 30; it is quite hollow, forming a concavity sufficient to contain four or five middle-sized persons standing together withinside. The chief of its branches, which is much greater in dimensions than many parent oaks, is supported by a couple of large wooden props, on accoun[t] of its weight being too great to be kept up by the main bod[y] of the tree. There are many fine oaks in numerous othe[r] parts of the empire; as in Salcey forest, Northamptonshir[e] and in the Duke of Hamilton's park in Lanarkshire. Th[e] wood of this tree is the most durable that grows, an[d] its use in naval and domestic purposes is exceeding[ly] great.

There are several kinds of oak timber used in this countr[y] but none are equal to the common British oak, which is mo[re] durable than any other wood attaining the same siz[e]. The oak imported from America is very inferior to that [of]

England; the oak from the central parts of Europe is also inferior, especially in compactness and resistance of cleavage. The knotty oak of England, when cut down at a proper age, (from fifty to seventy years,) is the best timber known, for at once supporting a weight, resisting a strain, and not splintering by a cannon-shot; hence its value in ship-building.

OASIS, is the appellation given to those fertile spots, watered by springs and covered with verdure, which are scattered about the great sandy deserts of Africa. In Arabic they are called wadys. The Arabic and the Greek name seem to contain the same root, and possibly the word may be originally a native African term. The most noted are in the Libyan desert, namely, Angila, Siwah, the great oasis west of Thebes, or El Khargeh; the little oasis, or Wah el Bahryeh, and several smaller ones, which are noticed under Egypt. Fezzan also may be considered as a great oasis of the Sahara. Hornemann has described Fezzan; Brown has given an account of the oasis of El Khargeh, and Cailliaud of the smaller oases west of Egypt.

The oases appear to be depressions in the table-land of Libya. On going from the Nile westward, the traveller gradually ascends till he arrives at the summit of an elevated plain, which continues nearly level, or with slight undulations, for a considerable distance, and rises higher on advancing towards the south. The oases are valleys sunk in this plain, and when you descend to one of them you find the level space or plain of the oasis similar to a portion of the valley of Egypt, surrounded by steep hills of limestone at some distance from the cultivated land. The low plain of the oasis is sand-stone or clay, and from this last the water rises to the surface and fertilizes the country; and as the table-land is higher in the latitude of Thebes than in that of Lower Egypt, we may readily imagine that the water of the oases is conveyed from some elevated point to the south, and being retained by the bed of clay, rises to the surface wherever the limestone superstratum is removed.

OBELISK, (from the Latin, *obeliscus*,) a quadrangular pyramid, very slender and high; raised as an ornament in some public place, or to show some stone of enormous size; and frequently charged with inscriptions and hieroglyphics.

Borel derives the word from the Greek, οβελος, *a spit, broach, spindle*, or even a kind of *long javelin*. Pliny says, the Egyptians cut their obelisks in form of sunbeams; and that, in the Phœnician language, the word *obelisk* signifies *ray*.

The Egyptian priests called their obelisks the *sun's fingers;* because they served as styles, or gnomons, to mark the hours on the ground. The Arabs called them *Pharaoh's needles;* whence the Italians call them *aguglia;* and the English *Cleopatra's needles*. *See* Cleopatra's Needles.

The difference between obelisks and pyramids, according to some, consists in this, that the latter have large bases, and the former very small ones, compared with their height; though Cardan makes the difference to consist in this, that obelisks are to be all of a piece, or consist of a single stone; and pyramids of several.

The proportions of the height and thickness are nearly the same in all obelisks; that is, their height is nine, or nine and a half, sometimes ten times their thickness; and their thickness, or diameter, at top, is never less than half, nor greater than three-fourths, of that at bottom.

This kind of monument appears to have been very ancient; and, we are told, was first made use of to transmit to posterity the principal precepts of philosophy which were engraven on them in hieroglyphic characters. In after-times they were used to immortalize the actions of heroes, and the memory of persons beloved.

The first obelisk we know of was that raised by Rameses, king of Egypt, in the time of the Trojan war. It was 40 cubits high, and, according to Herodotus, employed 20,000 men in building. Phius, another king of Egypt, raised one of 45 cubits; and Ptolemy Philadelphus another, of 88 cubits, in memory of Arsenoë. *See* Porphyry.

Augustus erected an obelisk at Rome, in the Campus Martius, which served to mark the hours on an horizontal dial, drawn on the pavement.

F. Kircher reckons up fourteen obelisks, celebrated above the rest, viz., that of Alexandria, that of the Barberins, those of Constantinople, of the Mons Esquilinus, of the Campus Flaminius, of Florence, of Heliopolis, of Ludovisio, of St. Mahut, of the Medici, of the Vatican, of Mount Cœlius, and that of Pamphylia.

One of the uses of obelisks among the ancients was, to find the meridian altitudes of the sun at different times of the year. Hence they served instead of very large gnomons. One of the obelisks now standing at Rome, that of St. John's Lateran, is in height 108 English feet, without the pedestal; and the other obelisk, brought to Rome by Augustus, buried under the Campus Martius, wants but little of the same height. Pliny gives a description of this gnomon, lib. xxxvi. sect. 15. From him it appears, that there was laid down, from the foot of the obelisk northward, a level pavement of stone, equal in breadth to the breadth of the obelisk itself, and equal in length to its shadow at noon, upon the shortest day; that is to say, that its length was to the height of the obelisk, almost as 22 to 10, and that under this pavement, there were properly let in parallel rulers of brass, whose distance from the point, directly under the apex of the obelisk, were perfectly equal to the length of the shadow thereof at noon, on the several days of the year, as the same lengths decreased from the shortest day to the longest, and again increased from the longest day to the shortest. Vide *Phil. Trans.* No. 482, art. 5, vol. xliv. p. 365; where we also find some remarks by Mr. Folkes on Hardouin's *Amendment of a Passage in Pliny's Natural History*, lib. ii. sect. 74, about the length of the shadows of gnomons in different latitudes.

OBLIQUE LINE. When one straight line stands upon another, and makes unequal angles therewith, the angles are said to be *oblique*, the one being greater than a right-angle, and the other less. Hence a line is only oblique, as it relates to another line: without this distinction, the word would be destitute of meaning.

Oblique Angle, one that is greater or less than a right angle.

Oblique-angled Triangle, one that has no right angle.

Oblique Arches, are those which conduct high roads across a river, canal, open drain, &c., in an oblique direction. —Oblique arches are otherwise called *skew bridges*. *See* Bridge Arch.

OBLONG (from the Latin *oblongus*) a rectangle of unequal dimensions.

OBSERVATORY, or Observatorium, a place destined for observing the heavenly bodies; or a building usually in form of a tower, raised on some eminence, and covered with a terrace for making astronomical observations. The more celebrated observatories are, 1. The Greenwich Observatory, or Royal Observatory of England, was built in 1676, by order of Charles II. at the solicitation of Sir Jonas Moore and Sir Christopher Wren, and furnished with the most accurate instruments by the same, particularly a noble sextant of seven feet radius, with telescopic sights. The province of observing was first committed to Flamsteed, a man who seemed born for the employment. For fourteen years, with unwearied pains, he watched the motions of the planets, and particularly those of the moon, as he had been instructed; that a new theory of that planet being found, exhibiting all her irregularities, the longitude might thence be determined. In the year 1690, having provided himself with a mural arch of seven feet diameter, well fixed in the plane of the meridian, he verified his catalogue of the fixed stars, (which hitherto had depended altogether on the distances measured with the sextant,) after a new and very different manner, viz., by taking the meridian altitudes, and the movements of culmination, or the right ascension and declination. With this instrument he was so pleased, that he laid the use of the sextant almost wholly aside; and in this way was the astronomer-royal employed for thirty years; in the course of which time nothing had appeared in public worthy so much expense and preparation; so that the observer seemed rather to have been employed for his own sake, and that of a few friends, than for the public; though it was notorious, the observations that had been made were very numerous, and the papers swelled to a great bulk. This occasioned Prince George of Denmark, in 1704, to appoint certain members of the Royal Society, viz., the Hon. Fr. Robarts, Sir Christopher Wren, Sir Isaac Newton, Dr. Gregory, and Dr. Arbuthnot, to inspect Flamsteed's papers, and select such as they should think fit for the press, purposing to print them at his own expense, but the prince dying before the impression was half finished, it lay still for some time; till at length it was resumed by order of Queen Anne, and the care of the press committed to Dr. Arbuthnot, and that of correcting and supplying the copy to Dr. Halley. Such was the rise and progress of the "Historia Cœlestis," the principal part whereof is the catalogue of fixed stars, called also the Greenwich Catalogue. Flamsteed was succeeded by Dr. Halley; and Dr. Halley, in 1742, by Dr. Bradley, so deservedly celebrated for his discovery of the aberration of the stars, and the mutation of the earth's axis; after Dr. Bradley, the appointment was, in 1762, conferred upon Mr. Bliss, who was succeeded in 1785 by Dr. Maskelyne, the late worthy astronomer-royal; upon whose demise, in 1811, this important office was conferred upon Mr. Pond.

The Greenwich observatory is found, by very accurate observation, to lie in 51° 28′ 30″ north latitude.

2. The French Observatory, built by Louis XIV. in the Fauxbourg St. Jacques, Paris, is a very singular, but withal, a very magnificent building. It is eighty feet high, and at the top there is a terrace. It is here M. de Lahire, M. Cassini, &c., were employed. This observatory was begun in 1664, and finished in 1672. The difference in longitude between this and Greenwich Observatory is 20° 20′ 15″ each. In the Paris Observatory, is a cave, or cellar, of 170 feet descent, for making various experiments, particularly such as relate to congelations, refrigerations, indurations, conservations, &c. And in this cave there is a thermometer of M. de Lahire, which is always at the same height, indicating the temperature of the place to be always the same.

3. Tycho Brahe's observatory in the little island of Ween, or the Scarlet Island, between the coasts of Schonen and Zealand in the Baltic, was erected and furnished with instruments at his own expense; and was called by him Uranienburgh. In this place, he spent twenty years in observing the stars.

We may enumerate here some other observatories, as that of Pekin, erected by a late emperor of China in his capital, upon the recommendation of the Jesuit missionaries; and that of the Brahmins at Benares, in the East Indies, of which we give the following description:—

The observatory at Benares, built by order of the emperor Akbar, was once a magnificent structure; the lower part of it is now, however, converted into stables; the court-yards and apartments are still spacious. It stands on the banks of the Ganges, and the summit is approached by a staircase leading to a large terrace, where numerous instruments still remain in great preservation; stupendously large, immoveable from the spot, and built of stone, some of them being upwards of twenty feet in height. Their graduation is very exact.

OBTUNDING, (from the Latin *obtundo*,) the blunting or taking away a sharp corner.

OBTUSE, (from the Latin) anything that is blunt.

Obtuse-angled Triangle, a triangle which has an obtuse angle.

Obtuse Section of a Cone, a name given to the hyperbola, by ancient geometricians, because they considered it only in such a cone, whose section through the axis was an obtuse-angled triangle.

OCHRE, in painting, a colour prepared from a species of earth, also termed ochre, composed of fine, soft, smooth, and argillaceous particles, slightly coherent, rough to the touch, and easily diffusable in water; ochre is of various colours. Yellow is the most prevalent, but there are red, green, blue, and black ochres. The colouring matter of ochre is almost always oxide of iron. Red chalk is much used for drawing; for this purpose, it should be free from grit, and not too hard. In order to free it from grit, and render it better for use, it is sometimes pounded, washed, mixed with gum, and cast into moulds of convenient shape and size. Under the name of reddle, this substance is much used for the marking of sheep, and, when mixed with oil, for the painting of pales, gates, and the wood-work of out-buildings.

OCTAGON, (from ὀκτω, *eight*, and γωνία, *sides*) a figure of eight sides, and consequently as many angles. When all the sides and all the angles are equal, the figure is called *a regular octagon.*

OCTAHEDRON, or Octaedron, (Greek, ὀκτάεδρος) in geometry, one of the five regular bodies, consisting of eight equal and equilateral triangles.

The octahedron may be conceived as consisting of two quadrilateral pyramids put together at their bases.

Its solidity, therefore, is had by multiplying the quadrangular base of either by one-third of the perpendicular height of one of them, and then doubling the product. The square of the side of an octahedron is in a subduple ratio of the square of the diameter of the circumscribing sphere. See Regular Body.

OCTOGON, *See* Octagon.

OCTOSTYLE, (from ὀκτὼ, *eight*, and ςῦλος, *a column*) an ordonnance with eight columns. It is generally understood of columns when their axes are all in the same plane as in the portico of the Pantheon at Rome, and the Parthenon at Athens.

ODEUM, (Greek, ὠδειον) among the ancients, was a place for the rehearsal of music to be sung in the theatre.

Odeum was sometimes also extended to buildings that had no relation to the theatre. Pericles built an odeum at Athens where musical prizes were contended for. Pausanias says that Herod, the Athenian, built a magnificent odeum for the sepulchre of his wife.

Ecclesiastical writers also use odeum for the choir of church.

ODOMETER, an instrument for measuring the distance travelled over by a chaise or other carriage; it is attached to the wheel, and by means of an index and dial-plate, shows the distance gone over.

ŒCUS, (Greek) a word used by Vitruvius, to denote some apartment connected with the dining-room. The œci were very magnificent, as will appear by reading chapters v. and vi. book vi. of Newton's Vitruvius.

OFFICES, (French) in architecture, denote all the apartments that serve for the necessary occasions of a great house, or palace, or those where the servants are employed; as kitchens, pantries, brewhouses, confectioneries, fruiteries, granaries, &c., as also wash-houses, wood-houses, stables, &c. The offices are commonly in the *bassecour;* sometimes they are sunk under ground, and well vaulted.

OFFSETS, those planes of a wall which connect two faces in different parallel planes, where the upper part recedes from the lower.

OGEE, or O-G, in architecture, a moulding, consisting of two members, the one concave, the other convex, the same with what is otherwise called *cymatium.*

Vitruvius makes each member of the ogee a quadrant of a circle; Scammozzi, and some others, make them somewhat flatter, and strike them from two equilateral triangles.

The figure of an ogee bears some resemblance to that of an S.

OGIVES, in architecture, arches or branches of a Gothic vault, which, in lieu of being circular, pass diagonally from one angle to another, and form a cross with the other arches which make the side of the squares, whereof the ogives are diagonals.

The middle, where the ogives cut or cross each other, is called the *key*, which is sometimes carved in form of a rose, or a *cul de lampe.* The members or mouldings of the ogives are called *nerves*, *branches*, or *reins;* and the arches which separate the ogives, *double arches.*

OILLETS, OILLETTES, or OYLETS, (from the French *œil*, an eye). Eyelet-holes, small openings, or holes of various forms in the walls of fortified places, through which missiles were discharged on the besiegers.

OLD RED SANDSTONE, in *geology*, the lowest member of the carboniferous group of strata, extensively developed in the counties of Shropshire and Herefordshire, in England; Brecknockshire, in Wales; and Dumfrieshire and Forfarshire in Scotland. It lies between the carboniferous series and the silurian rocks. It consists of many varieties and alternations of silicious sandstones, and conglomerates of various colours, red predominating. According to Bakewell, the old red sandstone is a graywacke, coloured red by the accidental admixture of oxide of iron.

OLYMPIAN GAMES, the chief of the four great national festivals of the Greeks, were celebrated at Olympia, a sacred spot on the banks of the Alpheus, near Elis, every fifth year. The exact interval at which it recurred, was one of forty-nine and fifty lunar months alternately; so that it fell sometimes in the month of Appollonius (July) sometimes in the month of Parthenius (August.) The period between two celebrations, was called an Olympiad. It lasted during five days.

The Olympian festival consisted of religious ceremonies, athletic contests, and races. The chief deity who presided over it was Jupiter Olympius, whose temple at Olympia, containing the ivory and gold statue of the god by Phidias, was one of the most magnificent works of art in Greece. The games consisted of horse and foot races, leaping, throwing, wrestling, and boxing, and combinations of these exercises. The earliest of these games was the foot-race, which was the only one revived by Iphitus. The space run, was the length of the stadium in which the games were held, namely, about 600 English feet.

Wrestling was introduced in the 18th Olympiad (B.C.708). The wrestlers were matched in pairs by lot; when there was an odd number, the person who was left by the lot without an antagonist, wrestled last of all with him who had conquered the others. The athlete who gave his antagonist three throws, gained the victory. There was another kind of wrestling, in which, if the combatant who fell could drag down his antagonist with him, the struggle was continued on the ground, and the one who succeeded in getting uppermost and holding the other down gained the victory.

Boxing was introduced in the 23rd Olympiad (B.C. 688). The boxers had their hands and arms covered with thongs of leather, called cestus, which served both to defend them, and to annoy their antagonists. Virgil describes the cestus as armed with lead and iron; but this is not known to have been the case among the Greeks. In these games, the combatants fought naked.

The horse-races were of two kinds, with chariots, or without. The chariot-race was generally with four-horsed chariots, and was introduced in the 25th Olympiad (B.C. 680.) The course had two goals in the middle, at the distance probably of two stadii from each other. The chariots started from one of these goals, turned round the other, and returned along the other side of the hippodrome. This circuit was made twelve times. The great art of the charioteer consisted in turning as close as possible to the goals, but without running against them, or against the other chariots. The places at the starting-post were assigned to the chariots by lot.

There were two sorts of races on horseback, namely, that in which each competitor rode one horse throughout the course, and the other in which, as the horse approached the goal, the rider leaped from his back, and keeping hold of the bridle, finished the course on foot. *See* CIRCUS and HIPPODROME.

It seems to be generally admitted that the chief object of this festival was to form a bond of union for the Grecian states. Besides this, the great importance which such an institution gave to the exercises of the body, must have had an immense influence in forming the national character. Regarded as a bond of union, the Olympian festival seems to have had but little success in promoting kindly feelings between the Grecian states, and perhaps the rivalry of the contest may have tended to exasperate existing quarrels; but it undoubtedly furnished a striking exhibition of the nationality of the Greeks, of the distinction between them and other races. Perhaps the contingent effects of the ceremony were, after all, most important. During its celebration, Olympia was a centre for the commerce of all Greece, for the free interchange of opinions, and for the publication of knowledge. The concourse of people from all parts of Greece afforded a fit audience for literary productions, and gave a motive for the composition of works worthy to be laid before them. Poetry and statuary received an impulse from the demand made upon them to aid in perpetuating the victors fame.

ONE-PAIR-OF-STAIRS, signifies the first story, or floor, by passing up the stairs, or pair of stairs, as they are frequently called, from the entrance-floor to the next floor, which is denominated the one-pair-of-stairs floor, and frequently (though very improperly) the first floor, the entrance floor being naturally the first floor.

OOLITE. *See* ROE-STONE.

OPAE, the space, signifies the space between joists. *See* Newton's Vitruvius, book iv. chap. ii.

OPENING. *See* APERTURE.

OPERA HOUSE, a theatre for the express purpose of performing operas or musical dramas.

OPISTHODOMOS, the enclosed space behind a temple. The treasury at Athens was so called, because it stood behind the temple of Minerva.

OPPOSITE ANGLES, those which are formed by two straight lines crossing each other, but not two adjacent angles.

Opposite Cones, those to which a straight line can be everywhere applied on the surfaces of both cones.

Opposite Sections, the sections made by a plane cutting two opposite cones.

OPTIC PYRAMID. *See* Perspective.

Optic Rays. *See* Perspective.

OPTICS, (from the Latin, *optica*) is properly the science of direct vision. In a larger sense, the word is used for the science of vision, or visibles in general; in which sense, optics includes catoptrics and dioptrics, and even perspective.

In its more extensive acceptation, optics is a mixed mathematical science, which explains the manner by which vision is performed in the eye; treats of sight in the general; gives the reasons of the several modifications or alterations which the rays of light undergo in the eye; and shows why objects appear sometimes greater, sometimes smaller, sometimes more distinct, sometimes more confused, sometimes nearer, and sometimes more remote. In this extensive signification, it is considered by Sir Isaac Newton, in his admirable work called *Optics*.

Optics make a considerable branch of natural philosophy; both as it explains the laws of nature, according to which vision is performed; and as it accounts for abundance of physical phenomena, otherwise inexplicable.

From optics likewise arises perspective, all the rules of which have their foundation in optics. Indeed, Tacquet makes perspective a part of optics; though John, Archbishop of Canterbury, in his *Perspectiva Communis*, calls optics, catoptrics, and dioptrics, by the common name *perspective*.

This art, for so it should be considered rather than as a science, was revived, or re-invented, in the sixteenth century. It owes its birth to painting, and particularly to that branch of it which was employed in the decoration of the theatre. Vitruvius informs us, that Agatharchus, instructed by Æschylus, was the first who wrote upon this subject; and that afterwards the principles of this art were more distinctly taught by Democritus and Anaxagoras, the disciples of Agatharchus. How they described the theory of this art we are not informed, as their writings have been lost; however, the revival of painting in Italy was accompanied with a revival of this art; and the first person who attempted to lay down the rules of perspective, was Pietro del Borgo, an Italian. He supposed objects to be placed beyond a transparent tablet, and endeavoured to trace the images which rays of light, emitted from them, would make upon it. The book which he wrote upon this subject, is not now extant; and this is the more to be regretted, as it is very much commended by the famous Egnazio Dante. Upon the principles of Borgo, Albert Durer constructed a machine, by which he could trace the perspective appearance of objects. Balthazar Parussi, having studied the writings of Borgo, endeavoured to make them more intelligible. To him we owe the discovery of points of distance, to which all lines that make an angle of 45 degrees with the ground-line are drawn. Soon after, Guido Ubaldi, another Italian, found that all the lines, which are parallel to each other and to the horizon, if they be inclined to the ground-line, converge to some point in the horizontal line; and that through this point, also, a line drawn from the eye, parallel to them will pass. These principles combined, enabled him to make out a pretty complete theory of perspective. Great improvements were made in the rules of perspective by subsequent geometricians, particularly by Professor Gravesande, and still more by Dr. Brook Taylor, whose principles are, in a great measure, new, and much more general than those of any person before him. Although Dr. Taylor really invented this excellent method of perspective, yet it is suggested by Mr. Robins, that the same method was published by Guido Ubaldi in his *Perspective*, printed at Pesaro, in 1600. In this treatise the method is delivered very clearly, and confirmed by most excellent demonstrations. In the last book, Ubaldi applies his method to the delineation of the scenes of a theatre; and in this, as far as the practice is concerned, he is followed by Signor Sabatellini, in his *Practica di Fabrica Scene*, of which there was a new edition at Ravenna in 1638; and to this was added a second book, containing a description of the machines used for producing the sudden changes in the decorations of the stage. In the catalogue of the great Sir Isaac Newton's works, at the end of his *Life*, is a work on perspective, written in Latin; *Newtoni Elementa Perspectivæ Universalis*, 1746. 8vo. We are indebted to opticians of a much later period for ingenious devices to apply the knowledge they had of optics, and especially of perspective, to the purpose of amusement.

For the principles and practice of Perspective, see that article, where they will be fully treated of.

ORANGERY, a gallery in a garden, or parterre, exposed to the south, but well closed with a glass window, to preserve oranges in during the winter season.

The orangery of Versailles is the most magnificent that ever was built; it has wings, and is decorated with a Tuscan order.

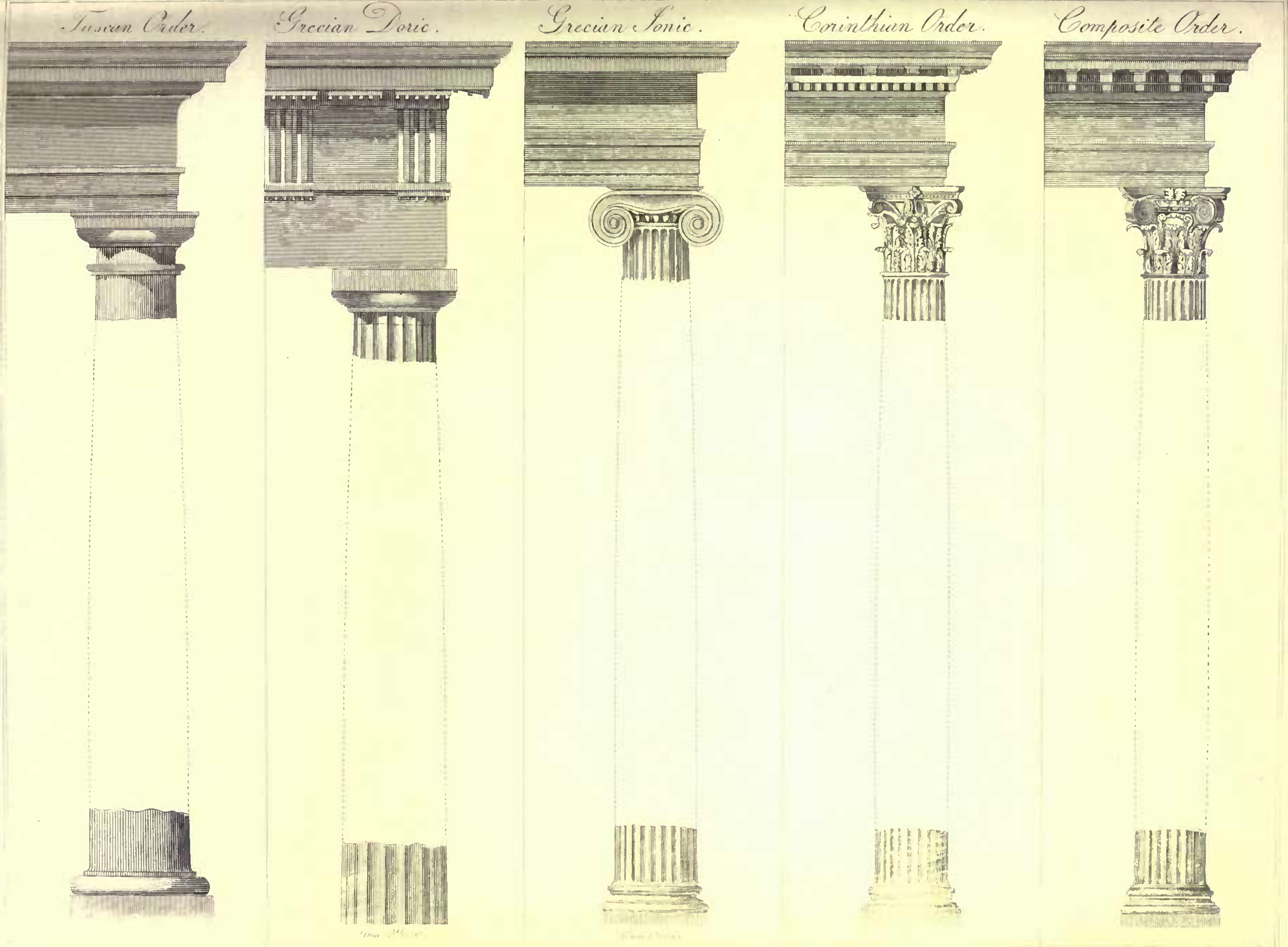
ORATORY, (from the Latin, *oratorium*, a temple,) a closet or apartment in a large house, near a bedchamber, furnished with a small altar, or an image, for private devotion, among the Romanists. The ancient oratories were little chapels adjoining to monasteries, wherein the monks offered up their prayers, before they had churches.

In the sixth and seventh centuries, oratories were little churches built frequently in burial-grounds, without either baptistry, cardinal, priest, or any public office, the bishop sending a priest to officiate occasionally.

ORB, (from the Latin *orbis*, a sphere,) a knot of flowers, or herbs, in a Gothic ceiling, placed upon the intersection of several ribs, in order to cover the mitres of every two adjoining ribs. This is otherwise called *boss*.

ORCHESTRA, in ancient theatres, a place set apart for the chorus, and in modern theatres that division in which the musicians are located. *See* Theatre.

ORDER, the perfect arrangement and composition of any architectural work; but the term is more especially used to designate the various methods of arrangement employed in Grecian or Classical architecture, and is definitely applied to such a portion of a building as may comprehend the whole design by a continuity and repetition of its parts. By those who put faith in Vitruvius, the Grecian orders are supposed to be but an imitation of the parts of a primitive hut, and which, according to his theory, originally consisted of a roof or covering, supported by posts made of the trunks of trees in four rows, forming a quadrangular enclosure. Beams were laid upon the tops of the posts, in order to connect them, in their longitudinal direction, in one body. To support the covering, timbers were laid from beam to beam across the breadth; and to throw off the wet, other beams were laid parallel to those resting upon the posts, but jutting farther over on each side of the edifice; and these again supported inclined timbers, which overhung their supports, and formed


Tuscan Order.
Grecian Doric.
Grecian Ionic.
Corinthian Order.
Composite Order.

ORNAMENTS.

PLAT

Fig. 3.

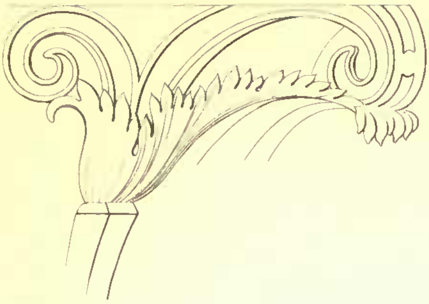


Fig. 2.

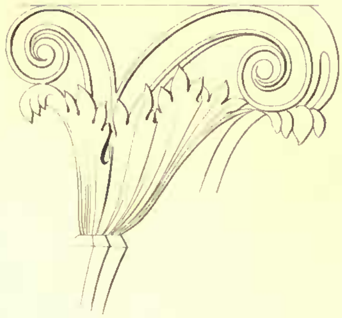


Fig. 1.

Fig. 6

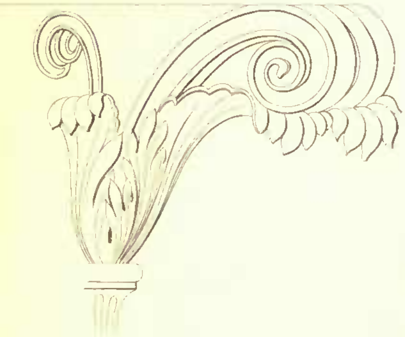


Fig. 5

Fig. 4.

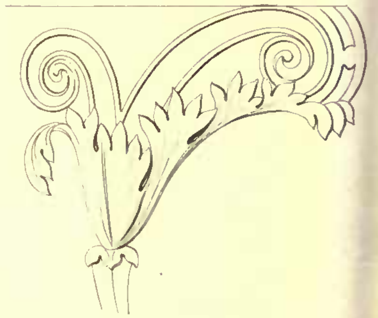


Fig. 9

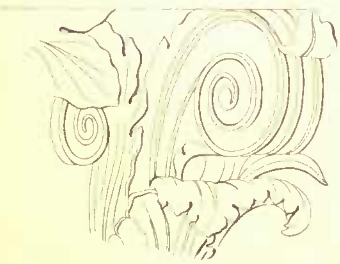


Fig. 8.

Fig. 7.

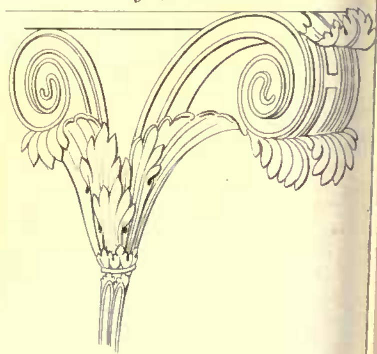


Fig. 12.

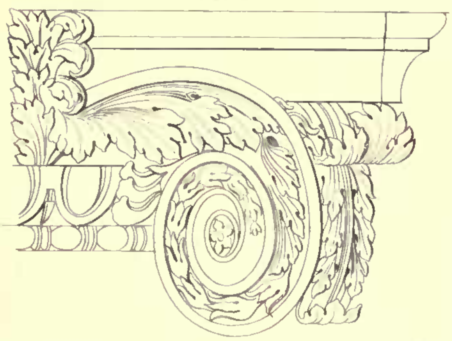


Fig. 11.

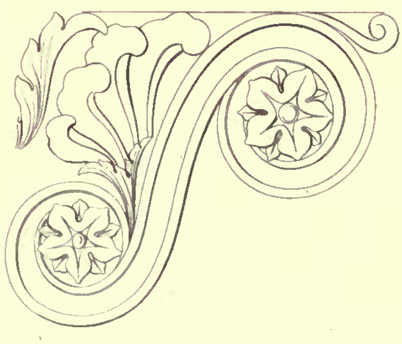


Fig. 10.

a ridge in the middle of the roof, for throwing off the wet; and thus the part supported formed three principal distinct portions, which, in process of time, were decorated with certain mouldings, or other ornaments, each part still preserving its distinct mass, though perhaps not exactly similar to the original form. The three parts, taken as a whole, were called *the entablature:* the lower part, consisting of the linteling beams, was called *the epistyle*, or *architrave:* the middle part, which receded from the epistyle, was called *the zoophorus*, or *frieze;* and the upper part, which projected considerably over the frieze, being in imitation of the ends of the roof, was called *the cornice*.

Therefore the entablature consists of a cornice, frieze, and architrave.

The posts received the name of *columns*, which always consist of two principal divisions at least, and frequently of three. The columns were ornamented at the top in imitation of the stones laid upon the posts in the original wooden hut, for throwing off the rain. These decorations at the top received the name of *capital*, and each of the wooden posts that of *shaft*.

When ornaments were added to the foot of the shaft, they were termed *the base*.

The order, therefore, consists principally of a column and entablature. The column is subdivided into a shaft and capital, or, at most, into three principal parts, a base, shaft, and capital; and the entablature, as has been observed, into architrave, frieze, and cornice. These parts are again divided into smaller portions, termed *mouldings*, or other ornaments. *See* Architecture, Orders of.

Order, *Attic*, the pilaster of an attic. *See* Attic.

Order, *Caryatic*, that in which the entablature is supported by women instead of columns. *See* Caryatic.

Order, *Gothic*, the pointed style of architecture, usually called *Gothic*. *See* Architecture, Castle, and Gothic.

Orders, *Greek*, are the Doric, Ionic, and Corinthian. *See* each of these articles.

Order, *Persian*, that where the entablature is supported by men instead of columns. The history is related in Newton's *Vitruvius*, book i. chap. i. page 3. *See* Persians.

Order of Temples, otherwise called Species, are the amphiprostyle, the antæ, the dipteral, the peripteral, and the prostyle. *See* those respective articles.

ORDINANCE, or Ordonnance, the same as Order: which see.

ORDINATES, in geometry and conics, are lines drawn from any point of the circumference of an ellipsis, or other conic section, perpendicularly across the axis, to the other side.

The Latins call them *ordinatim applicatæ*.

The halves of each of these are properly only *semi-ordinates*, though popularly called *ordinates*.

The ordinates of a curve may more generally be defined to be right lines parallel to each other, terminated by the curve, and bisected by a right line called the *diameter*. In curves of the second order, if any two parallel right lines be drawn so as to meet the curve in three points, a right line, which cuts these parallels, so as that the sum of two parts terminating at the curve on one side the secant, is equal to the third part terminated at the curve on the other side, will cut all other right lines parallel to these, which meet the curve in three points, after the same manner, *i. e.* so as that the sum of the two parts on one side will always be equal to the third part on the other side. And these three parts, equal on either side, Sir Isaac Newton calls *ordinatim applicatæ*, ordinates of curves of the second order.

Ordinate, in an ellipsis, hyperbola, and parabola. *See* the respective articles.

ORGANICAL DESCRIPTION OF CURVES, a method of describing curves upon a plane by continued motion.

ORIEL WINDOW, in architecture, a projecting angular window, mostly of a triagonal or pentagonal form, and divided by mullions and transomes into different bays and other compartments. These windows are not peculiar to the pointed style, as they are of frequent occurrence in the barbarous style which succeeded it. During the reigns of Elizabeth and James I. they became still more common than they had been before in the pointed style.

ORLE (French, formed from the Latin *orletum* or *orlum*, of *ora*, a border or list) a fillet under the ovolo or quarter-round of a capital.

When at the top or bottom of the shaft, it is called *cincture*.

Palladio also uses orle for the plinth of the bases of the columns and pedestals.

ORNAMENTS (from the Latin *ornamentum*, to embellish) in architecture, all the sculpture, or carved work, with which a piece of architecture is enriched.

Plate I. Some of the most beautiful specimens of ornaments, in scrolls and branches, used in the capitals of columns, in Grecian and Roman antiquity.

Figures 1, 2, 3, 4, 5, Specimens from the most beautiful remains of Grecian architecture. *Figure* 5 is taken from the capitals of that elegant piece of antiquity the Lantern of Demosthenes.

Figures 6, 7, 8, 9, 10, 11, 12, are from the ancient remains of Roman architecture. In particular, *Figure* 9, is taken from the temple of Vesta, at Tivoli; *Figure* 10, from the three remaining columns of the temple of Jupiter Stator, at Rome; *Figure* 12, from the arch of Titus.

Ornaments in Relievo, those carved on the contours of mouldings.

ORTHOGONAL FIGURE (from ὀρθὸς, *true*, and γωνία, *an angle*) the same as rectangular.

ORTHOGRAPHICAL PROJECTIONS. *See* Projection.

ORTHOGRAPHY (ὀρθὸς, *true*, and γραφω, *to describe*) in architecture, the elevation of a building, showing all the parts thereof in their true proportion. The orthography is either *external* or *internal*.

Orthography, *External*, a delineation of the outer face or front of a building, exhibiting the principal wall, with its apertures, roof, ornaments, and everything visible to an eye placed at a distance, before the building.

Orthography, *Internal*, called also Section, a delineation or draught of a building, such as it would appear were the external wall removed. *See* Perspective.

Orthography, in geometry, the art of drawing or delineating the fore-right plan or side of any object, and of expressing the heights or elevations of each part.

This art has received its name from its determining things by perpendicular right lines falling on the geometrical plan; or rather, because all the horizontal lines are here straight and parallel, and not oblique, as in perspective representations.

Orthography, in fortification, the profile or representation of a work; or a draught so conducted, as that the length, breadth, height, and thickness of the several parts are expressed; such as they would appear, if it were perpendicularly cut from top to bottom.

OSCULATING CIRCLE, or Kissing Circle, the circle of curvature. That circle whose radius is equal to the radius of curvature of any other curve at a particular or specified point. *See* CURVE.

OVA (from the Latin *ovum*, an egg) an ornament in form of an egg, usually employed in the echinus.

OVAL, a figure in geometry, bounded by a curve line returning to itself.

Under this general definition of an oval is included the ellipsis, which is a mathematical oval; also all other figures which resemble the ellipsis, though with very different properties; and, in short, all curves which return to themselves, go under the name of ovals.

For a description of the mathematical oval, the reader will turn to the article ELLIPSIS, where, it is presumed, he will meet with full satisfaction.

One of the most remarkable properties of the oval kind is the following:

Plate I. *Figure* 1.—Let C E F G be a circle, O its centre; draw any line, E I, through the centre O; then take any point, F, in the circumference. Let F I be an inflexible line, and let M be a given point in the line F I; then, if the point F be conceived to move round the circumference of the circle, while the point, I, the end of this line, F I, moves or slides along the line E I, the point M will describe an oval, almost similar to the conic ellipsis. As we have not seen any equation of this figure, it is presumed that the following investigation, by the author, will be acceptable:

Draw F H perpendicular to the diameter, E G, of the circle, cutting E G at H; also draw M P perpendicular to E I, cutting E I always in P, wherever the point M is situated. Let A be the point in the straight line E I, in which M will coincide when F is brought to E, and B the point where M will coincide when F comes to G.

Then let A P $= x$
P M $= y$
E H $=$
H F $= s$
I M $= a$
I F $= b$
and E G $= d$

From the property of the circle we have H F$^2 = d\,v - v^2$; then, by similar triangles, I F H and I M P, we have

$$\text{IF}^2 : \text{IM}^2 :: \text{HF}^2 : \text{PM}^2;$$

$$\text{That is, } b^2 : a^2 :: d\,v - v^2 : y^2 = \frac{a^2}{b^2}(d\,v - v^2)$$

$$\text{Therefore, } y = \frac{a}{b}(d\,v - v^2)^{\frac{1}{2}}$$

Then, to find the value of $x =$ A P, we have

$$\text{IP}^2 = \text{IM}^2 - \text{PM}^2 = a^2 - \frac{a^2}{b^2}(d\,v - v^2) = \frac{a^2}{b^2}(b^2 - d\,v + v^2);$$

$$\text{Therefore, IP} = \frac{a}{b}(b^2 - d\,v + v^2)^{\frac{1}{2}};$$

$$\text{But IM : IP :: MF : PH;}$$

$$\text{That is, } a : \frac{a}{b}(b^2 - d\,v + v^2)^{\frac{1}{2}} :: c : \text{PH} = \frac{c}{b}(b^2 - d\,v + v^2)^{\frac{1}{2}}$$

$$\text{IE} = \text{IP} + \text{PH} + \text{HE} = (b^2 - d\,v + v^2)^{\frac{1}{2}} \times \frac{a+c}{b} + v;$$

$$\text{IA} = \text{IE} - \text{AE} = \frac{a+c}{b} \times (b^2 - d\,v + v^2)^{\frac{1}{2}} + v - c;$$

$\text{AP} = \text{IA} - \text{IP} = \frac{c}{b}(b^2 - d\,v + v^2)^{\frac{1}{2}} + v - c$; by which the value of A P, corresponding to P M or $y = \frac{a}{b}(d\,v - v^2)^{\frac{1}{2}}$, may be found in the most simple manner.

Therefore, if A P in the figure were always equal to the versed sine E H of the circle, the curve described by the motion of the point M, would really be an ellipsis; and because P M or $y = \frac{a}{b}(d\,v - v^2)^{\frac{1}{2}}$ it follows, that the axis perpendicular to the ordinates, is to the axis parallel to the ordinates, in the ratio of b to a; that is, in the ratio of I F to I M nearly.

Let $a = 20$, $b = 40$, $c = 20$, and $d = 10$; then will $y = \frac{a}{b}d\,(v - v^2)^{\frac{1}{2}} = \frac{1}{2}(6\,v - v^2)^{\frac{1}{2}}$; from which the following values are obtained, according to the different assumptions of the versed sine, v, of the circle:

$$\text{Assume } v = 1, \text{ then } \frac{1}{2}(6 \times 1 - 1^2)^{\frac{1}{2}} = \frac{1}{2}(6 - 1)^{\frac{1}{2}} = \frac{5^{\frac{1}{2}}}{2} = 1.118;$$

$$v = 2, \quad \frac{1}{2}(6 \times 2 - 2^2)^{\frac{1}{2}} = \frac{1}{2}(12 - 4)^{\frac{1}{2}} = \frac{8^{\frac{1}{2}}}{2} = 1.4142;$$

$$v = 3, \quad \frac{1}{2}(6 \times 3 - 3^2)^{\frac{1}{2}} = \frac{1}{2}(18 - 9)^{\frac{1}{2}} = \frac{9^{\frac{1}{2}}}{2} = 1.5;$$

$$v = 4, \quad \frac{1}{2}(6 \times 4 - 4^2)^{\frac{1}{2}} = \frac{1}{2}(24 - 16)^{\frac{1}{2}} = \frac{8^{\frac{1}{2}}}{2} = 1.4142;$$

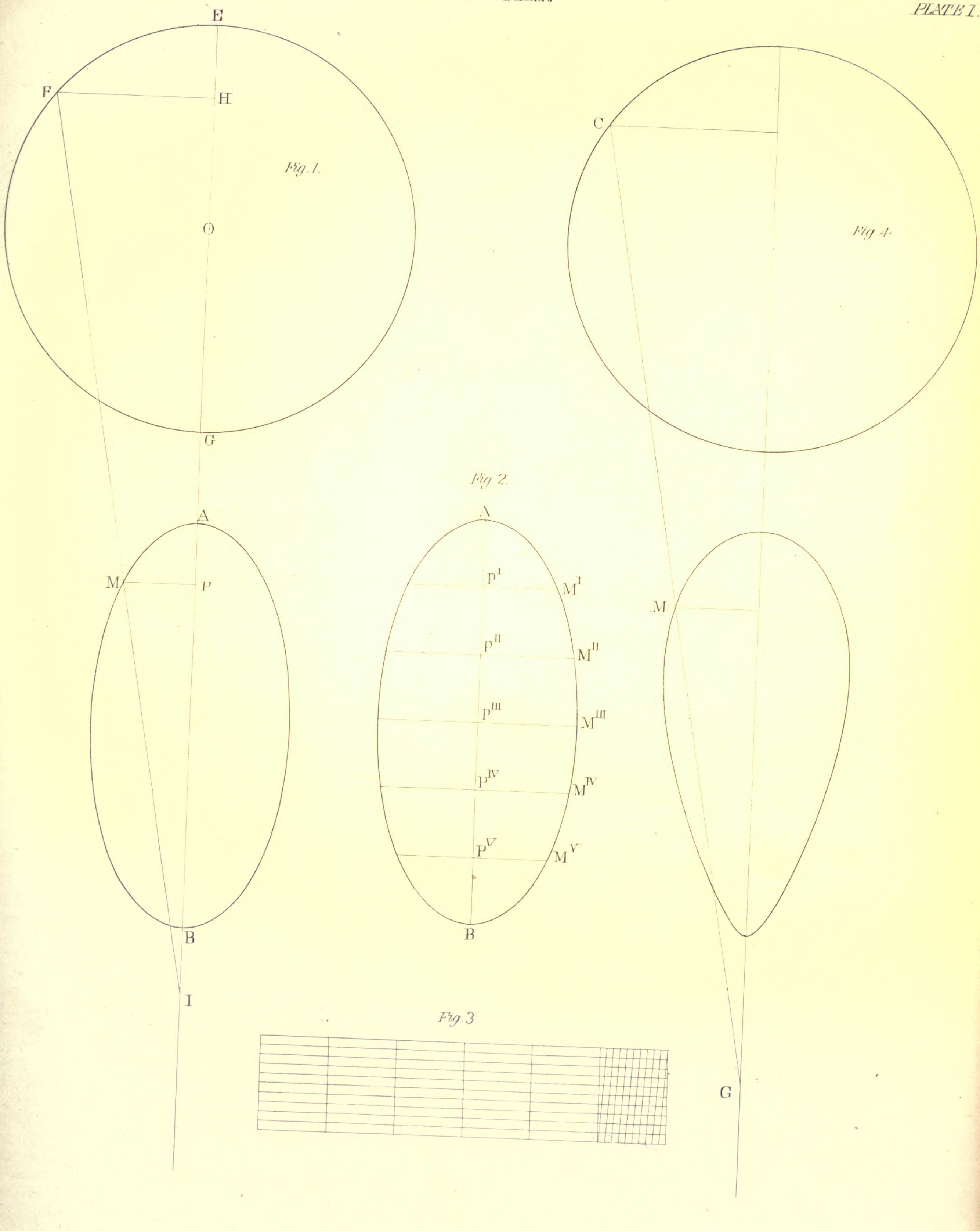
$$v = 5, \quad \frac{1}{2}(6 \times 5 - 5^2)^{\frac{1}{2}} = \frac{1}{2}(30 - 25)^{\frac{1}{2}} = \frac{5^{\frac{1}{2}}}{2} = 1.118.$$

Then, because $x = \frac{c}{b}(b^2 - d\,v + v^2)^{\frac{1}{2}} + v - c = \frac{1}{2}(1600 - 6\,v + v^2) + v - 20$, we shall have the following value of x, by the different assumptions of v, which must be those answering to y, as before:

$$v = 1, \text{ then } x = \frac{1}{2}(1600 - 6 \times 1 + 1^2)^{\frac{1}{2}} + 1 - 20 = 0.96872;$$

$$v = 2, \quad x = \frac{1}{2}(1600 - 6 \times 2 + 2^2)^{\frac{1}{2}} + 2 - 20 = 1.94993;$$

OVAL.



Invented by P. Nicholson.
Drawn by M. A. Nicholson.

Engraved by J. C. Buttre.

$$v = 3, \text{ then } x = \frac{1}{2}(1600 - 6 \times 3 + 3^2)^{\frac{1}{2}} + 3 - 20 = 2.94367;$$

$$v = 4, \quad x = \frac{1}{2}(1600 - 6 \times 4 + 4^2)^{\frac{1}{2}} + 4 - 20 = 3.94993;$$

$$v = 5, \quad x = \frac{1}{2}(1600 - 6 \times 5 + 5^2)^{\frac{1}{2}} + 5 - 20 = 4.96872;$$

Therefore the abscissas, and the corresponding ordinates of the figure, are as follow:

When $x = .96872$, then $y = 1.1180$;
$x = 1.94993$, $y = 1.4142$;
$x = 2.94367$, $y = 1.5$;
$x = 3.94993$, $y = 1.4142$;
$x = 4.96872$, $y = 1.1180$.

Figure 2.—Draw the line A B equal to the diameter d, which is 6, from any scale of equal parts, as *Figure* 3, (but the scale to be used ought to be a diagonal one); make A P′ = 0.96872, A P″ = 1.94993, A P‴ = 2.94367, A P^{iv} = 3.94993, A P^{v} = 4.96872; then, having drawn all the lines, P M, cutting A B at right angles, on both sides of A B make P′ M′ = 1.1180, P″ M″ = 1.4142, P‴ M‴ = 1.5, P^{iv} M^{iv} = 1.4142, and P^{v} M^{v} = 1.1180; and through all the points A, P′, P″, P‴, P^{iv}, P^{v}, draw a curve, which will be the oval required.

Abscissas.	Distances.	Differences.
A P′ = 0.96872	.96871 .98121	.01250
A P″ = 1.94993		.01253
A P‴ = 2.94367	.99374 1.00626	.01252
A P^{iv} = 3.94993		.01253
A P^{v} = 4.96872	1.01879 .98128	.03751
A P^{vi} = 6.		

So that the last distances, being a little wider than the first, show the figure to be an eggoid.

Another oval, which may be generated in a similar manner, is the following:

Figure 4.—Let C D H F be a circle; let any point, G, be taken in the plane of description; let C be the extremity of an inflexible line; let the point C be carried round the circumference of the circle, while the line always moves through the point G; then will any point, M, taken in this line, describe the oval required.

It is hoped that the reader will be satisfied with this mechanical description, as the investigation of the principle would extend this article to too great a length.

It is now upwards of twenty-five years since the author discovered the two above methods; and a machine for describing the former has been since exhibited for sale in Cornhill, which Mr. J. B. Taylor has applied to the art of engraving with considerable success; and though not mathematically true, it describes a beautiful curve, so very near to an ellipsis, that the defect cannot be detected by the eye. For describing concentric ellipses, or those which have their axes in the same ratio, no method can be so easily applied, as nothing more is required than to adopt the radius to the length of the curve.

A most beautiful figure of an oval may be derived from the equation of a circle of the higher orders; as $y^{m+1} = x^m (a - x)$. The proportion of the figure may be varied at pleasure.

To find the point in the axis through which the ordinate of the greatest breadth passes. As we have the value of $y = (a x^m - x^{m+1})^{\frac{1}{m+1}}$, it is evident that such value has a maximum; therefore, as $a x^m - x^{m+1}$ will have a maximum,

$$m a x^{m-1} \dot{x} - (m+1) x^m \dot{x} = o;$$

$$\frac{m a x^m}{x} = (m+1) x^m;$$

$$\frac{m a}{x} = (m+1);$$

$$m a = (m+1) x;$$

$$\text{and } x = \frac{m a}{m+1}.$$

Now let $m = 2$; then will $y = (a x^m - x^{m+1})^{\frac{1}{m+1}}$ become $y = (a x^2 - x^3)^{\frac{1}{3}}$; therefore, to make an oval of this description to any length and breadth, we have in this case $x = \frac{m a}{m+1} = \frac{2a}{3}$; consequently, the value of the ordinate, when it is a maximum, is $y = \left(\frac{4 a^3}{27}\right)^{\frac{1}{3}} = \frac{a}{3} 4^{\frac{1}{3}}$; hence, to make the length and breadth equal to each other, we have $y = \frac{3}{32^{\frac{1}{3}}} (a x^2 - x^3)^{\frac{1}{3}} = .945 (a x^2 - x^3)^{\frac{1}{3}}$ nearly, three decimal places only being used. Now let p be any proportion, as $\frac{1}{2}, \frac{2}{3}, \frac{3}{4}$, or any multiple of the semi-axis of the curve; then will $y = .945\, p\, (a x^2 - x^3)^{\frac{1}{3}}$. Let $p = \frac{1}{2}$, and $a = 9$; then $y = .4725 (9 x^2 - x^3)^{\frac{1}{3}}$.

Now when $x = o$, then will $y = o$; and when $x = a$, then will $y = o$ again; therefore, by assuming x equal to the following values:

$x = 1$, then will $y = .4725 \; (9 - 1)^{\frac{1}{3}} = .945$;
$x = 2$, $y = .4725 \; (36 - 8)^{\frac{1}{3}} = 1.435$;
$x = 3$, $y = .4725 \; (81 - 27)^{\frac{1}{3}} = 1.785$;
$x = 4$, $y = .4725 \; (144 - 64)^{\frac{1}{3}} = 2.036$;
$x = 5$, $y = .4725 \; (225 - 125)^{\frac{1}{3}} = 2.193$;
$x = 6$, $y = .4725 \; (324 - 216)^{\frac{1}{3}} = 2.250$;
$x = 7$, $y = .4725 \; (441 - 343)^{\frac{1}{3}} = 2.178$;
$x = 8$, $y = .4725 \; (576 - 512)^{\frac{1}{3}} = 1.890$;

Plate II. *Figure* 5. is a curve drawn, according to these abscissas, and ordinates drawn by the diagonal scale, *Figure* 6.

But if, in the following ordinates of the figure,

when $x = 1$, $y = 1.890$
$x = 2$, $y = 2.870$
$x = 3$, $y = 3.570$
$x = 4$, $y = 4.072$
$x = 5$, $y = 4.386$
$x = 6$, $y = 4.5$
$x = 7$, $y = 4.356$
$x = 8$, $y = 3.78$

be respectively multiplied by p, we shall have the axis to the maximum breadth of the figure in any given ratio, according to the value of p. Thus if $p = \frac{1}{2}$, then the axis of the curve will be to its greatest breadth, parallel to the ordinates, as 2 to 1; for instance,

when $x = 1,\ y = .945$;
$x = 2,\ y = 1.435$;
$x = 3,\ y = 1.785$;
$x = 4,\ y = 2.036$;
$x = 5,\ y = 2.193$;
$x = 6,\ y = 2.25$;
$x = 7,\ y = 2.178$;
$x = 8,\ y = 1.890$;

Again, suppose it were required to make the length of the axis to the greatest breadth, as 3 to 2;

then, when $x = 1,\ y = 1.890 \times \frac{2}{3} = 1.260$;

$x = 2,\ y = 2.870 \times \frac{2}{3} = 1.913$;

$x = 3,\ y = 3.570 \times \frac{2}{3} = 2.380$;

$x = 4,\ y = 4.072 \times \frac{2}{3} = 2.714$;

$x = 5,\ y = 4.386 \times \frac{2}{3} = 2.924$;

$x = 6,\ y = 4.500 \times \frac{2}{3} = 3.$

$x = 7,\ y = 4.356 \times \frac{2}{3} = 2.904$;

$x = 8,\ y = 3.780 \times \frac{2}{3} = 2.580$;

So that, fixing upon the length, divide that length into nine equal parts, and draw lines through the points of division; the length being thus the scale of the work, set off the ordinates on both sides of the axis, according to the value x; that is, each of the first pair of ordinates, 1.26; each of the next pair, 1.913; and so on.

The body of the vase, *Figure* 7, is drawn by this equation.

Another very useful proportion is that in which the greatest double ordinate is three-quarters of the length. From this we shall have the several values of y, as follow:

When $x = 1,\ y = 1.890 \times \frac{3}{4} = 1.417$;

$x = 2,\ y = 2.870 \times \frac{3}{4} = 2.152$;

$x = 3,\ y = 3.570 \times \frac{3}{4} = 2.677$;

$x = 4,\ y = 4.072 \times \frac{3}{4} = 3.054$;

$x = 5,\ y = 4.386 \times \frac{3}{4} = 3.289$;

$x = 6\ \ y = 4.500 \times \frac{3}{4} = 3.375$;

$x = 7,\ y = 4.356 \times \frac{3}{4} = 3.267$;

$x = 8,\ y = 3.780 \times \frac{3}{4} = 2.835$;

If the oval be required to have a longer taper, we may use the equation $v = (a x^3 - x^4)^{\frac{1}{4}}$, instead of $y = (a x^2 - x^3)^{\frac{1}{3}}$, which will produce a most beautiful figure; now the property being $y = (a x^3 - x^4)^{\frac{1}{4}}$; let $a = 8$, then $y = (8 x^3 - x^4)^{\frac{1}{4}}$

Let

$x = 1$ then $y = (8 - 1)^{\frac{1}{4}} = (7)^{\frac{1}{4}} = 1.626$;
$x = 2 \quad y = (8 \times 8 - 16)^{\frac{1}{4}} = (48)^{\frac{1}{4}} = 2.632$;
$x = 3 \quad y = (8 \times 27 - 81)^{\frac{1}{4}} = (135)^{\frac{1}{4}} = 3.408$;
$x = 4 \quad y = (8 \times 64 - 256)^{\frac{1}{4}} = (256)^{\frac{1}{4}} = 4.000$;
$x = 5 \quad y = (8 \times 125 - 625)^{\frac{1}{4}} = (375)^{\frac{1}{4}} = 4.400$;
$x = 6 \quad y = (8 \times 216 - 1296)^{\frac{1}{4}} = (432)^{\frac{1}{4}} = 4.559$;
$x = 7 \quad y = (8 \times 343 - 2401)^{\frac{1}{4}} = (343)^{\frac{1}{4}} = 4.303.$

These several roots are obtained from two extractions of the square root, as below; the last extraction is only carried to three places of decimals, as being amply sufficient, to construct the figure.

$(7)^{\frac{1}{4}} = (2.6457513)^{\frac{1}{2}} = 1.626$;
$(48)^{\frac{1}{4}} = (6.9282032)^{\frac{1}{2}} = 2.632$;
$(135)^{\frac{1}{4}} = (11.6189500)^{\frac{1}{2}} = 3.408$;
$(256)^{\frac{1}{4}} = (16.0000000)^{\frac{1}{2}} = 4.000$;
$(375)^{\frac{1}{4}} = (19.3649167)^{\frac{1}{2}} = 4.400$;
$(432)^{\frac{1}{4}} = (20.7846097)^{\frac{1}{2}} = 4.559$;
$(343)^{\frac{1}{4}} = (18.5202592)^{\frac{1}{2}} = 4.303.$

Since $x = \frac{m\,a}{m + 1}$ in every description of an oval; therefore, in this particular curve, where m is equal to 3, we shall have $x = \frac{3\,a}{4}$; that is, the greater double ordinate will pass through a point in the axis, distant from the extremity where the abscissa begins three-quarters of the length of the axis.

But in order to accommodate this equation to every length and breadth, it will be eligible in the first place to calculate the ordinates, so as to make the greatest double ordinate equal to the length of the axis, as in the preceding equation. The value of the greatest ordinate will therefore be $y =$

$$(a x^3 - x^4)^{\frac{1}{4}} = \left(\frac{27\,a^4}{64} - \frac{81\,a^4}{256}\right)^{\frac{1}{4}} = \left(\frac{27\,a^4}{256}\right)^{\frac{1}{4}} = \frac{a}{4} \times 27$$

$$= \frac{27^{\frac{1}{4}}\,a}{4}; \text{ hence } \frac{27^{\frac{1}{4}}\,a}{4} : \frac{a}{2} :: (a x^3 - x^4)^{\frac{1}{4}} : \frac{2}{27^{\frac{1}{4}}}(a x^3 - x^4)$$

So that $y = \frac{2}{27}(a x^3 - x^4)^{\frac{1}{4}}$ when the greatest double ordinate is equal in length to the axis; and if r be the ratio which the axis has to the greatest double ordinate, $y = \frac{2\,r}{27^{\frac{1}{4}}}(a x^3 - x^4)^{\frac{1}{4}} = .877\,r\,(a x^3 - x^4)^{\frac{1}{4}}$.

If the several values of y, as before calculated, be multiplied by .877, we shall obtain the following:

When $x = 1,\ y = 1.626 \times .878 = 1.427$;
$x = 2,\ y = 2.632 \times .878 = 2.311$;
$x = 3,\ y = 3.408 \times .878 = 2.999$;
$x = 4,\ y = 4.000 \times .878 = 3.511$;
$x = 5,\ y = 4.400 \times .878 = 3.866$;
$x = 6,\ y = 4.559 \times .878 = 4.$;
$x = 7,\ y = 4.303 \times .878 = 3.778$;

Each of these values being multiplied by r, will give the proportion of the figure required.

Now let $r = \frac{1}{8}$;

Figure 8 is drawn by these numbers; the vase, *Figure* … and the jug, *Figure* 10, are drawn by the same equation, varying the numbers.

OVAL.

Fig. 5.

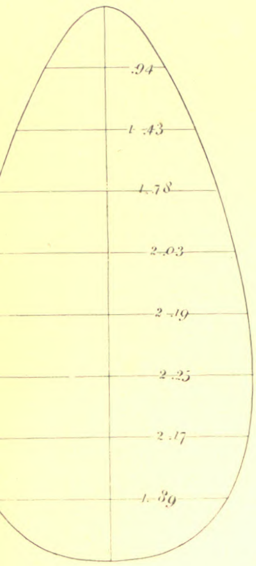


Fig. 12.

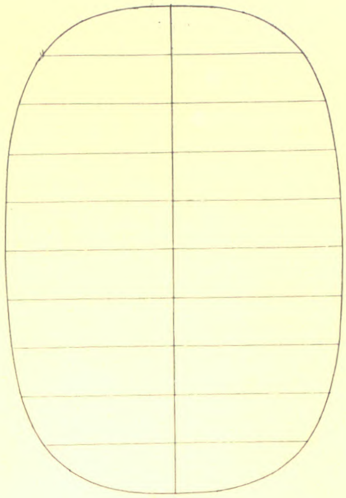


Fig. 11.

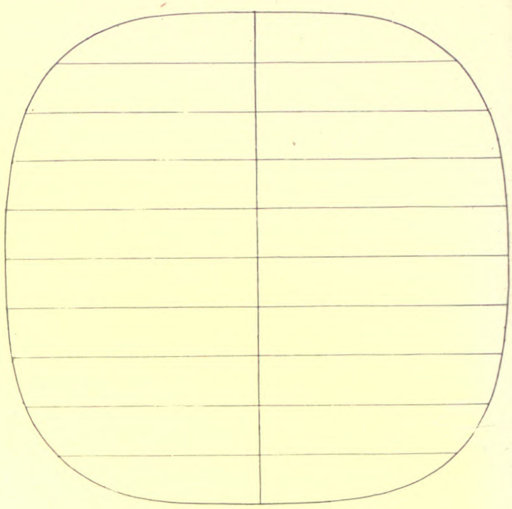


Fig. 6.

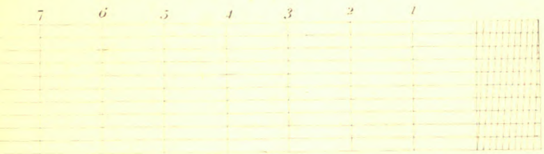


Fig. 13.

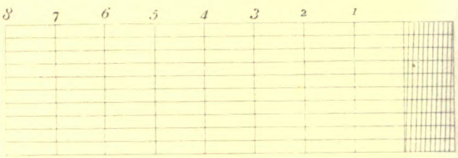
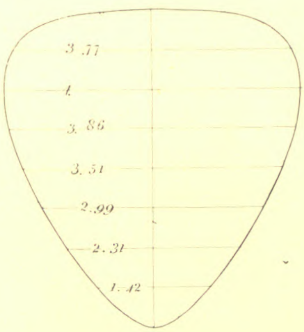


Fig. 8.



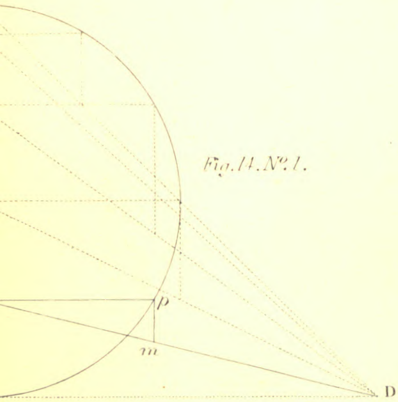


Fig. 14. No. 1.

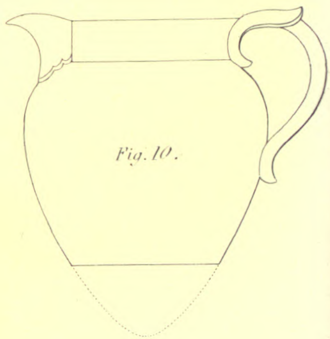
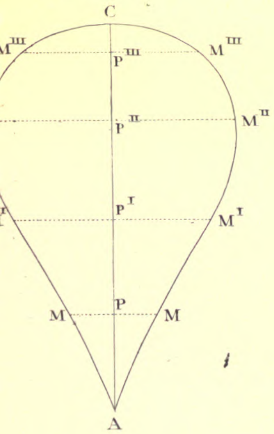


Fig. 10.

Fig. 14. No. 2.



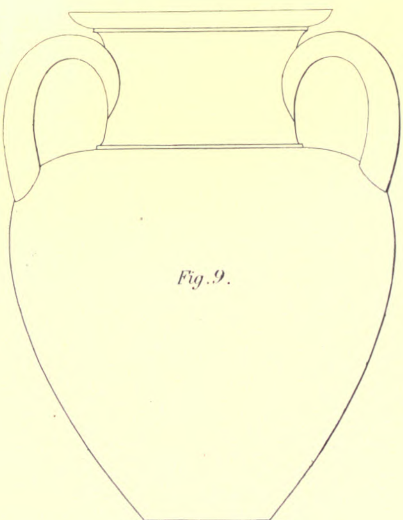


Fig. 9.

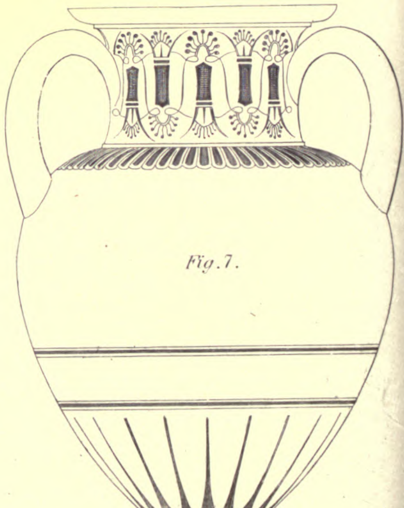


Fig. 7.

...ented by P. Nicholson.
...wn by M.A. Nicholson.

Engraved by J.C. Buttre.

then when $x = 1, y = 1.427\,r = .475$
$x = 2, y = 2.31\,r = .77$
$x = 3, y = 2.99\,r = .996$
$x = 4, y = 3.51\,r = 1.17$
$x = 5, y = 3.86\,r = 1.286$
$x = 6, y = 4.\,r = 1.333$
$x = 7, y = 3.778\,r = 1.259$

Again, let $r = \frac{1}{2}$;
then when $x = 1, y = 1.427\,r = .713$;
$x = 2, y = 2.31\,r = 1.155$;
$x = 3, y = 2.99\,r = 1.495$;
$x = 4, y = 3.51\,r = 1.755$;
$x = 5, y = 3.86\,r = 1.93$;
$x = 6, y = 4.\,r = 2.$
$x = 7, y = 3.778\,r = 1.889.$

Let $r = \frac{2}{3}$;
then when $x = 1, y = 1.427\,r = .951$;
$x = 2, y = 2.31\,r = 1.54$;
$x = 3, y = 2.99\,r = 1.99$;
$x = 4, y = 3.51\,r = 2.34$;
$x = 5, y = 3.86\,r = 2.57$;
$x = 6, y = 4.\,r = 2.66$;
$x = 7, y = 3.778\,r = 2.518.$

And, lastly, let $r = \frac{3}{4}$;
then when $x = 1, y = 1.427\,r = 1.07$;
$x = 2, y = 2.31\,r = 1.73$;
$x = 3, y = 2.99\,r = 2.24$;
$x = 4, y = 3.51\,r = 2.63$;
$x = 5, y = 3.86\,r = 2.89$;
$x = 6, y = 4.\,r = 3$;
$x = 7, y = 3.778\,r = 2.833.$

Another equation, which gives the oviform figure more well at the quicker end, is the following: $y = (a^2 x^2 - x^4)^{\frac{1}{2}}$. Let

$x = 1$ then $y = (100 - 1)^{\frac{1}{2}} = 99^{\frac{1}{2}} = 3.15$;
$x = 2$ $y = (400 - 16)^{\frac{1}{2}} = 384^{\frac{1}{2}} = 4.42$;
$x = 3$ $y = (900 - 81)^{\frac{1}{2}} = 819^{\frac{1}{2}} = 5.31$;
$x = 4$ $y = (1600 - 256)^{\frac{1}{2}} = 1344^{\frac{1}{2}} = 6.05$;
$x = 5$ $y = (2500 - 625)^{\frac{1}{2}} = 1875^{\frac{1}{2}} = 6.58$;
$x = 6$ $y = (3600 - 1296)^{\frac{1}{2}} = 2304^{\frac{1}{2}} = 6.92$;
$x = 7$ $y = (4900 - 2401)^{\frac{1}{2}} = 2499^{\frac{1}{2}} = 7.07$;
$x = 8$ $y = (6400 - 4096)^{\frac{1}{2}} = 2304^{\frac{1}{2}} = 6.92$;
$x = 9$ $y = (8100 - 6561) = 1539^{\frac{1}{2}} = 6.26.$

Calling the abscissal axis the height, the construction may e accommodated to any given dimensions, as follows; for is purpose we have the fluxion of $a^2 x^2 - x^4 = 0$; there-re $4 x^3 \dot{x} = 2 a^2 \dot{x}$; consequently $x^2 = \frac{a^2}{2}$; and hence $x = \frac{a}{2^{\frac{1}{2}}}$ ill give the point through which the greatest double ordi-ate passes. If therefore this quantity be substituted for x n the equation $y = (a^2 x^2 - x^4)^{\frac{1}{2}}$, then will $y = \left(\frac{a^4}{2} - \frac{a^4}{4}\right)^{\frac{1}{2}}$ $= \left(\frac{2a^4}{4} - \frac{a^4}{4}\right)^{\frac{1}{2}} = \left(\frac{a^4}{4}\right)\frac{a}{2^{\frac{1}{2}}} =$; therefore $\frac{a}{2^{\frac{1}{2}}} : \frac{a}{4} :: (a^2 x^2 - x^4)^{\frac{1}{2}}$ $\frac{1}{2^{\frac{1}{2}}}(a^2 x^2 - x^4)^{\frac{1}{2}} = 7071\,(a^2 x^2 - x^4)^{\frac{1}{2}}$; so that, taking $x =$, we shall have $y = \frac{a}{2}$, as it ought to be. Therefore, if the tio be r, we shall have $.7071\,r\,(a^2 x^2 - x^4)^{\frac{1}{2}}$, for any propor-on according to the nominal value of r. Now let $r = \frac{2}{3}$, then a being 10, as before, we shall have the several values of y as follow:

when $x = 1$, then $y = 2.23$;
$x = 2$ $y = 3.13$;
$x = 3$ $y = 3.75$:
$x = 4$ $y = 4.28$;
$x = 5$ $y = 4.65$;
$x = 6$ $y = 4.89$;
$x = 7$ $y = 5.00$;
$x = 8$ $y = 4.89$;
$x = 9$ $y = 4.43.$

If the equation of the curve be $y = (c^3 - x^3)^{\frac{1}{3}}$, the following values of y will be found, supposing $c = 5$;

when $x = 0, y = (125 - 0)^{\frac{1}{3}} = 5.$;
$x = 1, y = (125 - 1)^{\frac{1}{3}} = 4.986$;
$x = 2, y = (125 - 8)^{\frac{1}{3}} = 4.89$;
$x = 3, y = (125 - 27)^{\frac{1}{3}} = 4.610$;
$x = 4, y = (125 - 64)^{\frac{1}{3}} = 3.936$;
$x = 5, y = (125 - 125)^{\frac{1}{3}} = 0.$

Figure 11, is drawn by these numbers, according to the diagonal scale, *Figure* 13.

Figure 12, is drawn by the same equation, to a different set of numbers, to the same scale, *Figure* 13.

Another equation, by which figures of this description may be obtained, is the following:

$y = (a\,x - x^2)^{\frac{1}{2}}$. Let $a = 10$,
$x = 1, y = (10 - 1)^{\frac{1}{2}} = 1.73$;
$x = 2, y = (20 - 4)^{\frac{1}{2}} = 2.$;
$x = 3, y = (30 - 9)^{\frac{1}{2}} = 2.14$;
$x = 4, y = (40 - 16)^{\frac{1}{2}} = 2.21$;
$x = 5, y = (50 - 25)^{\frac{1}{2}} = 2.23.$

But perhaps the most beautiful figure of the oval species is the ellipsis. The equation of the circle is $y = (d\,x - x^2)^{\frac{1}{2}}$; let $d = 20$, then will $y = (20\,x - x^2)^{\frac{1}{2}}$; then when

$x = 1, y = (20 - 1)^{\frac{1}{2}} = 19^{\frac{1}{2}} = 4.3588989$;
$x = 2, y = (40 - 4)^{\frac{1}{2}} = 36^{\frac{1}{2}} = 6.$
$x = 3, y = (60 - 9)^{\frac{1}{2}} = 51^{\frac{1}{2}} = 7.1414284$;
$x = 4, y = (80 - 16)^{\frac{1}{2}} = 64^{\frac{1}{2}} = 8.$
$x = 5, y = (100 - 25)^{\frac{1}{2}} = 75^{\frac{1}{2}} = 8.660254$;
$x = 6, y = (120 - 36)^{\frac{1}{2}} = 84^{\frac{1}{2}} = 9.1651514$;
$x = 7, y = (140 - 49)^{\frac{1}{2}} = 91^{\frac{1}{2}} = 9.539392$;
$x = 8, y = (160 - 64)^{\frac{1}{2}} = 96^{\frac{1}{2}} = 9.797959$;
$x = 9, y = (180 - 81)^{\frac{1}{2}} = 99^{\frac{1}{2}} = 9.9493744$;
$x = 10, y = (200 - 100)^{\frac{1}{2}} = 100^{\frac{1}{2}} = 10.$

From these numbers, ellipses may be constructed, of any length and breadth, by multiplying them by the ratio of the axis $\frac{1}{4}, \frac{1}{2}, \frac{3}{4}, \frac{1}{3}, \frac{2}{3}$, supposing the breadth to be $\frac{1}{4}, \frac{1}{2}, \frac{3}{4}, \frac{1}{3}, \frac{2}{3}$ of the length.

A kind of oval, as it is called, which may easily be described through points, is the following:

Figure 14, No. 1, describe a semicircle, A P C, on the diameter A C, for the length: draw A D perpendicular and equal to A C; take any point, B, in A C; join B D; draw B p parallel to A D, cutting the circle in p; draw $p\ m$ perpendicular to B p, cutting B D at m; make A C, No. 2, equal to A C, No. 1; and every A P in No. 2, equal to every A B in No. 1; also every P M in No. 2, equal to the corresponding $p\ m$ in No. 1: through all the points, M, draw a curve.

This figure is of the form of a *pear*, and not what may be denominated *an oval*.

OVICULUM, in ancient architecture, a little ovum, or egg.

OVOLO, (from the Latin *ovum*, an egg) a convex moulding, of which the lower extremity recedes from a perpendicular or vertical line drawn from the upper. *See* MOULDINGS.

OUNCE, a small weight, the sixteenth part of a pound avoirdupois, and the twelfth part of a pound Troy.

OUTER DOORS, those which are common to both the exterior and interior sides of a building, made to prevent entrance at the pleasure of the occupier.

OUTFALL, or OUTLET, the exit or termination of a drain, &c., where it discharges its contents.

OUTLINE, the contour or boundary of an object.

OUT OF WINDING, a term used by artificers to signify that the surface of a body is that of a plane; or, when two straight edges are in the same plane, they are said to be out of winding.

OUT-TO-OUT, an expression used when a dimension is taken to the utmost bounds of a body or figure.

OUTWARD ANGLE, the same as salient angle.

OXYGON, (Greek, οξος, *sharp*, and γωνία, *an angle*), an acute-angled triangle.

P.

PACE, two and a half feet. The geometrical pace is five feet, and 60,000 such paces make one degree of the equator.

PACE, a raised platform, such as the dais at the upper end of the old halls, &c.

PADDLE, (from the Welsh, *pattal*) a small sluice, similar to those by which locks are filled or emptied.

PADDLE HOLES, the crooked arches through which the water passes from the upper pond of a canal into the lock, to fill it; or through which it is let out into the lower pond, on the entrance and exit of vessels. They are sometimes called CLOUGH ARCHES.

PADDLE WEIRS. *See* LOCK WEIRS.

PADDOCK, or PADDOCK COURSE (from the Saxon *pado*, or Dutch *padde*) a piece of ground generally taken out of a park, ordinarily a mile long, and a quarter of a mile broad, encompassed with pales or a wall, for the exhibiting of races with greyhounds, for wagers, plates, or the like.

At one end of the paddock was a little house, where the dogs were to be entered, and whence they were slipped; near which were pens to enclose two or three deer for the sport.

The deer, when turned loose, ran along by the pale; and the spectators were placed on the other side.

Along the course were several posts; viz., the lawpost, 160 yards from the dog-house and pens; the-quarter-of-a-mile post; half-mile post; and pinching post; beside the ditch, a place made to receive the deer, and preserve them from farther pursuit. Near the ditch were the judges, or triers.

PÆSTUM, a town of Italy, about sixty miles distant from Naples, remarkable for the remains of a large and very beautiful temple, dedicated to Neptune, and of the Doric order. Remains of other temples, an amphitheatre and the city wall, are also to be seen here.

PAGOD, or PAGODA, a name probably Indian, which the Portuguese have given to all the temples of the Indians, and all the idolaters of the East.

These pagods, or pagodas, are mostly square; they are stone buildings, which are not very lofty, and are crowned with a cupola. Within they are very dark; for they have no windows, and only receive their light through the entrance. The image of the idol stands in the deepest and darkest recess of the temple; it is of a monstrous shape, and of uncouth dimensions, having many arms and hands. Some of these idols have eight, and others sixteen arms; with a human body, and the head of a dog, with drawn bows and instruments of war in their hands. Some of them are black, others of a yellowish hue. In some pagodas there are no images, but only a single black polished stone, lying upon a round altar, covered with flowers and sandal-wood, which were strewed upon it. Greater veneration is manifested for these stones than for the idols themselves. Their worship of these divinities consists in throwing themselves upon the ground, and making their salam, or salutation, with their hands, and ejaculating their prayers in silence, in that posture. The offerings which they are accustomed to present to their gods, consist of flowers, rice, pieces of silk and cotton, and sometimes gold and silver. Everything is laid before the idols, and is taken care of by the Bramins, who profit the most by it. They guard the pagodas both by day and night. The pagodas of China are lofty towers, which sometimes rise to the height of nine stories, of more than 20 feet each. *See* CHINESE ARCHITECTURE.

In order to give such an idea of these buildings as may enable the reader to judge with respect to the early state of the arts in India, we shall briefly describe two, of which we have the most accurate accounts. The entry to the pagoda of Chillambrum, near Porto Novo, on the Coromandel coast, held in high veneration on account of its antiquity, is by a stately gate under a pyramid, 122 feet in height, built with large stones above forty feet long, and more than five feet square, and all covered with plates of copper, adorned with an immense variety of figures, neatly executed. The whole structure extends 1332 feet in one direction, and 936 in another. Some of the ornamental parts are finished with an elegance entitled to the admiration of the most ingenious artists. The pagoda of Seringham, superior in sanctity to that of Chillambrum, surpasses it as much in grandeur; and, fortunately, we can convey a more perfect idea of it by adopting the words of an elegant and accurate historian. This pagoda is situated about a mile from the western extremity of the island of Seringham, formed by the division of the great river Caveri, into two channels. "It is composed of seven square enclosures, one within the other, the walls of which are 25 feet high, and four thick. The enclosures are 350 feet distant from one another, and each has four large gates with a high tower; which are placed one in the middle of each side of the enclosure, and opposite to the four cardinal points. The outward wall is near four miles in circumference, and its gateway to the south is ornamented with pillars, several of which are single stones 33 feet long, and nearly five in diameter: and those wh form the roof are still larger; in the inmost inclosures are the chapels. About half a mile to the east of Seringham, and nearer to the Caveri than the Coleroon, is another large pagoda, called Jembikisma; but this has only one inclosure. The extreme veneration in which Seringham is held, arises from a belief that it contains that identical image of the god Wistchnu, which used to be worshipped by the god Brahma. Pilgrims from all parts of the Peninsula come here to obtain absolution, and none come without an offering of money; and a large part of the revenue of the island is allotted for the maintenance of the Brahmins who inhabit the pagoda; and these, with their families, formerly composed a multitude not less than forty thousand souls maintained without labour, by the liberality of superstition. Here, as in all the other great pagodas of India, the Brahmins live in a subordination which knows no resistance, and slumber in a voluptuousness which knows no wants."

The pagodas of the Chinese and Siamese are exceedingly magnificent. *See* Indian Architecture.

PAINTERS, *House*. Painter's work is measured by the square yard in the same manner as wainscoting, the mouldings being measured by a thread. The sashes of windows are paid for by the piece; and it is usual to allow double measure for carved mouldings, &c.

PAINTING, the art of imitating the appearances of natural objects, by means of artificial colours spread over a surface; the colouring substances being used either dry, as in crayon painting; or compounded with some fluid vehicle, as oil, water, or solutions of different gums and resins in oil or spirits, &c.

The theory and practice of this ingenious art are divided by its professors into five principal parts; viz., *invention*, or the power of conceiving the materials proper to be introduced into a picture; *composition*, that of arranging those materials; *design*, that of delineating them; *chiaro-scuro*, or the arrangement and management of the lights and shades, and of light and dark colours; and *colouring*, whose name sufficiently designates its end.

Painting, *Economical*, that application of artificial colours, compounded either with oils or water, which is employed in preserving or embellishing houses, ships, furniture, &c. &c. The term economical, applies more immediately to the power which oil and varnishes possess, of preventing the action of the atmosphere upon wood, iron, and stucco, by interposing an artificial surface; but it is here intended to use the term more generally; in allusion to the decorative part, as applied to buildings; as well as to its more essential ones; and as it is employed by the architect, throughout every part of his work, both externally and internally.

In every branch of painting in oil, as applicable either to churches, theatres, houses, or any other public or private buildings, or edifices, the general process will be found very similar; or with such variations, as will easily be suggested by the judicious artist or workman.

The first coatings, or layers, if on wood or iron, ought always to be of ceruse or white lead, the very best that can be obtained; which should have been previously ground very fine in nut or linseed oil, either over a stove with a muller, or, as that mode is too tedious for large quantities, it may be passed through a mill. If used on wood, as shutters, doors, or wainscoting made of fir or deal, it is highly requisite to destroy the effects of the knots; which are generally so completely saturated with turpentine, as to render it, perhaps, one of the most difficult processes in the business to conquer. The best mode in common cases, is to pass over the knots with ceruse ground in water; bound by a size made of parchment, or some other animal substance. When that is dry, paint the knots with white lead ground in oil, to which add some powerful siccative, or dryer; as red lead, or litharge of lead, about one-fourth part of the latter. These preparations should be done carefully, and laid very smoothly with the grain of the wood. When the last coat is dry, which will be in twelve or twenty-four hours, then smooth it with pumice-stone, or give the work the first coat of paint, prepared, or diluted with nut or linseed oil. When that is dry, all the nail-holes or other irregularities on the surface should be carefully stopped with a composition of oil and Spanish white, a whiting commonly known by the name of putty: but which is frequently made and sold in the shops of very inferior articles. When that is done, let the work be painted over again, with the same mixture of white lead and oil, somewhat diluted with the essence of oil of turpentine, which process should be repeated not less than three or four times, if the work is intended to be left, when finished, of a plain white or stone colour; if of the latter, the last coat should have a small quantity of ivory or lamp-black added to reduce its whiteness a little; and this is also of service in preserving the colour from changing: a circumstance which the oil is apt to produce. But if the work is to be finished of any other colour, either gray, green, &c., it will be requisite to provide for such colour, after the third operation, particularly if it is to be finished flat, or as the painters style it, dead white, gray, fawn, &c. In order to finish the work flatted or dead, (which is a mode much to be preferred for all superior works; not only for its appearance, but also for preserving the colour and purity of the tint) after the work, supposing it to be wood, has been painted four times in oil-colour, as directed in general cases, one coat of the flatted colour, or colour mixed up with a considerable quantity of turpentine, will be found sufficient; although in large surfaces it will frequently be requisite to give two coats of the flatting colour to make it quite complete. Indeed, on stucco it will be almost a general rule; but as that will be hereafter treated on, we shall at present say no more concerning it.

It must be observed, that in all the foregoing operations, it will be requisite to add some sort of siccative. A very general and useful one is made by grinding in linseed, or, perhaps, prepared oils, boiled, are better, about two parts of the best white copperas, which must be well dried, with one part of litharge of lead; the quantity to be added will much depend on the dryness or humidity of the atmosphere at the time of painting, as well as the local situation of the building.

It is highly proper here to observe, that there is a kind of copperas made in England, and said to be used for some purposes in medicine, that not only does not assist the operation of drying-in the colours, but absolutely prevents those colours drying, which would otherwise have done so by themselves. The best dryer for all fine whites, and other delicate tints, is saccharum saturni, or sugar of lead, ground in nut-oil; but which being very active, a small quantity, about the size of a walnut, will be sufficient for twenty pounds of colour, where the basis is ceruse. It will be always worthy to be observed, that the greatest care should be taken to keep all the utensils, brushes, &c., particularly clean, or the colours will soon become very foul, so as to destroy the surface of the work. If this should so happen, the colour should be passed through a fine sieve, or canvass; and the surface of the work be carefully rubbed down with sand-paper, or pumice-stone; and the latter should be prepared by being ground in water, if the paint be tender, or recently laid on.

The above may suffice as to painting on wood, either on outside or inside works; the former being seldom finished otherwise than in oil, four or five coats are generally quite sufficient.

We shall now proceed to note what is requisite for the painting of new walls, or stucco, not painted before and prepared for oil-colours.

It does not appear that any painting in oil can be done to any good or serviceable effect in stucco, unless not merely the surface appear dry, but that the walls have been erected a sufficient time to permit the mass of brick-work to have acquired a sufficient degree of dryness: when stucco is on battened work, it may be painted over much sooner than when prepared as brick. Indeed, the greatest part of the mystery of painting stucco, so as to stand or wear well, certainly consists in attending to these observations; for whoever has observed the expansive power of water, not only in congelation, but also in evaporation, must be well aware that when it meets with any foreign body obstructing its escape, as oil-paintings for instance, it immediately resists it; forming a number of vesicles, or particles, containing an acrid lime-water, which forces off the layers of plaster, and frequently causes large defective patches extremely difficult to get the better of.

Perhaps, in general cases, where persons are building on their own estates, or for themselves, two or three years are not too long to suffer the stucco to remain unpainted; though frequently, in speculative works, as many weeks are scarcely allowed. Indeed, there are some nostrums set forth in favour of which it is stated, in spite of all the natural properties of bodies, that stucco may, after having been washed over with these liquids, be painted immediately with oil-colours. It is true there may be instances, and in many experiments some will be found, that appear to counteract the general laws of nature; but, on following them up to their causes it will be found otherwise.

Supposing the foregoing precautions to have been attended to, there can be no better mode adopted for priming or laying on the first coat on stucco, than by linseed or nut-oil, boiled with dyers, as before mentioned, with a proper brush; taking care, in all cases, not to lay on too much, so as to render the surface rough and irregular, and not more than the stucco will absorb. It should then be covered with three or four coats of ceruse, or white lead, prepared as described for painting on wainscoting; letting each coat have sufficient time to dry hard. If time will permit, two or three days between each layer will not be too long.

If the stucco be intended to be finished of any given tint, as gray, light green, apricot, &c., it will then be proper, about the third coat of painting, to prepare the ground for such tint by a slight advance towards it.

Gray is made with ceruse, Prussian blue, ivory black, and lake; sage green, pea, and sea greens, with white, Prussian blue, and fine yellows; apricot and peach, with lake, white, and Chinese vermilion; fine yellow fawn colour, with burnt terra Sienna, or umber, and white; olive greens, with fine Prussian blue and Oxfordshire ochre.

Painting in distemper, or water-colours mixed with size, stucco, or plaster, which is intended to be painted in oil when finished, but not being sufficiently dry to receive the oil, may have a coating in water-colours, of any given tint required, in order to give a more finished appearance to that part of the building. *See* DISTEMPER FRESCO.

Straw colours may be made with French white, ceruse, and masticot, or Dutch pink. Grays, fine, with some whites, and refiners' verditer. An inferior gray may be made with blue-black, or bone-black, and indigo. Pea-greens, with French green, Olympian green, &c. Fawn colour with burnt terra de Sienna, or burnt umber and white: and so of any intermediate tint. The colours should all be ground very fine, and incorporated with white, and a size made of parchment, or some similar substance; isinglass being too expensive for common works.

It will not require less than two coats of any of the foregoing colours in order to cover the plaster, and bear out with a uniform appearance. It must be recollected, that when the stucco is sufficiently dry, and it is desirable to have it painted in oil, the whole of the water-colour ought to be removed; which may be easily done by washing; and when quite dry, proceed with it after the directions given in oil-painting of stucco.

When old plastering has become discoloured by stains, and it is desired to have it painted in distemper; it is then advisable to give the old plaster, when properly cleaned off and prepared, one coat at least of white lead ground in oil, and used with spirits of turpentine, which will generally fix all old stains; and when quite dry, will take the water-colours very kindly.

The above processes will also apply to old wainscoting, in cases where temporary painting is only required; but cannot be recommended for durability.

PADDLE WEIRS, see LOCK WEIRS.

PALACE, (from the Latin *palatium*), a word implying, in its stricter sense, a royal abode, but occasionally applied t the residences of other persons; the accompanying epithe indicating the quality of the inhabitants, as imperial palace ducal palace, &c. In Italy the term Palazzo, taken by itself is used for any large mansion or nobleman's house; an palaces of this class constitute, after churches, the principa architectural features of Genoa, Florence, Rome, Milan Vicenza, Venice, and other cities, to which they impart a air of grandeur which is wanting in the street architectur of this country; for in spite of all other defects, and the ba taste they frequently display, they generally possess th redeeming quality of dignity. Our own metropolis, on th contrary, possesses scarcely half a dozen private mansion that have any pretensions to external nobleness of style. I fact, the most palazzo-like buildings we have are our moder club-houses. Neither are any of our royal palaces, with th single exception of Windsor, stamped with architectur magnificence; both in extent and style they are surpassed b several of the country seats of our nobility. Througho the whole of Europe very few royal palaces, whatever may b their magnitude, are at all distinguished by superior arch tectural taste. In the French capital it is only the easte façade of the Louvre, the river-front, and the inner-cou which can lay claim to beauty or richness, the Tuileri being only a mass of quaint grotesqueness. The Vatican Rome is merely a huge irregular pile; and Versailles and t Escurial, notwithstanding the millions they cost, are both mon ments of exceedingly bad taste. Though far from beautif the royal palace at Madrid, begun in 1737, from the desig of Giambattista Sachetti, an Italian architect, is a stately a regular pile, it being 470 feet square, and 100 in height, b the effect such a mass would otherwise produce is grea impaired by the number of mezzanines. The same rema applies to the celebrated palace erected by the king of Napl about the middle of the last century, at Caserta, and of wh Vanvitelli was the architect. This building is certai characterized by magnitude, for it extends 731 feet from e to west, and 569 from north to south; yet of either grand of conception, or majesty of style, there is very little, c tainly not enough, to reconcile us to the prodigal execution so very indifferent a design. The royal palace at Stockh is a stately edifice in the Italian style, although the origi design, by Count Tessin, was considerably curtailed.

original imperial winter palace at St. Petersburgh was a vast pile erected by the Italian architect Rastrelli, in the reign of the empress Elizabeth, of most imposing aspect towards the quay of the Neva, but exceedingly heavy and grotesque as to style.

Enormous as have been the sums expended upon many of these edifices, every one of them falls very short of the ideal of a royal palace, in which, if anywhere, not only all the luxury and pomp of architecture, but a certain colossal dignity of aspect, should present itself. This can never be accomplished where stories above stories are allowed to display themselves externally. That is but a vulgar species of architectural grandeur which is produced by a numerical multiplication of little parts and features. All the rooms required for the accomodation of an extensive household should be turned towards inner courts, and the whole exterior, having only a single range of lofty windows above the ground-floor, should be left for the unrestrained display of architecture, and sculpture upon a noble scale, without any intermixture of littlenesses. By such a disposition, too, convenience would perhaps be found far better consulted than at present, because, while all the apartments for official and state receptions and court entertainments could be connected together, the whole of the vast number of subordinate rooms required in such a habitation would be concentrated within the general plan, and at the same time might be kept entirely apart, by means of galleries between the outer and inner range, communicating at intervals with lesser vestibules and staircases attached to the suites of lesser rooms and private apartments of every description.

PALÆSTRA, or Palestra, (from the Greek παλαιςρα) among the ancient Greeks, a public building, where the youth exercised themselves in wrestling, running, playing at quoits, &c.

Some say the palestræ consisted of a college and an academy; the one for exercises of the mind, the other for those of the body. But most authors rather take the palestra to be a xystus, or mere academy for bodily exercises, according to the etymology of the word, which comes from παλη, *wrestling*, one of the chief exercises among the ancients.

The length of the palæstra was marked out by stadia, each equal to 125 geometrical paces; and hence the name *studium* was given to the arena whereon they ran.

PALATINE BRIDGE, a bridge of ancient Rome, now called St. Mary's bridge, which crosses over from the present church of St. Mary the Egyptian, at the lower end of the Forum Boarium to the Via Transtiberina. This bridge is supposed to be that which Livy speaks of (*Decad.* 4. lib. 10.) built by M. Fulvius, washed down by the Tiber, and afterwards rebuilt by the censors Scipio Africanus and L. Mummius. Another indundation having damaged it, Pope Gregory XIII. repaired it, partly upon the old piles, in the year 1575. But another inundation sweeping away some of it in 1598, it has never since been repaired, so as to be serviceable.

PALE, (from the Latin *palus*) a little pointed stake, or piece of wood, used in making enclosures, separations, &c.

PALES, or Piles, in carpentry, rows of stakes driven deep in the ground to make wooden bridges over rivers, and to erect other edifices on.

Du-Cange derives the word from the Latin name *palla, a hanging* or *piece of tapestry*: the ancients gave the name *pales* to the hangings or linings of walls: thus a chamber was said to be *paled* with cloth of gold, with silk, &c., when covered with bands or stuffs of two colours. Hence also the original of the word pale, *a stake*, &c.

Tertullian observes, that the Romans planted pales to serve as boundaries of inheritances; and that they consecrated them to the god Terminus, under the name of *Pali Terminales.*

Ovid tells us, they were crowned and adorned with flowers, festoons, &c., and that the god was worshipped before these pales. *See* Terminalia.

Pales for building, serve to support the beams which are laid across them, from one row to another; and are strongly bound together with cross pieces. *See* Piles.

PALETTE (French) among painters, a little oval table, or piece of wood, or ivory, very thin and smooth; on and round which the painters place the several colours they have occasion for, to be ready for the pencil.

The middle serves to mix the colours on, and to make the teints required in the work. It has no handle, but a hole at one end, to put the thumb through to hold it.

PALING, in agriculture, a kind of fence-work for fruit-trees, &c., planted in exposed places.

It consists of three small posts driven into the ground, at a foot and half distance, with cross bars nailed to each other, near the top.

In fixing the pales in form of a triangle, room is to be left for the tree to play and bow by the high winds, without galling. The trees are to be bound to a stake for a year or two; after which fern or straw may be stuffed in between the tree and uppermost rails, to keep it upright.

If the place be open to deer, rabbits, or the like, a post is to be nailed to the bar between every two pales.

Paling Fence, that sort of fence which is constructed with pales.

PALISADE (French) or Palisado (Italian) in fortification, an enclosure of stakes or piles driven into the ground, each six or seven inches square, and nine or ten feet long: three of which are hid under ground. They are fixed about six inches asunder, and braced together by pieces nailed across them near the tops, and secured by thick posts at the distance of every four or five yards.

Palisades are placed in the covert-way, at three feet from, and parallel to, the parapet or ridge of the glacis, to secure it from being surprised. They are also used to fortify the avenues of open forts, gorges, half-moons, the bottoms of ditches, the parapets or covered ways; and, in general, all posts liable to surprise, and to which the access is easy.

Palisades are usually planted perpendicularly; though some make an angle inclining towards the ground next the enemy, that the ropes cast over them, to tear them up, may slip.

Palisades, *Turning*, are an invention of M. Coehorn, in order to preserve the palisades of the parapet of the covert-way from the besiegers' shot.

These palisades are so arranged that as many of them as stand in the length of a rod, or in about ten feet, turn up and down like traps; so as not to be in sight of the enemy till they just bring on their attack; and yet are always ready to do the proper service of palisades.

PALLADIAN ARCHITECTURE. A style of Italian Architecture introduced by Palladio, for an account of which see Italian Architecture, and the following article.

PALLADIO, ANDREA, in biography, a celebrated Italian architect, born at Vicenza in 1518. He obtained instructions from the poet Trissino, who discovering in him a genius for sculpture and the arts connected with it, taught him the elements of the mathematics, and explained to him the works of Vitruvius. He soon obtained distinction as an architect, and having an opportunity of accompanying his patron to Rome, he employed all his faculties in examining the remains of ancient edifices in that capital, and formed his taste upon them. On his return, many works of importance were committed to him, which he managed with great skill, and obtained for himself a high reputation. He was now sent for to Venice, where he built the palace Foscari in the style of pure antiquity. Several other Italian cities were afterwards decorated with magnificent edifices, public and private, of his construction, and he was invited to the court of Emanuel Philibert, Duke of Savoy, who received him with distinguished honours. To Palladio is chiefly attributed the classic taste which reigns in so many of the buildings of Italy. His master-piece is reckoned the Olympic theatre at Vicenza, in imitation of that of Marcellus at Rome. He died in that city in 1580, having greatly improved the art, not only by his edifices, but by his writings, which are standard performances. Of these the following account is given: his *Treatise on Architecture*, in four books, was first published at Venice in 1570, folio, and has several times been reprinted. A magnificent edition, in three volumes, folio, was published at London in 1715, in Italian, French, and English. Another, equally splendid, has since been published at Venice, in four volumes, folio, with the addition of his inedited buildings. Lord Burlington published in London, in 1730, a volume entitled, *Idisegni delle Terme Antiche di Andrea Palladio*. He composed a small work, intitled *Le Antichità di Roma*, not printed till after his death. He illustrated Cæsar's *Commentaries*, by annexing to Badelli's translation of that work, a preface on the military system of the Romans, with copper-plates, designed, for the most part, by his two sons, Leonida and Orazio, who both died soon after. Palladio was modest in regard to his own merit, but he was a friend to all men of talents; his memory is highly honoured by the votaries of the fine arts; and the simplicity and purity of his taste have given him the appellation of the Raphaël of architects.

PALLADIUM (from the Greek Παλλας, *the goddess of war*) in antiquity, a statue of the goddess Pallas, or Minerva, three cubits high, holding a pike in the right hand, and a distaff and spindle in the left, preserved in Troy, in the temple of Minerva, on which the fate of that city is said to have depended.

The tradition is, that in building a citadel, in honour of Pallas, and a temple in the most elevated part of it, the palladium dropped from heaven, and marked out the place which the goddess was pleased to possess. After this, Apollo gave an oracle, importing that Troy should never be taken while the palladium was found within its walls: which occasioned Diomedes and Ulysses, during the Trojan war, to undertake the stealing of it. For this purpose having entered the citadel by night, or by means of secret intelligence, they stole away this valuable pledge of the security of the Trojans, and conveyed it into their camp; where they had scarcely arrived, when the goddess gave testimonies of her wrath

It is said, there was, anciently, a statue of Pallas preserved at Rome, in the temple of Vesta; which some pretended to be the true palladium of Troy, brought into Italy by Æneas: it was kept among the sacred things of the temple, and only known to the priests and vestals. This statue was esteemed the destiny of Rome; and there were several others made perfectly like it, to secure it from being stolen. There was also a palladium in the citadel of Athens, placed there by Nicias.

PALLIER, or Paillier (French) in building, a landing-place in a stair-case, which being broader than the rest of the stairs, serves to rest upon. The term, which is pure French, is not much used by English builders. On large staircases, where there are sometimes several pillars in a range or line, the palliers ought each to have, at least, the width of two steps. Vitruvius calls the palliers on landing-places of the theatres *diazomata*.

PALLIFICATION, or Piling, in architecture, the act of piling the ground-work, or strengthening it with piles, or timber driven into the ground; this plan is adopted upon moist or marshy soils, where an edifice is intended to be erected.

PALM, a measure of length among the Italians, but varying in value in different localities. The palm of Genoa measures nine inches, nine lines, that of Naples eight inches seven lines, that of Palermo eight inches five lines, and the modern Roman palm eight inches three and a half lines.

PALMYRA, *Ruins of*, or Palmyrene Ruins, the ruins of a celebrated city of this name, situate in a desert of Syria, in the pachalic of Damascus, about 48 leagues from Aleppo, and as far from Damascus. This city, under the name of Tadmor, appears to have been originally built by Solomon (1 Kings, ix. 18. 2 Chron. viii. 4.) Josephus assures us, that this was the same city which the Greeks and Romans afterwards called Palmyra; and it is still called Tadmor by the Arabs of the country. But many circumstances besides the style of the buildings, render it probable that the present ruins are not those of the city built by Solomon, though neither history nor tradition mention the building of any other.

With respect to the ruins, they appear to be of two distinct periods; the oldest are so far decayed as not to admit of mensuration, and seem to have been reduced to that state by the hand of time; the others appear to have been broken into fragments by violence. Of the inscriptions, none are earlier than the birth of Christ, nor are any later than the destruction of the city by Aurelian, except one, which mentions Dioclesian. It is scarcely less difficult to account for the situation of this city than for its magnificence; the most probable conjecture is, that as soon as the springs of Palmyra were discovered by those who first traversed the desert in which it is situated, a settlement was made there for the purpose of carrying on the trade to India, and preserving an intercourse between the Mediterranean and the Red Sea. This trade, which flourished long before the Christian æra, accounts not only for its situation, but also for its wealth. As it lay between Egypt, Persia, and Greece, it was natural to expect, that traces of the manners and sciences of those nations should be discovered among the Palmyrenes; who accordingly appear to have imitated the Egyptians in their funeral rites, the Persians in their luxury, and the Greeks in their buildings; and therefore the buildings, which now lie in ruins, were probably neither the works of Solomon, nor of the Seleucidæ, nor, few excepted, by the Roman emperors, but of the Palmyrenes themselves.

Palmyra was formerly encompassed by palms and fig trees, and covered an area, according to the Arabs, of near ten miles in circumference; and might probably hav[e] been reduced to its present confined and ruined state b[y] quantities of sand, driven over it by whirlwinds. Th[e] walls of the city are flanked with square towers; and it i[s] probable, from their general direction, that they include the great temple, and are three miles in circumference. Bu[t] of all the monuments of art and magnificence in this cit[y] the most considerable is the temple of the sun. The who[le] space containing its ruins, is a square of 220 yards, encon[-] passed with a stately wall, and adorned with pilasters with[in] and without, to the number of sixty-two on a side. With[in] the court are the remains of two rows of very noble marb[le] pillars, 37 feet high; the temple was encompassed w[ith] another row of pillars 50 feet high ; but the temple itself was only 33 yards in length, and 13 or 14 in breadth. This is now converted into a mosque, and ornamented after the Turkish manner. North of this place is an obelisk, consisting of seven large stones, besides its capital and the wreathed work about it, about 50 feet high, and, just above the pedestal, 12 in circumference. Upon this there was, probably, a statue, which the Turks have destroyed. At a small distance there are two others, and a fragment of a third, which gives reason for concluding that they were once a continued row. There is also a piazza 40 feet broad, and more than half a mile in length, enclosed with two rows of marble pillars, 26 feet high, and 8 or 9 feet in compass ; and the number of these, it is computed, could not have been less than 560. Near this piazza appear the ruins of a stately building, supposed to have been a banqueting house, elegantly finished with the best sort of marble. In the west side of the piazza there are several apertures for gates into the court of the palace, each adorned with four porphyry pillars, 30 feet long and 9 in circumference. There are several other marble pillars differently arranged, on the pedestals of which there appear to have been inscriptions both in the Greek and Palmyrene languages, which are now altogether illegible. Among these ruins there are also many sepulchres, which are square towers, four or five stories high, and varying in size and splendour. We are indebted for an account of these very magnificent remains of antiquity, partly to some English merchants who visited them in 1678 and 1691, (*Phil. Trans.* No. 217, 218, or Lowthorp's *Abr.* vol. iii.) but chiefly to Mr. Bouverie and Mr. Dawkins, accompanied by Mr. R. Wood, who travelled thither in 1751. The result of their observation was published in 1753, in the form of an Atlas, containing 57 copper-plates, admirably executed. Since this publication, it is universally acknowledged that antiquity has left nothing, either in Greece or Italy, to be compared with the magnificence of the ruins of Palmyra.

PAMPRE, a wreath composed of the leaves and fruit of the vine, employed to decorate the spiral grooves of twisted columns.

PANCARPI, garlands or festoons of flowers, fruit, &c.

PANEL, or Pannel (from the Latin *panellum*, a small pane), in joinery, a tympan, or square piece of wainscot, sometimes carved, framed, or grooved in a large piece, between two mounters or upright pieces, and two traverses or cross pieces. Hence also panels or panes of glass, are compartments, or pieces of glass of various forms ; square, hexagonal, &c.

Panel, in masonry, one of the faces of a hewn stone.

PANNIER, the same as Corbel ; which see.

PANORAMA, a picture exhibiting a succession of objects upon a spherical or cylindrical surface, the rays of light being supposed to pass from all points of external objects, through the surface, to the eye in the centre of the sphere, or axis of the cylinder.

This ingenious pictorial contrivance was first devised by an English artist, Robert Barker, about the year 1794 ; and is not so much a new mode of painting—the process itself being similar to scene-painting, or in distemper—as a novel application of it. Contrary to the diorama [*See* Diorama], the panorama forms the surface of a hollow cylinder, or rotunda (whence it is frequently called, in German, *Rundgemalde*, or *Rundbild*, cyclorama), in the centre of which is a detached circular platform for the spectators, covered over head to conceal the skylight, and thereby increase the illusion, and give greater effect to the painting itself. This latter is not painted on the walls, but upon canvass, like the scenes of a theatre, and afterwards fixed up, in order that the views may be changed, and a fresh one may be in progress while another is open for exhibition. Yet, although there is nothing whatever particular in regard to the execution or process of such pictures, they are attended with difficulties which can be mastered only by practice and experience.

The first of these arises from the circumstance, that the artist cannot either concentrate his light, or adapt the direction of it arbitrarily, as best suits his purpose ; but while portions of his view will be entirely in sunshine, the opposite one will be almost a mass of shadow ; the second is the difficulty of representing, on a curved surface, the straight horizontal lines of buildings ; the third and greatest of all is, that there can be no single fixed point of sight, since the eye traverses around the whole circle of the horizon. Hence it may be supposed, that many parts of such a picture would appear, if not quite distorted, more or less out of perspective. Yet such is not the case, no doubt partly because the eye accommodates itself to certain principal points fixed upon by the artist as centres of vision, and on account of the optical fascination attending the whole. The subjects generally chosen are views of cities, or interesting sites, whose entire locality and buildings may thus be vividly placed before the eye in a manner no less instructive than it is interesting.

Panoramic Projection is the method of forming a panorama from the geometrical consideration of the properties of vision.

In the following principles of the panorama, the surface on which objects are supposed to be represented is that of a cylinder ; though a sphere may be considered still more perfect, as its surface is everywhere equally distant from the eye ; but a cylindric surface is more convenient for the purpose of delineation ; and if the objects are not very distant from the intersection of a plane passing through the eye perpendicular to the axis, the distortion will not be perceptible. We premise the following definitions :

1. The cylindric surface on which objects are to be represented, is called, also, *the panoramic surface ;* and the picture formed is called *a panoramic view*, or *panoramic picture*.

2. *The point of sight* is the place where the organ of vision is placed, in order to receive the impression of the images of the objects on the panoramic picture.

3. *An original object* is any object in nature, or an object which may be supposed to exist, in a given position and distance, as a point, line, or solid.

4. *An original plane* is the plane on which original objects are supposed to be placed.

5. The point, where an indefinite original line cuts the picture, is called *the intersection of that original line.*

6. The line on the picture where an original plane meets or intersects it, is called *the intersection of that original plane.*

7. A line drawn through the point of sight parallel to an original line, is called *the parallel of that original line.*

8. A plane passing through the point of sight parallel to any original plane, is called *the parallel plane.*

9. A *surface of rays* is that which proceeds from an original line, or from any line of the original object, by rays from all points of that line terminating in the eye. If the line in the original object be straight, the surface of rays is called *a plane of rays*, *optic plane*, or *visual plane.*

10. When the rays proceed from one or more surfaces of an original object, the whole is called *a pyramid of rays*, or *optic pyramid ;* and if the base be circular, it is called *a cone of rays*, *visual cone*, or *optic cone.*

In every kind of projection from a given point, the projection of a straight line upon any surface is the intersection of a plane of rays with the surface from all points of the straight line to the given point. Therefore, the panoramic projection of a straight line is the intersection of the cylindric surface and a plane. If a right cylinder be cut by a plane perpendicular to its axis, the section is a circle; if cut parallel to the axis, the section is a rectangle; and if cut obliquely to the axis, the section is an ellipsis. If the surface of the cylinder be extended upon a plane with the sections of the cylindric surface, and a plane cut in each of the positions here stated, the section made by the plane perpendicular to the axis will be a straight line; and the section made by cutting it parallel to the axis will also be a straight line; but the section made by cutting it obliquely will be a curve of similar properties with that known to mathematicians by the name of *the figure of the lines;* therefore, the projection of every straight line in a plane passing through the eye perpendicular to the axis of the cylinder, will also be a straight line on the extended surface; and every straight line in a plane passing through the axis will also be a straight line on the extended surface, perpendicular to that formed by the plane passing through the eye perpendicular to the axis.

The panoramic projection of any straight line not in a plane passing through the eye perpendicular to the axis, nor in a plane passing through the axis, is in the curve of an ellipsis; for in this case the optic rays which cut the cylinder will neither be in a plane parallel to the axis, nor in a plane perpendicular to it.

The panoramic representation of any straight line in a plane perpendicular to the axis, but not passing through the eye, is in the curve of an ellipsis, and the optic plane will be at right angles to another plane passing through the axis at right angles to the original line.

In the panoramic representation of any series of parallel lines, the optic planes have a common intersection in a straight line passing through the eye, and the common intersection will be parallel to each of the original straight lines; therefore, the indefinite representations will pass through the extremities of the common intersection.

In the panoramic representation of any series of parallel lines in a plane perpendicular to the axis, but not passing through the eye, the common intersection of the optic planes is parallel to the plane on which the original lines are situated.

In the indefinite representations of any number of straight lines parallel to the axis, the visual planes will have a common intersection in the axis, and will divide the circumference of the cylinder into portions which have the same ratio to each other as the inclination of the visual planes.

If an original straight line parallel to the axis be divided into portions, the representations of the portions will have the same ratio to each other as the originals.

If in any original plane there be a series of straight lines parallel to each other, and also another series of straight lines parallel to each other, and at any given angle with the former series, the common intersections of the visual planes will make the same angle with each other, which any line of the one series makes with any one of the other series, and the common intersections will be in a plane parallel to the original plane; and, therefore, if the original plane be perpendicular to the axis, the common intersections of the visual planes will also be in a plane perpendicular to the axis. Hence the common intersections of visual planes from any two systems of straight lines, parallel to any two straight lines at a given angle with each other in a plane perpendicular to the axis, are also in a plane perpendicular to the axis, and make the same angle with each other which the two lines in the original plane make with each other.

11. The two points where the parallel of an original line inclined to the axis of the cylinder meets the panoramic surface, are called *the vanishing points of that original line.*

12. The intersection of the parallel of an original plane is called *the vanishing line of that plane.*

13. A straight line drawn from any point in the axis of the cylinder, at right angles to the same, to meet the panoramic surface, is called *the distance of the picture.*

14. *The centre of a plane parallel to the axis*, is the point where a straight line from the eye perpendicular to the plane meets it.

15. *The panoramic centre of a plane parallel to the axis*, is the point where a straight line drawn from the eye perpendicular to the plane, cuts the picture.

16. *The station point*, is the point where the axis intersects the original plane.

17. *The centre of an original line*, is the point where a straight line, drawn from the station point perpendicular to the original line, cuts the original line.

18. *The panoramic centre of an original line*, is the point where a straight line, drawn from the station point perpendicular to the original line, cuts the picture.

19. *The distance of an original plane parallel to the axis from the picture*, is the straight line drawn from the panoramic centre to the centre of the original plane.

20. *The distance of an original line from the picture*, is the straight line drawn from the panoramic centre to the centre of the original line.

21. *The distance of an original plane*, is the straight line drawn from the eye to the centre of the original plane.

22. *The distance of an original line*, is the straight line drawn from the station point to the centre of the line.

An original line parallel to the axis of the panorama ha[s] no vanishing points.

An original plane parallel to the axis of the panorama ha[s] two vanishing lines.

The vanishing line of a plane perpendicular to the axis o[f] the panorama, is a circle on the panoramic picture; but i[f] the panoramic surface be extended upon a plane, it becom[es] a straight line.

The vanishing lines of all planes inclined to the axis a[re] ellipses, and when extended upon a plane become sinic curves, which are also termed *panoramic curves*, as being t[he] only kind of curve which the cylindric picture produces wh[en] developed.

Problem I.—*Plate* I.—*Figure* 1.—*To describe the pan[o]ramic curve to given dimensions.*—Let A B be the length [of] the curve; bisect A D in C, draw C D perpendicular to A [B]; make C D equal to the deflection of the arc from the cho[rd] A B; from the point C, with the distance C D, describe t[he] quadrant D E; divide the arc D E into any number of eq[ual] parts, (say four) also divide either half, C B, into the sa[me] number (four) of equal parts; let *l*, *i*, *g*, be the points [of] division in the quadrantal arc; draw *l k*, *i h*, *g f*, perpen[di]cular to A B, cutting it at *k*, *h*, *f;* and let K, H, F, be the poi[nts] of division in C B; draw K L, H I, F G, perpendicular to A [B]; make K L, H I, F G, respectively equal to *k l*, *h i*, *f g;* c[on]struct perpendiculars upon C A, in the same manner; thro[ugh] all the points G, I, L, D, describe a curve, which will be t[he] ... of the panorama.

The curve A D B is that which would be found by cutt[ing] a semi-cylinder, whose circumference is A B, at an altit[ude] C D, distant on the surface from a plane perpendicular to [the] axis, at a quadrant distance from the point A or B in [the] extremity of the diameter of the plane perpendicular to [the] axis. Therefore the whole panoramic curve will be do[uble] the length of A B; the other part being a similar and e[qual]

Fig. 2. No. 1.

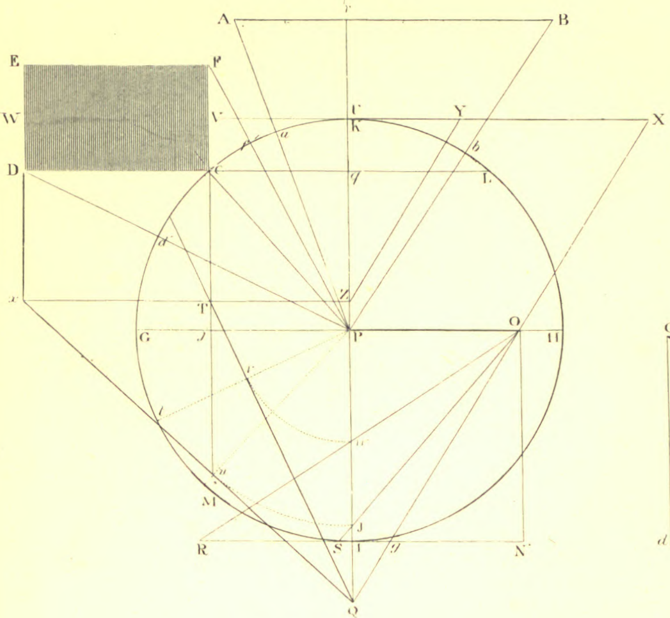


Fig. 2. No. 5.

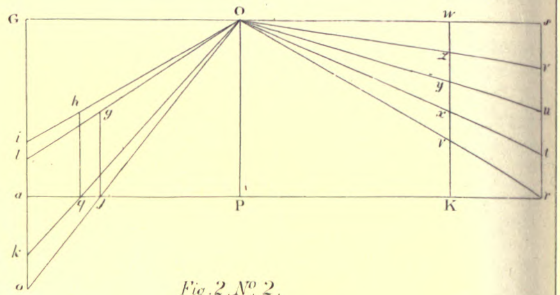


Fig. 2. No. 2.

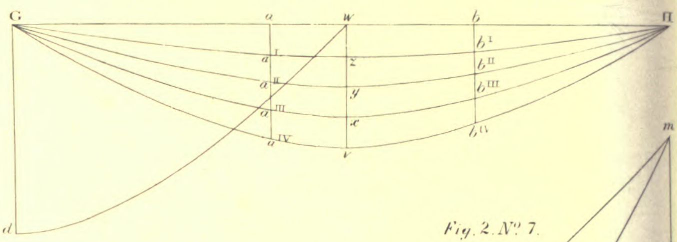


Fig. 2. No. 7.

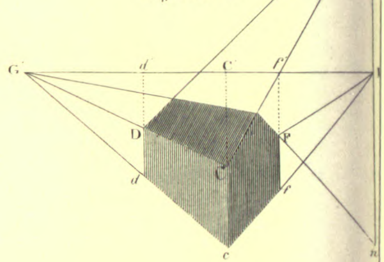


Fig. 1.

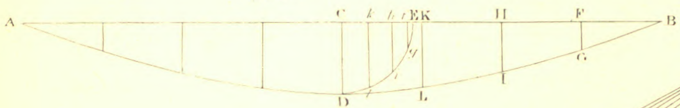


Fig. 3.

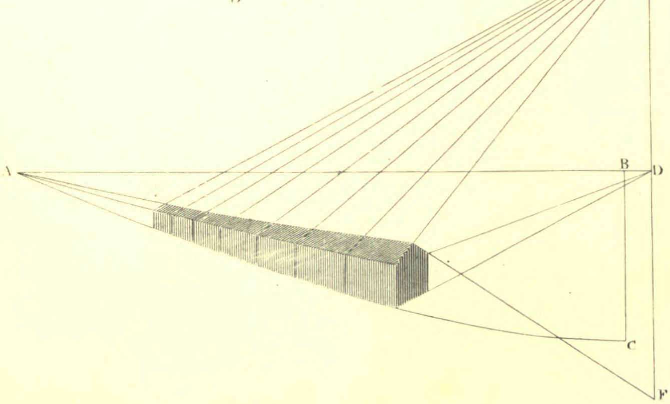


Fig. 2. No. 6.

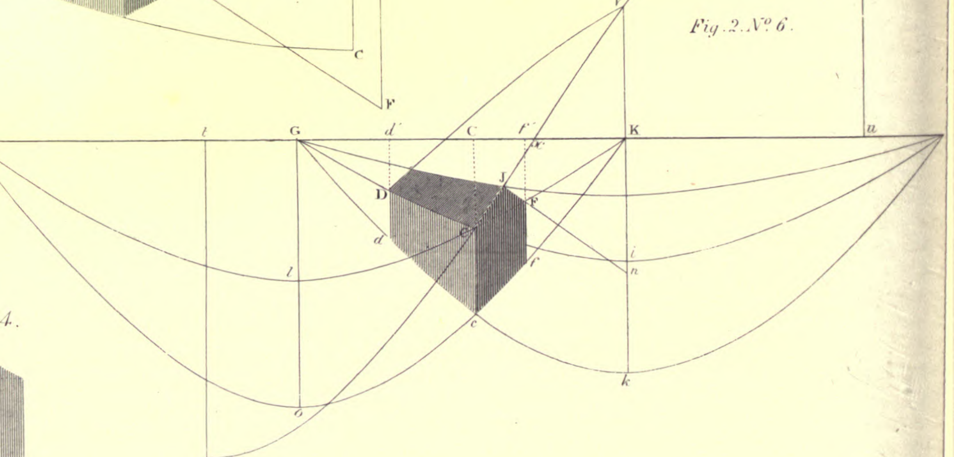


Fig. 2. No. 3.

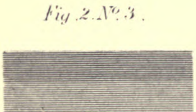
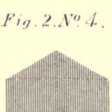


Fig. 2. No. 4.



Invented by P. Nicholson. Engraved by J. C

curve above the line A B, produced, and consequently a curve of contrary flexure.

The panoramic curve takes place when the cylinder is cut by a plane at oblique angles to the axis.

PROBLEM II.—*To find the indefinite representation of lines parallel to the original plane, in a plane parallel to the axis of the picture; given the height of the eye, the intersection of the original plane, and the distance of the original plane from the picture.*

Figure 2, No. 1.—Let P be the station point; G K H I the intersection of the picture; and A B a line in the original plane, on which the plane parallel to the axis stands.

In *Figure* 2, No. 5, draw P K, which make equal to P K, No. 1. In No. 5, draw P O and K w perpendicular to P K; make P O equal to the height of the eye; draw O w parallel to P K; produce P K to r; in No. 1, draw P r perpendicular to A B, cutting A B at r, and the intersection of the original plane with the panoramic surface at K; make P r, No. 5, equal to P r, No. 1: draw r s perpendicular to K P: in No. 5, make r t, t u, u v, equal to the height of the several lines, whose indefinite representations are required, above the original plane; produce O w, meeting r s at s; produce K z to meet O s at w; draw O r, O t, O u, and O v, cutting K w respectively at v, x, y, and z. In No. 2, make G H equal to the semi-circumference G K H, No. 1; bisect G H at w; draw w v perpendicular to G H; make w v, w x, w y, and w z, respectively equal to w v, w x, w y, and w z, No. 5; then with the common length G H, and the deflections w v, w x, w y, and w z, describe the curves G v H, G x H, G y H, G z H, which will be the development of the representation of the lines required, and G and H will be their vanishing points. For O P r s, No. 5, may be considered as a plane passing along the axis of the cylinder; O P the axis, O the eye, P the station point, K w a section of the cylindric surface, and O r, O t, O u, and O v, visual rays; and, consequently, the points v, x, y, z, will be the representations of r, t, u, v; and since r, t, u, v, may be considered as the centres of the original lines, whose representations are required, and since the optic planes of these lines cut the cylinder obliquely, the sections will be elliptical, and, consequently, their envelope will be the figure of the sines, as here described.

PROBLEM III.—*To describe the representation of a line in a plane perpendicular to the axis of the cylinder, giving the seat of the line on the original plane.*

In No. 2, draw G d perpendicular to G H; make G d equal to the descent or deflection of the curve, and describe the quadrantal sinical curve d w, and d w will be the representation of a line perpendicular to the plane, in which the originals of G v H, G x H, G y H, and G z H, are situated.

PROBLEM IV.—*Given the indefinite representation*, G z H, No. 2, *of a straight line, to determine the finite portion, whose seat is* A B, No. 1.

Draw P A and P B, No. 1, cutting the intersection at a and b; make w a, No. 2, equal to the extension of K a, No. 1; and w b, No. 2, equal to the extension of K b, No. 1; draw a a^{I} and b b^{I}, No, 2, perpendicular to G H, cutting the curve G z H at a^{I} and b^{I}, and a^{I} z b^{I} will be the finite portion required; a^{II} y b^{II}, a^{III} x b^{III}, and a^{IV} v b^{IV}, will be the same portions of the indefinite representations G y H, G x H, and G v H.

The following examples show the application of the principles in the representation of solid objects.

Example 1. *Figure* 2, No. 1.—Let C D E F, be the plan of a house, in contact with the picture at C. Through the station point P, draw G H, parallel to D C, cutting the intersection of the panoramic picture in the points G and H; also through P draw K I, parallel to E D, or F C, cutting the picture in I and K; then G and H are the vanishing points of all lines parallel to E F or D C, and I and K the vanishing points of all lines parallel to C F or D E; draw F P and D P, cutting the picture at f and d. Let W V be the ridge of the building, bisecting E D at W, and E C at V; produce W V to Y, cutting I K at U; make U Y equal to the height of the house, Nos. 3 and 4; and make the angle U Y Z equal to half the vertical angle of the roof, and let Y Z cut I K at Z; draw X Q parallel to Y Z, cutting K I, or K I produced at Q; draw Z x parallel to V W; produce E D to x, and F C to meet x Z at T; join Q x and Q T, which are the intersections of the optic planes formed by the inclined side of the roof, and the vertical planes standing upon D E and C F; draw I N parallel to P O, and O N parallel to I P. To find the inclination of the optic planes; draw P M perpendicular to x Q, cutting x Q at u, and the panoramic intersection at M; from P, with the distance P u, describe the arc u J, cutting P I at J; join O J; produce N I and O J to meet each other in S. In like manner, draw P t perpendicular to T Q, cutting T Q at v, and the panoramic intersection at t; from P, as a centre, with the radius P v, describe the arc v w, cutting I P at w; join O w; produce N I and O w to meet each other in R; then N O S is the inclination of the optic plane, whose intersection is Q x; and N O R is the inclination of the optic plane, whose intersection is Q T.

Figure 2, No. 6.—Upon any convenient line, I H, extend the panoramic intersection; according to the corresponding places of No. 1, as shown by similar letters; that is, I t, t G, G d', d C', C' f,' f' K, and K H, No. 6, would cover I t, t G, G d', d' C', C' f', f' K, and K H, No. 1. In No. 6, draw t R, O o, d' d, C' o, f' f, K k perpendicular to I H.

In No. 5, produce K P to a; make P a equal to the radius of the cylinder; through a draw i o parallel to O P; on P a make P j equal to P j, No. 1, and P q, No. 5, equal to P q, No. 1; draw j g and q h, No. 5, perpendicular to P a; make q h and j g each equal to the height of the walls, Nos. 3 and 4; join O g and O h; produce O g to l, and O h to i, meeting o i; produce O j and O q to meet G o at o and k.

In No. 6, make t R equal to N R, No. 1; G o equal to G o, No. 5; G l equal to G l; K k equal to G k; K i equal to G i; describe the panoramic curves I l K, I O K, G k H, G i H; then the curves I O K and G k H will cut each other at c, and the curves I l k, G i H, will cut each other at C, so that the points C', C, c, will be in the same perpendicular; C c will thus represent the angular line of the building. Let the perpendicular d' d cut the curve G i H at D, and the curve G k H at d; and the intercepted portion D d is the angular line at one end; in like manner, let the perpendicular f' f cut the curve I l k at F, and the curve I O K at f; and the intercepted portion F f of the perpendicular f' f, is the representation of the angular line at the other end; therefore c C D d represent the front, and c C F f the end, exclusive of the triangular part adjoining the roof, which will be formed in the following manner: make t x and x u equal to G K each; describe the same panoramic curve, R C x; and if the other semi-panoramic curve, x v w, is described, and if k K be produced to v, v will be the vanishing point for the gable top; and if K n be made equal to K, v, n will be the vanishing point of the other inclined plane of the roof; and thus the representation of lines and planes will have vanishing points and vanishing lines, as in the methods of describing the perspective representation of objects upon a plane surface; and if the points d, D, c, C, f, F, are found, and the lines c d, C D, and c f, C F, are made straight instead of being curved and produced, they will find their own vanishing points in the line I H; but more remote from each other than the points G and K.

What is here observed, is exemplified in No. 7, as will appear sufficiently clear by a little reflection.

The example here shown is very distorted, on account of the smallness of the panoramic cylinder, and the size of the object, which was obliged to be very large, in order to give a clear elucidation of the principles.

Example 2.—*Figure* 3, shows the panoramic representation of a row of houses, upon the surface of a cylinder of greater radius than that of *Figure* 2, No. 1, where the pictural objects appear much more agreeable to the eye than that of *Figure* 2; the lines which form the roofs are in this example represented as straight, though in reality they are curves, as a great deal of trouble is saved, and the error occasioned by their introduction is too trifling to be observed.

It remains to show the truth of the operations used in the construction of *Figure* 2. Let it now be proved that x Q and T Q are the intersections of the optic planes, formed by the inclined lines of the gables. From the definition given, an optic plane is one passing along an original line, and through the eye; therefore, if a straight line be drawn through the eye parallel to the original line, the line, thus passing through the eye, and the original line, will both be in the same plane, that is, both in the optic plane; and if two planes be drawn along two parallel lines, their intersections with a third plane will be parallel; now the parallels F T and K I are the intersections of two parallel planes; F T that of the vertical plane, in which the inclined original line is situated, and K I that in which the eye is situated, or in which the line parallel to the inclined line is situated; the point T is the intersection of the inclined line of the roof, and the point Q the intersection of the line drawn through the eye parallel to the inclined line of the roof; therefore the optic plane will pass through the points T and Q, and consequently T Q is the intersection of the optic plane and the original plane. In the same manner, it may be shown that x Q is the intersection of the optic plane, formed by the other inclined line of the farther gable in the same plane with the former line.

Next let it be shown that the angles N O S and N O R, No. 1, are the inclinations of the optic planes, whose intersections are x Q and T Q. The inclination of any two planes is measured by a third plane, perpendicular to their common intersection; now T Q is the intersection of the optic plane, and P v is perpendicular to T Q; and because P w is equal to P v, and P o perpendicular to P w, and equal to the height of the eye; conceive the plane of the triangle w P O to be raised perpendicular to the original plane, so that the base P w may coincide with P v; then O will represent the eye in its true place, and the point w will be upon v; and since the intersection T Q would be perpendicular to the plane of the triangle, every line drawn in the plane of the triangle from v, would be perpendicular to the intersection T Q, and consequently, the line drawn in this plane from v to O, would also be perpendicular to the intersection; therefore the angle P w O is the inclination of the plane, and, consequently, the alternate angle N O R. In the same manner, it may be shown, that N O S is the inclination of the plane whose intersection is x Q.

Now to show that N R is the deflection of the curve made by the optic plane, it only requires to be considered, that the transverse axis of the ellipsis made by the optic plane, is in the plane which measures the inclination of the optic plane to the original plane: for this purpose, P O N R may be considered as a semi-section of the cylinder along the axis, and N R a section upon the surface; therefore O R will represent half the greater axis, and N R the deflexion of the curve, or its descent below the vanishing line of the horizon. *Figure* 2, No. 5, is also to be considered as a section of the cylinder, of which O P represents the axis, G O and w K the sides: and because the appearance of all points in the same plane perpendicular to the axis, at equal distances from the station point, will be at the same height on the surface from the original plane, or from the plane passing through the eye parallel to the original plane, their heights will be found by setting their distances upon P a, then erecting lines perpendicular to P a, from each point of the section; then setting the heights of the points upon these lines, and drawing lines from O, through the top of each perpendicular till they cut G o; then the distance from G, to each point of section, gives the distance of each point from the plane passing through the eye upon the panoramic surface.

Now let the cylinder be conceived to be enveloped by No. 6, so that I H may fall upon the circumference of a circle in a plane perpendicular to the axis; then every line will fall in its true position, and the representative object will produce the same pyramid of rays as the original, the eye being supposed to be fixed at its true distance above the line I H; and, consequently, nothing more will be required to excite an idea of the existence of the object, than to give the representative surfaces their proper colours, light, and shade, according to the distance of the original. Hitherto straight lines have been represented by portions of the sinical curve when extended, or by portions of an ellipsis, when the sheet on which the objects are represented, is brought in contact with the surface of the cylinder, as they ought properly to be; but if the radius of the cylinder is of sufficient extension, and the objects to be represented of proper magnitude, any attempt to represent straight lines by curves from the hands of an artist would be absurd, except when the object to be represented is very near to the panoramic surface, in which case a curvature in the line may be sensible, also at a moderate distance: the curve can only be observed in a series of objects in a straight line; it will therefore be sufficient to represent the straight lines of each individual object by straight lines also, but to preserve the curve, or rather the polygonal figure inscribed in the sinical curve in the series, as the inflexions or angles will hardly be visible.

A straight line will therefore be represented by finding the representation of its extremities, and joining the representative points; but if it is of great extent, it may be obtained by finding a number of points, and joining every two adjoining points in succession by a straight line, and the whole will assume the form of a curve, which will be the representative of the straight line.

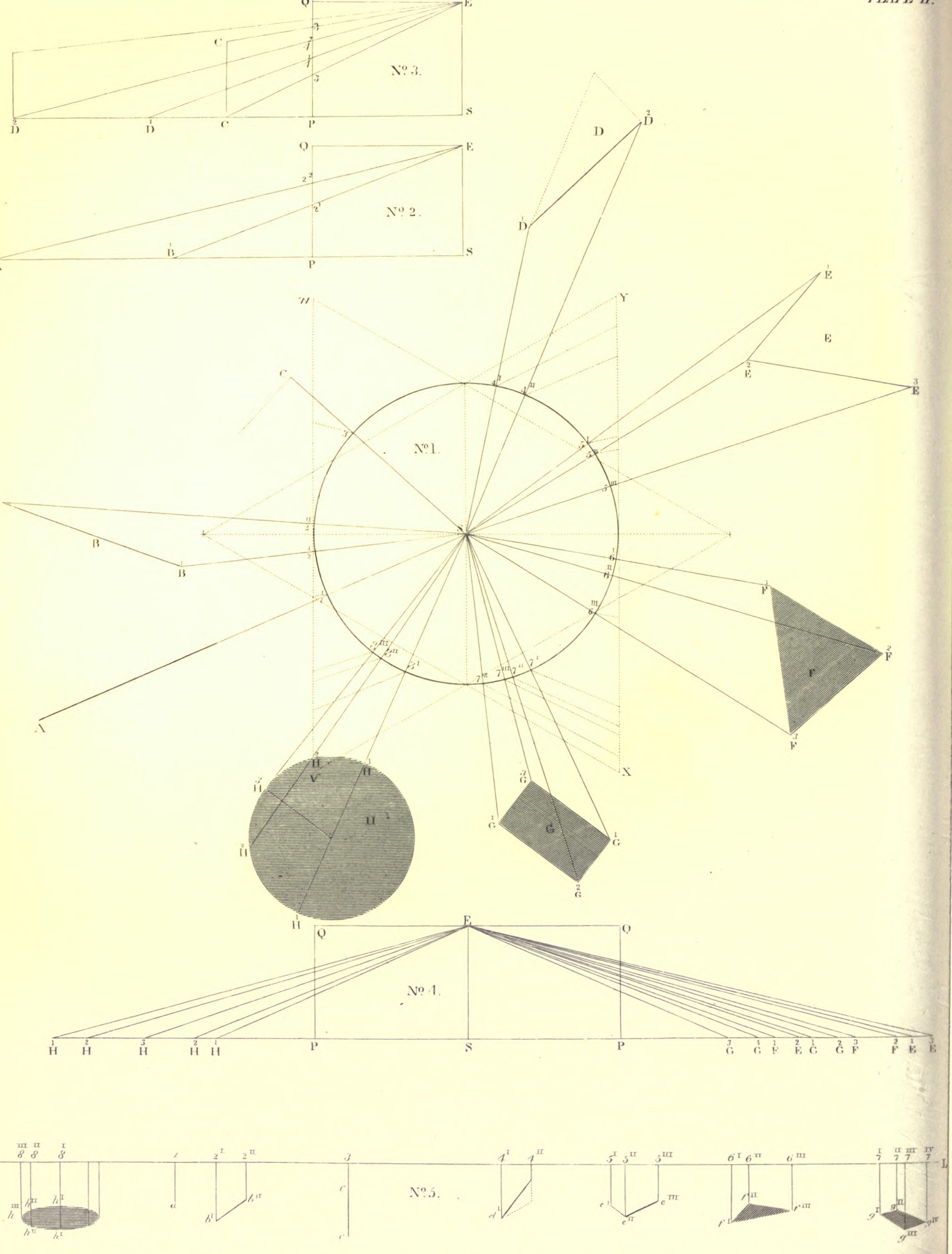
Plate II. shows a series of figures, such as may be supposed to constitute the whole of the practice of representing panoramic objects. S is the station point; the objects are referred to in alphabetical order from A, B, C, &c. to H; each extreme point of the linear parts of the same object has the same letter affixed, with a numerical index, which increases, by unity, in tracing round the circumference in progressive order. The points where the optic lines cut the panoramic surface, are numbered with the same figure from the same object, each number having an index corresponding to that of the point of the object to be represented. The numbers are placed in successive order, agreeing with that of the alphabet. No. 1 the intersection of the panorama and the original plane, with the figures of the objects to be represented.

No. 2, 3, 4, vertical sections of the panorama, passing along its axis, in order to ascertain the heights of the several places of each object; E the point of sight, or place of the eye; S the station point; P Q a section of the cylinder, showing the heights of the objects.

The objects to be represented are, A, a point, the optic ray from which cutting the intersection at 1; B a straight line, the optic ray from which cutting the intersection

PANORAMA

PLATE II.



; c a line standing upon c, the optic ray from which tting the intersection at 3; D an inclined plane, whose at is represented by D^1, D^2, the optic rays from which cutng the intersection at 4^1, 4^2; E an angle, the optic rays om which cutting the intersection at 5^1, 5^2, 5^3; F a triangle, e optic rays from which cutting the intersection at 6^1, 6^2, 6^3; a rectangle, the optic rays from which cutting the intersecon at 7^1, 7^2, 7^3, 7^4; and, lastly, H a circle, the optic rays om which cutting the intersection at 8^1, 8^2, 8^3.

The distances of the objects are placed upon the panoramic ctions No. 2, 3, 4, from S, upon the lines S P, or upon S P oduced; then drawing lines from the points to E, give the ights upon P Q.

The perpendicular standing upon c, No. 1, is thus found: No. 3, draw c c from c, perpendicular to S P, equal to the ight of the perpendicular upon c No. 1, and draw the raight lines c E, c E, No. 3, cutting P Q at 3 3, then 3 3 is e panoramic length of c c. The upper extremity of the clined line, D, will be found by ascertaining the panoramic ight of the perpendicular, from the elevated end to the iginal plane. No. 5 shows the panoramic representation of e several objects; V L the vanishing line of the horizon; e intersections of the optic rays are extended upon V L from o. 1, the references upon the intersection No. 1, and upon L, No. 5, being the same. The heights of the several points e taken from the sections No. 2, 3, and 4, from Q downwards wards P, and placed from the corresponding points in V L, o. 5, also downwards upon the perpendiculars, gives the veral points of the objects; thus *a* is the representation of e point A, No. 1; b^1, b^2, of B^1, B^2, &c. In the circle, the ints for half the curve are found, the other half being peated in the same order from the middle line, each line rving for two points, so that the three lines give eight ints; the extreme lines are tangents which are equivalent two points.

The points around the circumference of the intersection o. 1, are extended upon V W and X Y, according to the prinple of Renaldinus, by setting three-fourths of the radius, thout the circle, upon the opposite side of the tangents V W, d X Y, and transferring the divisions of V W and X Y upon L, No. 5, gives the points corresponding to the intersection. The panoramic surface being enveloped by No. 5, and the presentations of the objects placed in their true position, ll form the same picture at the point of sight, if correctly nted, as the objects themselves would in nature.

A practical method of forming all straight lines on the noramic surface in its place, without development, is to ertain the position of the objects, also the heights of the ntres of the lines to be represented; then fixing the eye in position, and holding a straight-edge parallel to the line be drawn in a plane with the point of sight and the point resenting the centre of the line, mark several points in same plane, on the panoramic surface; these points being ned, will give the representation of the line required. In paring for panoramic projections, whatever objects are inded to be represented, a proper point of view should be sen from this situation; a sketch of all the surrounding ects should be made according to the development of the orama; for though the painting itself may be performed on the cylindric surface, it is more eligible to sketch upon lane. The next thing to be done is to take a survey of objects, observing their positions to each other; then, a a plane table fixed on the point of view, quite level, e the successive angles of the surrounding objects by ans of a moveable limb, which may carry two pieces, one ach extremity, perpendicular to the surface of the plane e; one piece being fixed in the supposed axis of the panorama, containing a sight-hole for the point of view, so that the moveable part will consist of three bars, the bottom one serving as a straight edge for drawing the angles of position: the heights of the object may be marked upon the other limb parallel to that fixed in the axis; and let it be observed, that the point of view in the axis, the edge of the limb which gives the heights of the objects, and the edge of the bottom bar by which the angles are drawn, must be in a plane passing along the axis: mark the vertical lines on the sketch, and the lines on the plane table, which show their position, with corresponding characters, otherwise it would be difficult to distinguish what the numerous lines apply to. The moveable edge of the index, which describes the circumference of the cylinder, should be of ivory, as the various heights may be marked with pencil, and rubbed out at pleasure, as these heights may be transferred to a piece of paper, marking them with the same character as that of the sketch, and with the addition of the words *top of chymney*, *shaft*, *ridge of roof top of wall*, &c., as the heights may be the terminations of such parts of the said objects, or, instead of writing any word, a slight representation may be drawn of the parts of the object.

Instead of the ivory edge of the bar, which describes the panoramic surface, a slit, or very narrow aperture, formed by a double bar, may be used. The tendency of every line, horizontal or inclined, may be found by a fifth bar, moveable round a centre, which centre must also be moveable upon the edge of the limb which gives the panoramic heights of the objects; the plane in which this fourth bar moves must be a tangent to the panoramic surface, at the line which is intersected by the plane passing along the axis, along the straight-edge of the bottom bar, and along the edge where the heights of the objects are marked; then if the edge of this fourth moveable bar be brought in a plane with the eye and the original line, the angle which it forms with the edge of the vertical limb is the inclination of the line on the picture.

PANT, a conduit for water.

PANTHEON, (from the Greek παν, *all*, and θειον, *gods*,) in architecture, a temple or church, of a circular form, dedicated to all the gods, or to all the saints.

The Pantheon of ancient Rome is of all these edifices the most celebrated, and that from which all the rest take their name. It was built by Agrippa, son-in-law to Augustus, in his third consulate, twenty-five years before the Christian era; though several antiquaries and artists have supposed that the Pantheon existed long before, during the commonwealth, and that Agrippa only embellished it and added the portico. To this purpose they allege the authority of Dion Cassius, who, speaking of Agrippa, says, he also finished or perfected the Pantheon.

It was dedicated by him to Jupiter Ultor, Jupiter the Avenger, according to Pliny's account; according to Dion Cassius, to Mars, Venus, and Julius Cæsar; but, according to the most probable opinion, to all the gods; and had the name *Pantheon*, on account of the great number of statues of the gods, raised in seven niches all round it; and because it was built of a circular form, to represent heaven, the residence of the gods, or, because it was dedicated to all the gods, (*quasi* παντον θειον.) It had but one door. It was 144, or, as Fabricius says, 140 feet diameter within, and just as much in height, and of the Corinthian order. The roof was curiously vaulted, void spaces being left here and there for greater strength. The rafters, 40 feet long, were plated with brass. There were no windows in the whole edifice; but sufficient light was let in through a round hole in the top of the roof. Before each niche were two columns of antique yellow marble, fluted, each of one entire block.

The whole wall of the temple, as high as the grand cornice inclusive, was cased with divers sorts of precious marble in compartments; and the frieze was entirely of porphyry. The outside of the front was anciently covered with plates of gilt brass, and the top with plates of silver; in lieu of which, lead was afterwards substituted. The gates were of brass, and of extraordinary size and workmanship. The eruption of Vesuvius, in the reign of Tiberius, and a great fire in the reign of Titus, damaged the Pantheon very considerably; but it was successively repaired by Domitian, Adrian, and Septimius Severus: and having subsisted in all its grandeur till the incursion of Alaric, in the reign of Honorius, it was then stripped of several of its statues and ornaments of gold and silver. About thirty-nine years after this, Genseric, king of the Vandals, took away part of its marbles and statues; and, at length, Pope Boniface IV. obtaining this Pantheon of the Emperor Phocas, converted it into a church, without any alteration in the building, and dedicated it to the Virgin and all the martyrs; but, in 1665, Constantius II. stripped it of its inside and outside brazen coverings, which he transported to Syracuse. It still subsists at Rome, under the title of Notre Dame de la Rotonda.

The square of the Pantheon, or *Piazza della Rotonda*, is adorned with a fountain and an obelisk, and terminated by the portico of Agrippa. This noble colonnade consists of a double range of Corinthian pillars of red granite. Between the middle columns a passage opens to the brazen portals, which, as they unfold, expose to view a circular hall of immense extent, crowned with a lofty dome, and lighted solely from above. It is paved and lined with marble. Its cornice of white marble is supported by sixteen columns, and as many pilasters of Giotto antico; in the circumference there are eight niches, and between these niches are eight altars, adorned each with two pillars of less size, but the same materials. The niches were anciently occupied by statues of the great deities; the intermediate altars served as pedestals for the inferior powers. The proportions of this temple are admirable for the effect intended to be produced; its height being equal to its diameter, and its dome not an oval, but an exact hemisphere. The Pantheon is the most noble and perfect specimen of Roman art and magnificence which time has spared, or the ancients could have wished to transmit to posterity. It has served, in fact, as a model to succeeding generations, and to it Constantinople is indebted for Santa Sophia, and to it Rome, or rather the universe, owes the unrivalled dome of the Vatican. Upon the whole, this is the most ancient edifice that now remains in a state of full and almost perfect preservation.

There was also another Pantheon at Rome, dedicated to Minerva, as the goddess of medicine. It was in form of a decagon, and the distance from one angle to another measured $22\frac{1}{2}$ feet. Between the angles there were nine chapels of a round figure, designed for so many deities: and over the gate there was a statue of Minerva.

The Pantheon of Nismes, was a temple in that city, in which were twelve niches, for statues supposed to have been destined for the twelve great gods.

The Pantheon of Athens was, in many respects, little inferior to that at Rome, built by Agrippa. The Greek Christians converted it into a church, dedicated to the Virgin, under the name of *Panegia*, but the Turks changed it into a mosque.

In the Escurial is a magnificent chapel, called Pantheon, 35 feet in diameter, and 38 high from the pavement, which is of marble and jasper inlaid. The whole inside of the chapel is of black marble, except the lantern, and some ornaments of jasper and red marble. In this chapel are deposited the bodies of the kings and queens: there are only places made for twenty-six, eight of which are already filled.

PAN-TILES, *see* Tiles.

PANTOMETER, an instrument for measuring all sorts of elevations, angles, and distances.

PAPER, *Drawing*, a stout coarse kind of paper used for drawing upon, of which sheets are manufactured of the following sizes:

	Inches.		Inches.
Demy	20 by 15	Atlas	34 by 26
Medium . . .	22 " 17	Double Elephant	40 " 26
Royal	24 " 19	Antiquarian .	52 " 31
Super royal . .	27 " 19	Extra-Antiquarian	56 " 40
Imperial . . .	30 " 21	Emperor . . .	68 " 48
Colombier . .	34 " 23		

PARABOLA, (from the Greek παρα, *through*, and βαλλω, *to throw*) in geometry a curve line made by the common intersection of a conic surface and a plane which cuts it, and is parallel to another plane that touches the conic surface.

A conic section made by a plane ever so little inclined to the parabola on the one side, is an ellipsis; and a section made by a plane inclined ever so little on the other side, is an hyperbola; thus the parabola is the limit between these two curves, to which they both continually approach, while their transverse axes increase more and more; being, as it were, the passage from one of them to the other.

Parabola, a plain figure, bounded by a curve and a straight line, possessing the property that $a\,x = y^2$; in which x is the abscissa, and y the ordinate.

Parabolic Asymptote, in geometry, a parabolic line approaching to a curve, but never meeting it; yet by producing both indefinitely, their distance from each other becomes less than any given line.

There may be as many different kinds of asymptotes as there are parabolas of different orders.

When a curve has a common parabola for its asymptote, the ratio of the subtangent to the abscissa approaches continually to the ratio of two to one, when the axis of the parabola coincides with the base; but this ratio of the subtangent to the abscissa approaches to that of one to two, when the axis is perpendicular to the base. And by observing the limit to which the ratio of the subtangent and abscissa approaches, parabolic asymptotes of various kinds may be discovered.

Parabolic Conoid, See Paraboloid.

Parabolic Curve, the curved boundary of a parabola which terminates its area, except at the double ordinate.

Parabolic Spiral, or Helicoid, a curve arising from a supposition of the axis of the common parabola being bent into the periphery of a circle while the ordinates are portions of the radii next to the circumference.

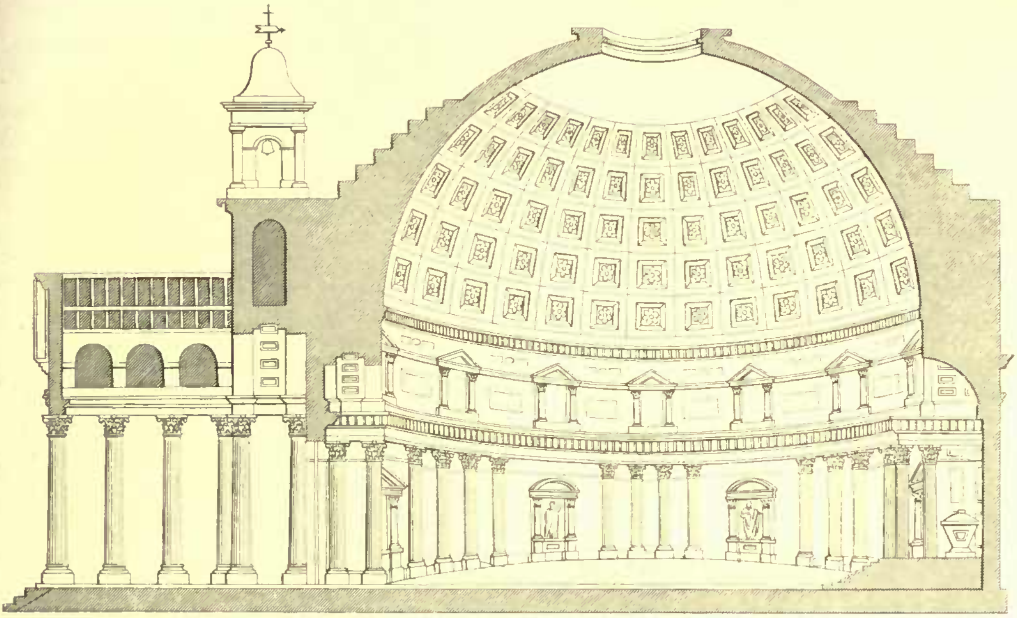
Paraboloid (from παραβολή and εἶδος) a solid formed by the revolution of a parabola about its axis. It is described by Harris as a parabolic firm curve, whose ordinates are supposed to be in subtriplicate, subquadruplicate, &c., ratio of their respective abscissas.

PARADIGRAMMATIZE, (from the Greek παραδειγμα, *an example*, and γραμμα, *a letter*) the act of forming all sorts of figures in plaster. The artists themselves are called *gypsochi*. Neither term is much used.

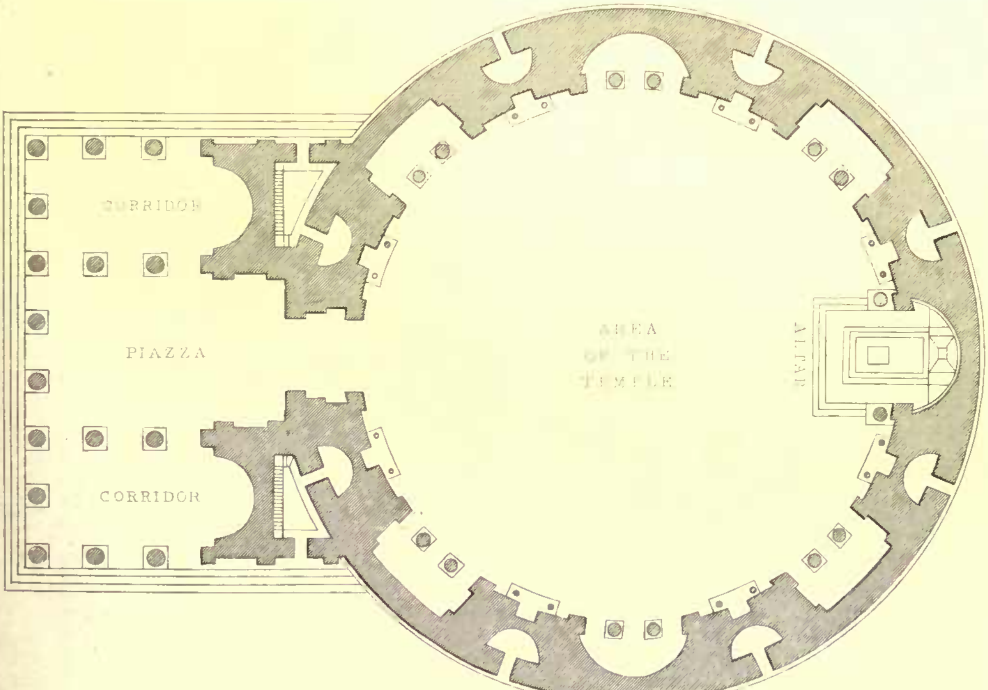
PARADOX (from the Greek παρα, *against*, and δοξα, *opinion*) in philosophy, a proposition seemingly absurd because contrary to the received opinions; but yet true in effect.

The Copernican system is a paradox to the common people; but the learned are all agreed as to its truth.

PLAN AND SECTION OF THE HEATHEN PANTHEON AT ROME.



PERSPECTIVE SECTION



GENERAL PLAN OF THE TEMPLE

own Arch^t. R. Thew. Sc

Geometricians have been accused of maintaining paradoxes; and, it must be owned, that some use very mysterious terms in expressing themselves about asymptotes, the sums of infinite progressions, the areas comprehended between curves and their asymptotes, and the solids generated from these areas, the length of some spirals, &c. But all these paradoxes and mysteries amount to no more than that the line or number may be continually acquiring increments, and those increments may decrease in such a manner, that the whole line or number shall never amount to a given line or number.

The necessity of admitting this is obvious from the nature of the most common geometrical figures; thus, while the tangent of a circle increases, the area of the corresponding sector increases, but never amounts to a quadrant. Neither is it difficult to conceive, that if a figure be concave towards a base, and have an asymptote parallel to the base (as it happens when we take a parallel to the asymptote of the logarithmic curve, or of the hyperbola, for a base) that the ordinate in this case always increases while the base is produced, but never amounts to the distance between the asymptote and the base. In like manner, a curvilinear area may increase while the base is produced, and approach continually to a certain finite space, but never amount to it; and a solid may increase in the same manner, and yet never amount to a given solid.

A spiral may in like manner approach to a point continually, and yet in any number of revolutions never arrive at it; and there are progressions of fractions, which may be continued at pleasure, and yet the sum of the terms shall be always less than a given number. In Maclaurin's *Fluxions* (book i. ch. 10. *et seq.*) various rules are demonstrated, and illustrated by examples, for determining the asymptotes and limits of figures and progressions, without having recourse to those mysterious expressions which have of late years crept into the writings of mathematicians. For, as that excellent author observes elsewhere, though philosophy has, and probably always will have, mysteries to us, geometry ought to have none.

PARALLEL, (from the Greek παραλληλος,) in geometry, a term applied to lines, figures, and bodies, which are every where equidistant from each other; or which, though infinitely produced, would never approach nearer to, nor recede farther from, each other.

Parallel Copings, such copings as have their upper surface parallel to the bed of the stone, as in those which cover the gable of a house.

Parallel Right Lines, such lines, as, though infinitely produced, could not meet at any finite distance.

Parallel Motion, among practical mechanics, denotes the rectilinear motion of a piston-rod, &c., in the direction of its length; and contrivances, by which such alternate rectilinear motions are converted into continuous rotatory ones, or *vice versa*, for pumps, steam-engines, saw-mills, &c., are usually called *parallel motions* or *parallel levers*. The object of the parallel motion is, to convert the motion of the end of a reciprocating beam or lever, into a vertical or rectilinear motion; or the continuous motion of a crank at once into a reciprocating motion.

The simplest and most obvious method of producing either of these effects, is to connect the end of the piston-rod to the beam, or the crank, by means of joints, with a connecting rod of a proper length between them, and confine the former, to preserve its rectilinear movement, by sliding through a collar, or in grooves. Friction-wheels may be used to make it work easily; but in machines which have great strains, the constant wear of the grooves or wheels, would soon produce looseness, and destroy the parallelism of the motion: recourse must, therefore, be had to parallel levers.

Parallel-Planes, those which if produced cannot meet at any finite distance.

Parallel Ruler, *See* Instruments.

Parallel Cut, in inland navigation, a counter drain, to carry off water, and prevent the adjoining lands from being flooded.

PARALLELOPIPED, (from the Greek παραλληλος, *parallel*) in geometry, one of the regular bodies, or solids, comprehended under six parallelograms, the opposite sides of which are similar, parallel, and equal.

A parallelopiped is by some defined an upright prism, whose base is a parallelogram, and the planes of whose sides are perpendicular to the plane of the base.

A rectangular parallelopiped is one whose bounding planes are all rectangles, and which stand at right angles to each other. Every rectangular parallelopiped is said to be contained under the planes that constitute its length, breadth, and altitude.

It is demonstrated, that if from one of the angular points of any parallelogram, a right line be elevated above the plane of the parallelogram, so as to make any angles with the contiguous sides of it, and there be also drawn, from the three remaining angular points, three other right lines parallel and equal to the former, and the extremes of these lines be joined, the figure thus described will be a parallelopiped. If the angle of the parallelogram be right, and the elevated line be erected perpendicular to the plane of the base, then will the parallelopiped be a rectangular one.

Parallelopiped, *Properties of the.* All parallelopipeds, prisms, and cylinders, &c., whose bases and heights are equal, are themselves equal.

Every upright prism is equal to a rectangular parallelopiped of equal base and altitude.

A diagonal plane divides the parallelopiped into two equal prisms: a rectangular prism, therefore, is half a parallelopiped upon the same base, and of the same altitude.

All parallelopipeds, prisms, cylinders, &c., are in a ratio compounded of their bases and altitudes; wherefore, if their bases be equal, they are in proportion to their altitudes; and conversely.

All parallelopipeds, cylinders, &c., are in a triplicate ratio of the homologous sides; and also of their altitudes.

Equal parallelopipeds, prisms, cones, cylinders, &c., are in the reciprocal ratio of their bases and altitudes.

Rectangular parallelopipeds, contained under the corresponding lines of three ranks of proportionals, are themselves proportionals.

To measure the surface and solidity of a parallelopiped.—Find the areas of the parallelograms I L M K, L M O N, and O M K P (*See* Parallelogram); add these into one sum, multiply that sum by 2, and the product will be the surface of the parallelopiped.

"If, then, the base, I L M K, be multiplied by the altitude, M O, the product will be the solidity.

Suppose L M $= 36$, M K $= 15$, M O $= 12$; then L I K M $= 36 \times 15 = 540$; L M O N $= 36 \times 12 = 432$; M O K P $= 15 \times 12 = 180$. The sum of which is $= 1152$, which multiplied by 2, gives the superficies equal to 2304. And 540×12 gives the solidity equal to 6480. Or the solid content of a parallelopiped may be obtained by multiplying the area of the base by the altitude of the parallelopiped. Thus, if the two dimensions of the base be 16 and 12 inches, and the height of the solid 10 inches; then the area of the base being 192, the content of the solid will be 1920 cubical inches.

The parallelopiped with oblique angles is a figure very common to many kinds of stones, especially of the softer sort.

PARALLELOGRAM, (from the Greek παραλληλος, *a parallel*, and γραμμα, *a figure*) in geometry, a quadrilateral right-lined figure, whose opposite sides are parallel and equal to each other.

A parallelogram is generated by the equable motion of a right line always parallel to itself.

When the parallelogram has all its four angles right, and only its opposite sides equal, it is called *a rectangle*, or *an oblong*.

When the angles are all right, and the sides are all equal, it is called *a square*, which some make a species of parallelogram, others not.

If all the sides are equal, and the angles unequal, it is called *a rhombus*, or *lozenge*.

If both the sides and angles be unequal, it is called *a rhomboides*.

Every other quadrilateral, whose opposite sides are neither parallel nor equal, is called *a trapezium*. See each of these articles.

In every species of parallelogram, a diagonal divides it into two equal parts; the angles diagonally opposite are equal; the opposite angles of the same side are, together, equal to two right angles; and every two sides are, together, greater than the diagonal. Every quadrilateral, whose opposite sides are equal, is a parallelogram.

Two parallelograms on the same, or on an equal base, and of the same height, or between the same parallels, are equal. Hence two triangles on the same base, and of the same height are also equal; as are all parallelograms or triangles whatever, whose bases and altitudes are equal among themselves.

Hence, also, every triangle is half a parallelogram upon the same or an equal base, and of the same altitude, or between the same parallels. Hence, also, a triangle is equal to a parallelogram having the same base and half the altitude, or half the base and the same altitude.

Parallelograms, therefore, are, in a given ratio, compounded of their bases and altitudes. If then the altitudes be equal, they are as the bases; and conversely.

In similar parallelograms and triangles, the altitudes are proportional to the homologous sides; and the bases are cut proportionally thereby. Hence similar parallelograms and triangles are in a duplicate ratio of their homologous sides, also of their altitudes, and the segments of their bases; they are, therefore, as the squares of the sides, altitudes, and homologous segments of the bases.

In every parallelogram, the sum of the squares of the two diagonals is equal to the sum of the squares of the four sides: and the two diagonals bisect each other.

This proposition M. de Lagny takes to be one of the most important in all geometry; he even ranks it with the celebrated forty-seventh of Euclid, and with that of the similitude of triangles; and adds, that the whole first book of Euclid is only a particular case of it. For if the parallelogram be rectangular, it follows, that the two diagonals are equal; and, of consequence, the square of a diagonal, or, which comes to the same thing, the square of the hypothenuse of a right angle is equal to the squares of the sides.

If the parallelogram be not rectangular, and, of consequence, the two diagonals be not equal, which is the most general case, the proposition becomes of vast extent; it may serve, for instance, in the whole theory of compound motions, &c.

There are three ways of demonstrating this proposition: the first by trigonometry, which requires twenty-one operations; the second geometrical and analytical, which requires fifteen. But M. De Lagny gives a more concise one, in the *Memoires de l' Acad.*, which only requires seven.

PARALLELOGRAM, *See* PENTAGRAPH.

PARAMETER (from the Greek παρα, *through*, and μετρεω, *to measure*) in conic sections, a constant right line in each of the three sections; called also *latus rectum*. In the parabola, the rectangle of the parameter and an abscissa are equal to the square of the correspondent semi-ordinate. *See* PARABOLA.

In an ellipsis and hyperbola, the parameter is a third proportional to a conjugate and transverse axis. *See* ELLIPSIS and HYPERBOLA.

PARAPET, (French) or BREASTWORK, in fortification, a defence or screen, on the extreme of a rampart, or other work, serving to cover the soldiers and the cannon from the enemy's fire.

The thickness of the parapet should be about eighteen or twenty feet, in order to be cannon-proof, and it should be about seven or eight feet high, when the enemy has no command above the battery; otherwise it should be raised high enough to cover the men while they load the guns. Its length depends on the number of guns to be employed in the battery: for one gun, it is common to allow eight yards in length, and six yards more for every other gun. The parapet consists of two parts; the wall contained in one piece from end to end, and about two and half or three feet high; and the merions, which are detached pieces of the parapet, leaving openings, called embrasures, through which the cannon deliver their shot.

The parapet of the wall is sometimes of stone. The parapet of the trenches is either made of the earth dug up; or of gabions, fascines, barrels, sacks of earth, or the like.

PARAPET, is also a little wall, breast-high, raised on the brinks of bridges, quays, or high buildings; to serve as a stay and prevent accidents from falling over.

In roof buildings, it assists in forming the gutter, and tends to resist the outward thrust of the roof by its weight or vertical pressure. It is worthy of remark, that in the late Gothic buildings, when the roofs were of a low pitch, and consequently had considerable lateral thrust, the walls were almost invariably terminated by a parapet.

PARASTATA, (Greek,) in ancient architecture, a kind of pier, or piedroit, serving as a defence or support to a column or arch.

Mr. Evelyn makes the parastata the same with pilaster; Barbaro and others, the same with antæ; and Daviler, the same with piedroit.

PARCLOSE, a screen frequently of open-work, employed in churches to separate chapels, tombs, and other portions of the church from the main body.

PARENT, ANTHONY, in biography, an eminent mathematician, born at Paris in the year 1666. At a very early period, he discovered a strong propensity to the study of mathematics; for, at the age of fourteen, accidentally meeting with a dodecahedron, upon every face of which was delineated a sundial, excepting the lowest, upon which it stood, he attempted to imitate them, and was led from the practice to investigate the theory, and in a short time wrote a treatise upon *Gnomonics*, which, though said to be extremely rude and unpolished, had the merit of being his own invention, as was a work on *Geometry*, which he wrote about the same time. At the earnest desire of his relations, he entered upon the study of the law, as a profession for his life; but he sooner completed his studies in that faculty, than he betook himself, with increased ardour, to those pursuits which accorded best with his genius and inclination. He attended, very diligently, the lectures of M. de la Hire and M. Sauveur, and, as soon as he felt himself capable of teaching others, he took pupils; and fortification being a branch of study which the war had brought into particular notice, he was called upon frequently to teach the principles of that science. In 1699, M. Fillau des Billets having been admitted a member of the Academy of Sciences at Paris, with the title of their academician, nominated M. Parent for his *élève*, who particularly excelled in that branch of knowledge. It was soon discovered that he directed his attention to all the subjects that came before the Academy, and that he was competent to the investigation of every topic which was recommended to their notice. In the year 1716, the king abolished the class of *élèves*, and on this occasion he made M. Parent an adjunct, or assistant member of the class of geometry. He lived but a short time to enjoy his honour, being in the same year cut off by the small-pox, when he was about fifty years of age. Although of a very irritable disposition, he is said to have possessed great goodness of heart; and though his means were extremely limited, he devoted much of his income to acts of benificence. He was author of *Elements of Mechanics and Natural Philosophy*, *Mathematical and Physical Researches*, a sort of journal, which first appeared in 1705, and which, in 1712, was greatly enlarged, and published in three vols., 4to.; and *A Treatise on Arithmetic*. Besides these, he wrote a great number of papers in the different French *Journals*, and in the volumes of the *Memoirs of the Academy of Sciences*, from the year 1700 to 1714, and he left behind him, in manuscript, many works of considerable research; among which were some complete treatises on divers branches of mathematics, and a work containing proofs of the divinity of Jesus Christ, in four parts.

PARGET, (from the Latin, *parces*, a wall,) in natural history, a name given to the several kinds of gypsum or plaster-stone, which, when slightly calcined, make what is called *plaster of Paris*, used in casting statues, in stuccoing floors and ceilings, &c.

The word *parget*, though generally applied to all the gypsums, is, however, given by the workmen principally to the two species which make up the first genus of that class, called by Dr. Hill the *pholides*. These are the Montmartre kind, and that of Derbyshire.

Pargeting, in building, a term used for the plastering of walls; sometimes for the plaster itself.

Pargeting is of various kinds; as, 1. White lime and hair mortar laid on bare walls. 2. On bare laths, as in partitioning and plain ceiling. 3. Rendering the insides of walls, or doubling partition walls. 4. Rough-casting on heart-laths. 5. Plastering on brickwork, with finishing mortar, in imitation of stone work; and the like upon heart-laths.

The term pargeting is also applied to the ornamental plaster-work common in timber houses of the Elizabethan period.

PARKER'S CEMENT. *See* Cement, Mortar, &c.

PARLOUR, (French, *parler*, to speak,) a room for conversation. Primarily, the apartment in a nunnery where the nuns are permitted to meet and converse with friends and visitors; hence with us the parlour is the room in a house which the family usually occupy when there are no visitors, as distinguished from a drawing-room, for the reception of company, or from a dining-room, when a distinct apartment is allotted for that purpose. The term is likewise used to signify a room on the ground-floor, and a better sort of apartment in houses of entertainment.

PARQUETRY, inlaid work, the same as Marquetry, which see.

PARSONAGE, a house adjoining, or in proximity to a church, the residence of the officiating priest.

PARTHENON, one of the finest temples of ancient Athens, dedicated to Minerva. It was of the Doric order, erected by Ictinas in the palmy days of Greek art, the sculptor being Phidias. It is situated about the middle of the citidal, and is built altogether of admirable white marble; the plan of it is above twice as long as it is broad, being 217 feet 9 inches long, and 98 feet 6 inches broad. It has an ascent on all sides of five steps. The peristyle consists of 46 pillars of the Doric order, chennelled, 8 whereof are distributed at each end of 17 on either side; they are 42 feet high, and 17½ feet in circumference, the intercolumns measuring 7 feet four inches.

The following particulars are extracted from Stuart:—"Within the peristyle, at either end, there was an interior range of 6 columns of 5½ feet in diameter, forming a vestibule to the door of the cella or *adytum*, these vestibules were ascended by two steps from the peristyle.

"The cella, 62½ feet broad within, was divided into two unequal chambers, of which one was nearly 44 feet long, and the other about 97½ feet long. The ceilings of the smaller chamber was supported by 4 columns, and of the larger by 16 columns; the order of these interior columns is unknown, as all traces of their ornaments appear to have perished; even their existence can be but conjectured by means of the construction of the pavement, and by a trace of *one* of the columns in either chamber.

"The existence of these internal columns is not, however, admitted by Wilkins, who made a very minute inspection of the building in 1801. The metopes were enriched with sculptures executed in high relief; the subject a series of combats between one of the Lapithæ and the Centaurs; in the tympan of the pediments, were sculptured groups of a colossal size, many of the figures being perfect *statues, wholly detached from the tympanum, and sculptured all round.* The circumstances attending the birth of Minerva, were represented over the one entrance, and also the contest between the goddess and Neptune for the *honour* of presiding over the affairs of the city; for the Athenians, in choosing a tutelary diety, did not omit the opportunity of paying a compliment to their national vanity. Behind the columns of both fronts, was another range of columns of lesser dimensions, advanced before the antæ of the pronaos and pasticum, contrary to the usual Greek practice, as the area of the pronaos and of the pasticum was elevated two steps above the peristyle. The entablature or frieze of the inner range was continued along the side-walls of the temple, and enriched with sculptures executed in bas relief; it was not broken by the insertion of triglyphs, but in the epistylium, the guttæ or drapo are introduced in the same manner as when the usual insertion of triglyphs was made. This afforded an opportunity for an uninterrupted representation of the grand procession which took place at the celebration of the Panathenæan festival.

"The transverse walls terminating the pronaos and pasticum, receded 12 feet behind the columns of the interior ranges, and doorways of ample width and height were left in them for the approaches to the cella. Stuart imagined the Parthenon to have been of that description of temples called Hypæthral, or those of which the cella was divided into three aisles, of which the two next the side-walls were covered with a roof, and the middle aisle left open to the sky. The researches of recent travellers having thrown additional light on this subject, his opinion is no longer tenable, and the passage in Vitruvius, which was considered to allude to this temple, has been shown to be a corruption of that author's text. There were no columns in the cella of the temple. The roof was unquestionably of timber, and covered with marble, sculptured so as to represent large tiles, after the mode observed in the temple of Jupiter at Olympia.

Some of the blocks of stone, of which the Parthenon is composed, are so closely fitted, that no separation is visible; and in some instances, where the adjoining fragments of two contiguous stones have broken off, they adhere almost as firmly as though they had never been disjoined; this cohesion is, however, only observable in the *vertical* joints, the separation between the horizontal beds of the blocks, is far more conspicuous. The want of cement was amply supplied by the liberal use of *iron cramps;* in a block of four feet in length, three cramps are sometimes found connecting it with the next adjoining. One set of cramps being used for connecting the stones of the same bed together, and the other for connecting the superincumbent courses; the first, which united both the end and at the sides, resembled the letter H, protracted so as to be from 11 to 15 inches in length. The others were plates of iron, 5 inches in depth, 3 in width, and $\frac{3}{4}$ of an inch thick. They are usually inserted half their depth into the stones beneath the vertical joints of the next superior course, the other remaining to be received into a groove made across the common joint of the two blocks meeting above it. Holes of the same form, but of greater dimensions, were sunk for the reception of the first sort of cramps, the space being filled around with melted lead; lead was also used in fixing the second sort of cramps in the horizontal courses, but no means appear to have been employed for its introduction at the angles of two blocks, whose vertical joint is immediately above them. The stones composing the shaft of each column, were held together by round pins of wood; *square* sockets of the same material were first sunk in the centre of two adjoining blocks, the socket of the lower course received half the pin, and the other half projected into the socket in the upper stone. The pins which have been found, appear to have shrunk very considerably; besides these, there were usually two metal plates of the kind already mentioned, inserted in those blocks composing the column, as in the other part of the building.

PARTITION, (from the Latin, *partitio*, to divide,) a wall which divides and separates one apartment from another. It may be either of brick, stone, or timber. When a partition wall has no support from below, it ought to be so constructed as to lay no stress upon the floor; and, therefore, a truss partition should be employed to discharge the weight. *See* TRUSS.

PARTY WALLS, in building, partitions of brick made between buildings in separate occupations, for preventing the spread of fire. For the regulations prescribed by act of Parliament, *see* HOUSE.

PARVIS, or PARVISE, a name formerly given to the porch of a church, but now applied to the area round a church. Of late, it has been used to signify the room often found above the porch of a church. It is supposed to be a corruption of *paradise.*

PASCAL, BLAISE, a celebrated mathematician and philosopher, born at Clermont, in Auvergne, in the year 1623. His father, who was a man of great consideration in his province, was also illustrious as a general scholar, as well as an able mathematician. To promote the studies of his only son, Blaise, he relinquished his official situation, settled at Paris, and undertook the employment of being his tutor. The pupil was, from a very early period, remarkably inquisitive, and desirous of knowing the principles of things; and when good reasons were not given to him, he would search for better; nor would he rest contented with any that did not appear to his mind well founded. His father soon discovered that the bent of his genius was decidedly to mathematics, from which he was determined, if possible, to keep him, lest he should, by this pursuit, be prevented from learning the languages. He accordingly locked up all the books that treated of geometry and the sciences, properly so called, and refrained even from speaking of them in his presence. On one occasion, however, the youth asked, with an importunity not to be put off, what was geometry? to which the father replied, "geometry is a science which teaches the way of making exact figures, and of finding out the proportions between them;" but, at the same time, he forbade him to speak or think of the subject any more; which was, perhaps, the very readiest way to excite in him an earnest desire to become acquainted with it. Accordingly, the science soon occupied all his thoughts; and though but twelve years of age, he was found, in the hours of recreation, making figures on the chamber-floor, with charcoal, the proportions of which he sought out by means of a regular, though perhaps uncouth, series of definitions, axioms, and demonstrations. It is said, apparently upon unquestionable authority, that he had proceeded with his inquiries so far as to have come to what was just the same with the thirty-second proposition of the first book of Euclid, and that without any assistance either from living instructors or the works of the illustrious dead. From this time, young Pascal had full liberty to indulge his genius in mathematical pursuits, and was furnished by his father with Euclid's Elements, of which he made himself master in a very short time. So great was his proficiency in the sciences, that, at the age of sixteen, he wrote a *Treatise on Conic Sec-tions*, which, in the judgment of the most learned men of the time, was considered as a great effort of genius. At the age of nineteen he contrived his admirable arithmetical machine furnishing an easy and expeditious method of making arith-metical calculations, in the fundamental rules, without an[y] other aid than that of the eye and the hand. About th[is] time, owing to ill health, he was obliged to suspend his studies which he was unable to renew for four years; when, havin[g] been witness to the famous Torricellian experiment respec[t]ing the weight of air, he instantly directed his attention t[o] discoveries in the science of pneumatics. He made a va[st] number of experiments, of which he circulated a printe[d] account through the whole of Europe. He soon ascertaine[d] the fact of the general pressure of the atmosphere, and com[-]posed a large treatise, in which he fully explained the subjec[t] and answered the objections which were advanced again[st] his theory: afterwards, thinking it too prolix, he divided [it] into two small treatises, one of which he entitled, *A Disse[r]tation on the Equilibrium of Fluids;* and the other, *An Ess[ay] on the Weight of the Atmosphere.* These treatises were n[ot] published till after the author's death.

The high reputation which M. Pascal had acquired, caus[ed] him to be looked up to by the most considerable mat[he]maticians and philosophers of the age, who applied for [his] assistance in the resolution of various difficult questions a[nd] problems. Among other subjects on which his ingenu[ity] was employed, was the solution of a problem suggested [by] Mersenne, which had baffled the penetration of all who h[ad] attempted it; this was to determine the curve described [in] the air by the nail of a coach-wheel, while the machine [is] in motion; which curve was at that time known by the na[me] of the *roullette*, but is now designated the *cycloid.*

Before this time he had drawn up a table of numbers, wh[ich,] from the form in which the figures were disposed, he ca[lled] his *Arithmetical Triangle.* He might perhaps have bee[n] ıventor of it, but it is certain that it had been treated of, century before Pascal's time, by Cardan, and other arithıetical writers.

When M. Pascal was in the twenty-fourth year of his age, nd the highest expectations were formed of the advantages o be attained in science from his labours, he on a sudden enounced the study of mathematics, and all human learning; evoted himself wholly to a life of mortification and prayer; nd became as great a devotee as almost any age has prouced. He was not, however, so completely abstracted from ne world, as to be wholly indifferent to what was passing in ; and in the disputes between the Jesuits and the Jansenists, he became a partisan of the latter, and wrote his elebrated *Provincial Letters*, published in 1656, under the ame of Lewis de Montalte, in which he only employed his alents of wit and humour in ridiculing the former. These etters have been translated into almost all the European anguages, and probably nothing did more injury to the cause f the Jesuits. The course of life which he prescribed to imself, proved unfavourable to his health of body and mind. His reason became in some measure affected, and in these ircumstances, an accident produced on his mind an impresion which could not be effaced. In 1654, while he was rossing the Seine in a coach-and-four, the two leading orses became unmanageable at a part of the bridge where he parapet was partly down, and plunged over the side into he river. Their weight fortunately broke the traces, by which means the other horses and the carriage were extriated on the bank of the precipice. In his then enfeebled tate, this fright was too much for the unfortunate Pascal; nd so serious were its effects on him, that he never afterwards had the possession of his mental faculties. He always magined that he was on the edge of a vast abyss on the left ide of him, and he would at no time sit down till a chair was placed there, to assure him there was no real danger. After languishing some years in this miserable state, he died t Paris in 1662, at the age of 39.

PASSAGES, the avenues or accesses which lead to the various apartments of a building.

Passages must always be convenient to give ready access, nd proportional in width and height to the magnitude of the ther apartments, and with suitable decorations.

PASTIL, or PASTEL, (from the Latin *pastillus*,) among ainters, &c. a sort of paste, made of several colours ground p with gum-water, either together or separately, in order to ıake crayons, to paint with on paper or parchment.

PASTOPHORIA, (Greek) in antiquity, apartments near ıe temples, for lodging the pastophori, or priests, whose usiness it was, at solemn festivals, to carry the shrine of the eity.

Clemens Alexandrinus, describing the temples of the gyptians, says, that "after having passed through magificent courts, you are conducted to a temple, which is at ıe farther end of these courts, and when a pastophorus ravely lifts up the veil, which is the door, to show you the eity within, which is nothing but a dog or a cat, or some ther animal." Apuleius speaks of the pastophori that cared the Syrian goddess.

In the temple of Jerusalem there were two courts surounded with galleries, and round about were several lodgingooms for the priests to lay up wood, wine, oil, salt, meal, pices, incense, vestments, valuable vessels, and provisions, ecessary for the sacrifices and lamps, as also for the support nd maintenance of the priests. *See* 1 Chron. ix. 26, 33; xvi. 16. Ezek. xl. 17, 18.

PASTORAL-STAFF, the official staff used by a bishop. ee CROZIER.

PATE, in fortification, a kind of platform, like what they call a horse-shoe; not always regular, but generally oval, encompassed only with a parapet, and having nothing to flank it. It is usually erected in marshy grounds, to cover a gate of a town, or the like.

PATEN, a plate or salver employed in the eucharist.

PATERA, (from *pateo*, I am open,) among antiquaries, a goblet, or vessel, used by the Romans in their sacrifices, in which they received the blood of their victims, offered their consecrated meats to the gods, and made libations.

On medals, the patera is seen in the hands of several deities; and frequently in the hands of princes, to mark the sacerdotal authority joined with the imperial, &c. Hence F. Joubert observes, that besides the patera, there is frequently an altar, upon which the patera seems to be pouring its contents.

The patera is an ornament in architecture, frequently introduced in friezes, fascias, and imposts, over which are hung festoons of husks or flowers; or they are sometimes used by themselves, to ornament a space; and in this case it is common to hang a string of husks or drapery over them; sometimes they are much enriched with foliage, and have a mask or head in the centre.

In vol. xiv. of the Archæologia, a description and plate are given of a Roman patera and vase dug up when sinking a ditch in Essex, in June, 1800. They were found near an ancient Roman road, between Camelodunum and Camboritum. "The metal vase and patera merit attention, as none similar to the first have been figured or described in the works of the society; nor do I know that any like either have been presented for their inspection. The vase is of that form which Montfaucon has figured in his 2d. vol., pl. 19, fig. 10, and calls a *præfericulum*, used by the Romans at their sacrifices, for pouring wine into the patera. *See* p. 88, where he controverts Festus's opinion that the præfericula were without handles. Another, more nearly resembling that here represented, is given in his 3d. vol., pl. 24, fig. 9, and called by Beger an *epichysis*, but not allowed to be such by Montfaucon. The metal patera which belongs to the above, differs from the earthen pateræ in general, by being bossed in the centre, a circumstance not easily to be accounted for, unless it was for the firmer fixing the præfericulum upon, when placed with the body at the time of interment." With the above Roman antiquities were found several little cups of Samian ware. "The uses of these elegant little cups have not," the antiquary continues, "that I know of, been ascertained by any author. The real purposes to which they were applied must remain at present in obscurity."

It may be stated, also, that the Hindoos, in their sacrifices and ceremonies, have immemorially used, and still use, articles exactly similar to those described in vol. xiv. of the Archæologia, plates 1 and 5; and it is curious to see how nearly they agree in form. A comparison of the article in the plates just adverted to, with those in plates 83, 86, and 105 of the Hindoo Pantheon, will strikingly evince this. The *sacrificial vase*, in the latter plate, has the same form, though more elaborately ornamented, as the above described præfericulum; and the others exhibit metallic circular pateræ, and the central embossment, which, though "not easily accounted for," is found among Hindoo mystics to have very profound allusions. The Roman patera has also the mysterious rim, or *yoni*, respecting which the reader may consult the work last referred to. Dr. Clarke, in his Travels, notices that "the patera used by priestesses in the rites of Ceres, had this pyramidal node or cone in the centre. A priestess is represented holding one of these, on a bas-relief, in the vestibule of Cambridge University library." Vol. ii., p. 334. Greek

Marbles, No. xv., p. 37. Similar articles are still used in the rites of the Hindoo Ceres; as are also the "little cups" described and exhibited in the Archæologia, as above referred to, and in many of the plates of the Hindoo Pantheon. In India, they are used for holding clarified butter, a common ingredient in the frequent oblations to fire; and unguents, and holy water, in the *sradha*, or funeral obsequies, and in other rites and ceremonies.

PATERNOSTERS, in architecture, a sort of ornaments in form of beads, either round or oval, used on baguettes, astragals, &c.

PAVEMENT, (from the Latin *pavimentum*, derived from *pavire*, to make the earth firm and strong by beating,) a layer or stratum of stone, or other matter, serving to cover and strengthen the ground of divers places, for the more commodious walking on, or for the passage of carriages.

The paving of streets is one of the most beneficial regulations of police that have been transmitted to us from our ancestors. Several cities had paved streets before the commencement of the Christian era; nevertheless, those which are at present the ornament of Europe (Rome excepted) were destitute of this great advantage till almost the twelfth or thirteenth century. It is probable that those people who first carried on the greatest trade, were the first who paid attention to have good streets and highways, in order to facilitate that intercourse which is so necessary to keep up the spirit of commerce. Accordingly, we are told by Isidorus (*Origin.* lib. xv. cap. 16), that the Carthaginians had the first paved streets, and that their example was soon copied by the Romans. Long before that period, however, Semiramis paved highways, as appears by the vain-glorious inscription which she herself caused to be put up (Strabo, lib. 16. Diod. Sicul. lib. ii. v. 13. Polyæni, *Stratagem*, lib. viii. cap. 26.) The streets of Thebes, and probably those of Jerusalem, were paved; but neither the streets of Rome nor the roads around it were paved during the time of its kings. In the year U. C. 188, after the abolition of the monarchical form of government, Appius Claudius, being then censor, constructed the first real highway, called after him the *Appian Way*, and, on account of its excellence, the *queen of roads*. The time when the streets were first paved cannot be precisely ascertained; some have referred this improvement to the year 578, after the building of the city; others to 584; and others to 459; at which several periods some parts of the city and suburbs might have been paved. That streets paved with lava, having deep ruts made by the wheels of carriages, and raised banks on each side, for the accommodation of foot-passengers, were found both at Herculaneum and Pompeii, is well known.

Of modern cities, the oldest pavement is commonly ascribed to that of Paris; but it is certain that Cordova, in Spain, was paved so early as in the middle of the ninth century, or about A. D. 850. The capital of France was not paved in the twelfth century, but the orders for this purpose were issued by the government in the year 1184, on which occasion it is said that the name of Lutetia, deduced from its dirtiness, was changed into that of Paris. Nevertheless, in the year 1641, the streets in many quarters of Paris were not paved. That the streets of London were not paved at the end of the eleventh century is asserted by all historians. It does not appear when paving was first introduced; but it was gradually extended as trade and opulence increased. Several of the principal streets, such as Holborn, which are at present in the middle of the city, were paved for the first time by royal command, in the year 1417; others were paved under Henry VIII.; some in the suburbs in 1544: others in 1571 and 1605: and the great market of Smithfield in 1614.

In England, the pavements of the principal streets &c., are made of various descriptions of materials, according to the kind of stone most readily procured. In London, Aberdeen granite, broken-stone, &c. are used. Wood and asphalte have also been used to a great extent. Courts, stables, kitchens, halls, churches, &c. are paved with tiles, bricks, flags, or fire-stone; sometimes with a kind of free-stone, and rag-stone.

In some cities, as at Venice, the streets, &c. are paved with brick; churches sometimes are paved with marble, and sometimes with mosaic work, as the Church of St. Mark, at Venice. In France, many of the public roads, streets, courts, &c., are paved with *gres*, or *grit*, a kind of free-stone.

In Amsterdam, and the chief cities of Holland, they call their brick pavement the *burgher-master's pavement*, to distinguish it from the stone or flint pavement, which usually takes up the middle of the street, and which serves for carriages; that which borders it being for the passage of people on foot.

The several kinds of pavement are as various as the materials of which they are composed, and whence they derive the name by which they are distinguished; as,

1. *Pebble-paving*, which is done with stones collected from the sea-beach, mostly brought from the islands of Guernsey and Jersey; they are very durable, indeed, the most so of any stone used for this purpose. They are used of various sizes, but those which are from six to nine inches deep are esteemed the most serviceable. When they are about three inches deep, they are denominated *bolders* or *bowlers;* these are used for paving court-yards, and other places not accustomed to receive carriages with heavy weights: when laid in geometrical figures, they have a very pleasing appearance.

2. *Rag paving* was formerly much used in London, but is very inferior to the pebbles; it is dug in the vicinity of Maidstone, in Kent, from whence it has the name of Kentish rag-stone; there are squared stones of this material fo paving coach-tracks and foot-ways.

3. *Purbeck pitchens;* squared stones used in foot-ways they are brought from the island of Purbeck, and als frequently used in court-yards; they are in general from si to ten inches square, and about five inches deep.

4. *Squared paving*, for distinction by some called *Scotc paving*, because the first of the kind paved in the manne that has been, and continues to be paved, came from Scotland the first was a clear close stone, called *blue wynn*, which now disused, because it has been found inferior to other since introduced, in the order they are hereafter placed.

5. *Granite of various kinds*, as:—

First—Guernsey Granite, a very close, hard, and durab stone, exceedingly well adapted for pavement, but subje to become polished, and consequently slippery. It is th kind of slipperiness which, for distinction sake, may called *dry*, as if black-lead had been rubbed upon it.

Second—Heron Granite; not so fine in its grain Guernsey, but very close, hard, and durable. Its defect a tendency to become *greasily* slippery—a very dangerc quality as respects the foot-passengers.

Third—Mount Sorrel Stone. This stone is pronounc by mineralogists to be not a Granite, but a Sienite. I extremely close, hard, and durable, and it has the r quality of neither becoming dryly nor greasily slippery. has all the very best qualifications of good paving-stone, (and it is a drawback of some importance) its intense ha ness makes it brittle under the hammer when be re-dressed.

Fourth—Aberdeen Granite. That which is commo ırmed the Old Blue Aberdeen, is a very fine stone, not so ırk in colour, more brilliant in appearance, almost as close texture, and equally durable, under wear, as the best uernsey stone; but there is sometimes a difficulty in)taining an ample supply for the London market. The ranites from Aberdeen vary much in colour and in texture ren in the same paving-stone, one end being often much inrior to the other.

Fifth—The Tyar Baggar Stone, also from Aberdeen, is dder in colour, and, although beautifully brilliant and close, ıd apparently hard, is decidedly inferior in durability to the ld Blue Aberdeen.

Sixth—The Foggintor Devonshire Granite is not, in its pearance, equal to Aberdeen, but there is an equality and ughness in its composition, which, as far as experience it has gone, leads us to consider it durable and servicele.

Seventh—The Haytor Devonshire Granite, perhaps from eater inequality of texture, has not proved so durable.

Eighth—The White Rock, a Cornish Granite, has worn ceedingly well in some streets of London.

The Cornish Granites are, however, generally too soft for e as paving-stones.

All these stones are less slippery than Guernsey or Hermme.

Ninth—The Budle Stone, from Northumberland, and the st of the Red and the Blue Scotch whinstones, scarcely now ke their appearance. They are very good stones.

An extremely dark-green Whinstone, from near Queensry, has been manufactured into curbstone and paving-stone, t it is decidedly too soft for use, for either purpose. Vari- kinds of limestone, or coarse marble, and ragstones and)bles, are used in provincial places, as they formerly were the streets of London; they are not now sent to the tropolis in any quantity.

. *Purbeck paving*, for footways, is, in general, got in large faces, about two inches and a half thick; the blue sort is hardest and the best of this kind of paving.

. *Yorkshire paving* is an exceedingly good material for same purpose, and is got of almost any dimensions, of the ıe thickness as the Purbeck; this stone will not admit the to pass through it, nor is it affected by the frost.

. *Ryegate*, or *fire-stone paving*, is used for hearths, stoves, ns, and such places as are liable to great heat, which does affect this stone, if kept dry.

. *Newcastle flags*, are stones about two feet square, and and a half or two inches thick; they answer very well paving out-offices; they are somewhat like the Yorke.

0. *Portland paving*, with stone from the island of Portl; this is sometimes ornamented with black marble s.

1. *Sweedland paving*, is a black slate, dug in Leicestere, and looks well for paving halls, or in party-coloured ing.

2. *Marble paving*, is mostly variegated with different rbles, sometimes inlaid in mosaic.

3. *Flat brick paving*, done with brick laid in sand, tar, or grout, as when liquid lime is poured into the ts.

4. *Brick-on-edge paving*, done with bricks laid edgewise he same manner.

5. Bricks are also laid flat or edgewise in herringe.

6. Bricks are also sometimes set endwise in sand, tar, or grout.

7. Paving is also performed with paving-bricks.

18. With ten-inch tiles.

19. With foot tiles.

20. With clinkers, for stables and out-offices.

21. With the bones of animals, for gardens, &c. And,

22. We have nob-paving, with large gravel-stones, for porticoes, garden-seats, &c.

By most writers, common stone pavements are divided into two classes: *rubble* causeway, in which the stones are of irregular shape, and very imperfectly dressed with the hammer; and *aisler* causeway, which is formed of stones of larger size accurately squared and dressed. In both kinds the excellence of the pavement depends greatly on the firmness and evenness of the bed, and the careful fitting of the stones to each other, which may be accomplished with very irregular stones by judicious selection. If one stone be left a little higher or lower than those adjoining it, or if it become so in consequence of defective building, the jolting of carriages in passing over the defective place, will quickly damage the pavement; the wheels acting like a rammer in driving the depressed stones deeper into the earth, while the derangement of the lateral support that each stone should receive from those adjoining it, occasions the dislocation of the pavement to a considerable distance, and the consequent working up of the earth through the disturbed joints. Defective joints form another fruitful source of injury and inconvenience both to the pavement itself and the vehicles jolted over it. If, as is often the case in inferior pavements, the edges of two adjoining stones do not meet with accuracy, narrow wheels will have a tendency to slip into the joint, and by doing so, to wear the edges of the stones, till, as may be frequently seen, the surface of each stone is worn into a convex that renders the footing of horses insecure, and causes the motion of vehicles drawn rapidly over them to consist of a series of bounds or leaps from one stone to another, accompanied by a degree of lateral slipping highly injurious to the carriage, while the irregular percussion produced tends greatly to the destruction of the pavement.

The formation of the bed on which the stones are to rest is of great importance, and various substances, as sand, gravel, broken-stone, &c., have been used by paviours for this purpose; the general introduction of concrete, however, has removed the difficulty formerly experienced, as, by means of this valuable composition, a firm, hard, and dry foundation is easily obtained.

The bed of the pavement should be laid with concrete.

For paving stones, hard rectangular blocks of granite are preferred, though whinstone, limestone, and even free-stone, may be used. Guernsey granite, as we have shown, appears to be the most durable, but it is more liable to become inconveniently smooth than some stones of inferior hardness. The stones may vary according to the traffic, from 6 to 10 inches deep, 6 to 18 inches long, and 4 to 18 inches wide; but it is very essential that the depth of all the blocks in one piece of pavement should be alike, and that where the width is unequal, the stones may be so sorted that all used in one course are uniform in this particular. The accurate dressing of the stones is a point often too little attended to; and an injudicious mode of forming contracts for paving, in which the payment has been by the square yard of paving laid, has, in connection with the effect of competition in bringing prices below the remunerating point, led to the use of stones in which the base is smaller than the upper surface, and which, when laid, scarcely come in contact with each other except at their upper edges. In some pavements the stones are made smaller at the top than at the bottom, the joints being filled up with stone-chips, concrete, or an asphaltic composition; and in those of the more common construction, the sides of the stones are occasionally hollowed, so as to receive a small quantity of gravel or mortar, which serves as a kind of dowelling. Ramming the stones with a heavy wooden rammer is a practice that has been much recommended, and it is considered that a more efficient application of the process, by means of a ramming machine, or *portable monkey*, would remove some of the defects arising from imperfect bedding; but when the stones are well laid, and bedded in strong mortar, as the best recent pavements are, a few blows with a wooden maul, of about fourteen pounds weight, are sufficient to fix them firmly in their place. Grouting with lime-water, poured all over the pavement, facilitates the binding of the whole together, and fills up the joints, so as effectually to prevent the working up of the substratum. The blocks are commonly laid in rows across the road, the joints in each row being different from those of the adjoining ones; but pavements of superior smoothness have been laid in courses stretching diagonally across the street, by which means all the joints are passed over by carriages with greater ease. This arrangement is particularly desirable at the intersection of streets, as it diminishes the risk of horses slipping. Longitudinal courses are objectionable, on account of the tendency of narrow wheels to enter the joints. In paving steep inclinations, it is well to use narrow stones, on account of the number of cross joints; or if large stones be used, to cut deep furrows across their surface, to afford secure footing.

The enormous expense of maintaining some of the great metropolitan thoroughfares, led to the introduction of various plans for paving with wood, asphalte, and other materials. Of these, with the exception of wood, little need be said, as a very short trial of any of them proved that they were not suited to bear the wear of London traffic. Wood-pavement, however, has been tried on so large a scale, and though not equal to broken granite, or a well-paved road, for durability, has yet so many advantages, that some account of it seems necessary. The most primitive descriptionof a wooden road, perhaps, is that known in America by the name of *corduroy road*, consisting of rough logs of timber laid close together across the track, but the wooden pavement, properly so called, seems to have been first used in Russia, and tried on a limited scale at Vienna, New York, and some other places. One of the earliest kind used consisted of blocks of fir or other wood cut in hexagonal cylinders of six or eight inches diameter, and from eight to twelve or fifteen inches deep, and placed close together, with the grain vertically. Such a pavement is smooth when first laid, but, unless the foundation be very carefully prepared, it is liable to sink into hollows like the common stone-pavement, owing to the want of cohesion between the individual blocks, a deficiency which it has been proposed to remedy by pegging or dowelling the pieces together, though their form is not very suitable for the purpose. Of the numerous other plans of wood-paving proposed, but one has been tried on an extensive scale, that of the Metropolitan Patent Wood-Paving Company. The mode of paving by this Company was invented by the Count de Lisle. In this the blocks are sawn into a rhomboidal shape, the upper surface forming an angle of about 65° with the direction of the grain, by which the durability of an end-section is in a great degree preserved, while the inclination of the sides causes each block to receive support from those adjoining it, and affords facilities for pinning the whole paving together by pegs. One course, or transverse row of blocks being laid so that they all incline in one direction, each block has on one side two projecting pegs, and on the other, two holes. The adjoining course is laid in like manner, but sloping in the opposite direction. By this disposition the two pegs on one side of a block enter two distinct blocks in the adjoining row, while the holes on the other side receive in like manner the pegs of two other blocks, so that each block is pinned to four others, besides receiving support from the adjoining blocks of its own course. Where this principle of construction is fully carried out, the whole pavement of a street becomes, as it were, one mass, being so pinned together that no block could be raised without breaking the dowels; but as it is necessary sometimes to disturb the pavement in order to get at the gas and water pipes, the practice of this Company has been to lay down the wood in masses of twenty-four or thirty-six blocks, so united by iron cramps that the blocks, thus connected together, may be laid down and taken up when necessary, at once. This sort of pavement is always laid on a well-formed foundation of concrete, about six inches deep.

Wood-pavement has been laid, to a great extent, in the principal thoroughfares of London, and in many provincial towns. Its undeniable advantages were its smoothness when first laid, producing great ease of draught, quietness, and cleanliness, but, on the other hand, its slipperiness rendered it, in some states of the weather, extremely dangerous to horses. Besides this objection, unless kept in a very high state of repair, it became rough and uneven, and if so kept, its expense was quite equal to a good broken-stone road, and much more so than a well-paved granite road.

The advocates of wood-pavement, however, have been obliged to abandon, in a great measure, its use for the public streets, and from these it is gradually disappearing, though it is still retained, and extensively used, for stables, warehouses, railway stations, &c.; in such places it answers exceedingly well, and is, perhaps, the best description of paving that can be adopted.

Foot-pavements of flag-stones require very little remark. The curb-stones should be very hard, and firmly set in cement, or in a bed of gravel or concrete. They should be set from four to six inches above the surface of the carriage-way, which may be made to abut immediately upon them without the intervention of a gutter. Where gutters are introduced, cast iron ones have sometimes been used; but in our opinion, dressed granite stone channels are to be preferred. The flag-stones, which should never be less than two inches and a half thick, are commonly bedded in mortar in a layer of gravel; but sometimes, when there are no cellars underneath, are laid dry. A slight degree of slope should be given to the pavement, to conduct water to the gutters, for which purpose a fall of one inch in ten feet is sufficient; while a steep inclination is objectionable from its danger in slippery weather. The best material for foot-pavements is Yorkshire stone.

Among the substitutes for common flagstones that hav been recommended, may be mentioned slate, which appear to be very durable. Some pavements or floors of thi material have been laid at the London Docks, where, amon other advantages, it is found preferable to wood in point o cleanliness. Tramways of slate two inches thick are foun strong enough to bear waggons or carts with four or five ton of goods; and some are laid, of only half that thickness, o an old wooden floor.

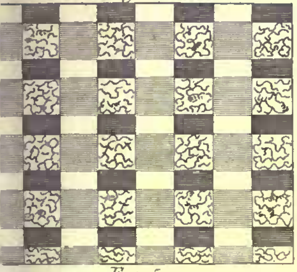
Several descriptions of asphalte have also been used f footways with various success. The best is that known Claridge's Asphalte of Syssel; this answered extremely we though not equal to Yorkshire stone. It has been us extensively for footways in railway stations and similar sit ations, for which it is well adapted.

PAVEMENT OF TERRACE, that which serves f covering in manner of a platform; whether it be over a va or a wooden floor. Those over vaults are usually of ston

PAVEMENT.

PLATE

Fig. 1.



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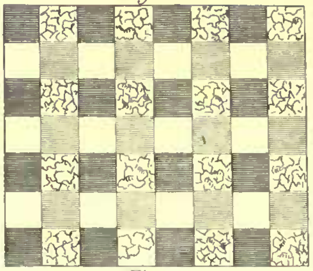

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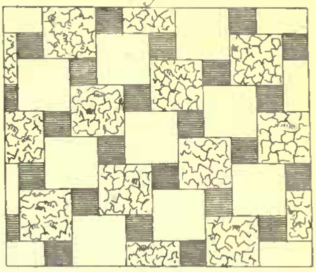

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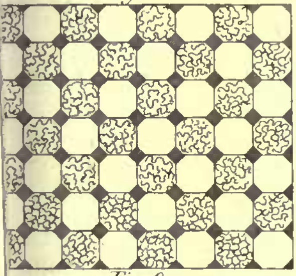

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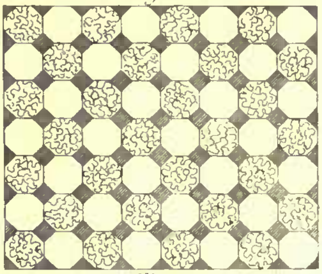

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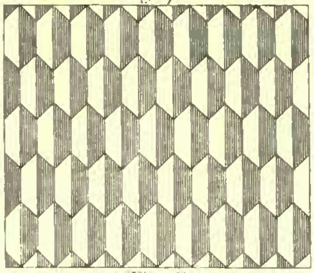

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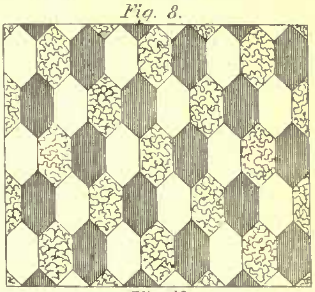

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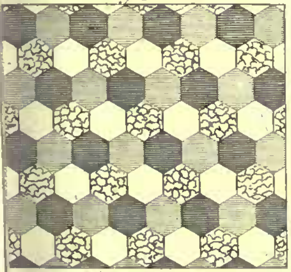

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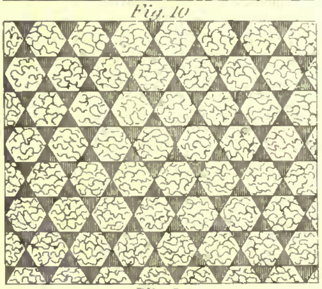

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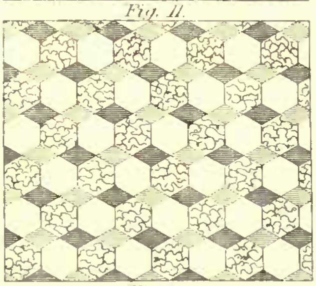
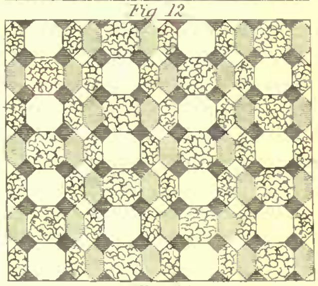


Fig. 12



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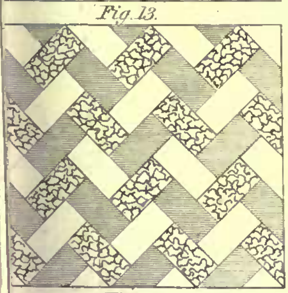

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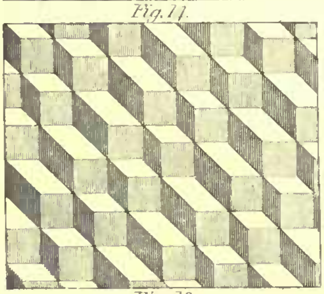

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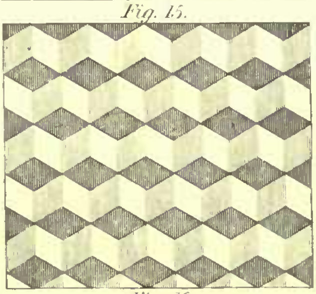

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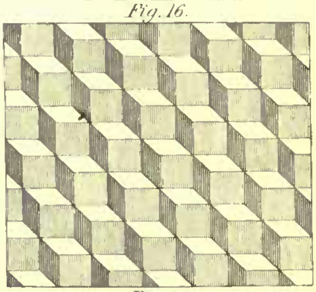

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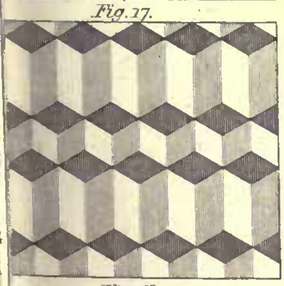

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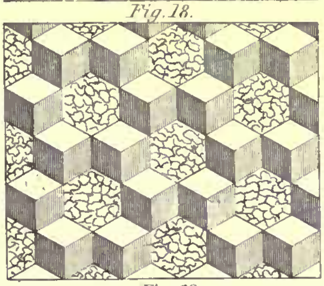

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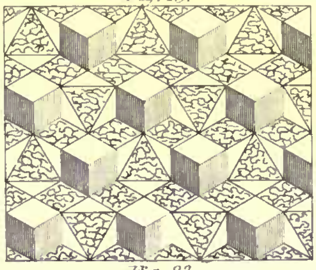

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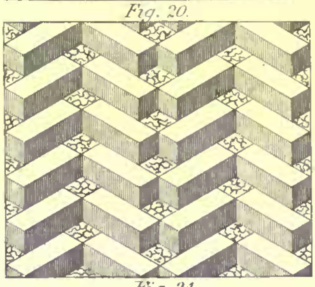

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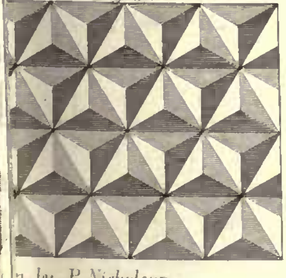

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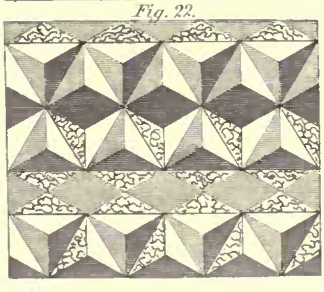

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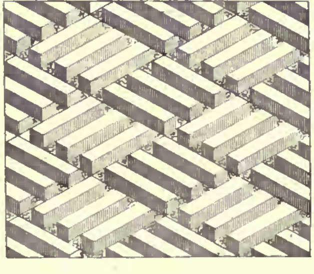

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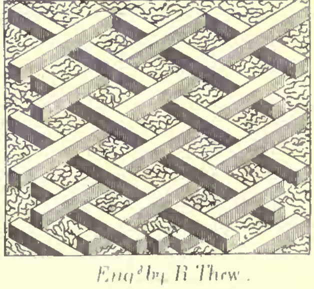

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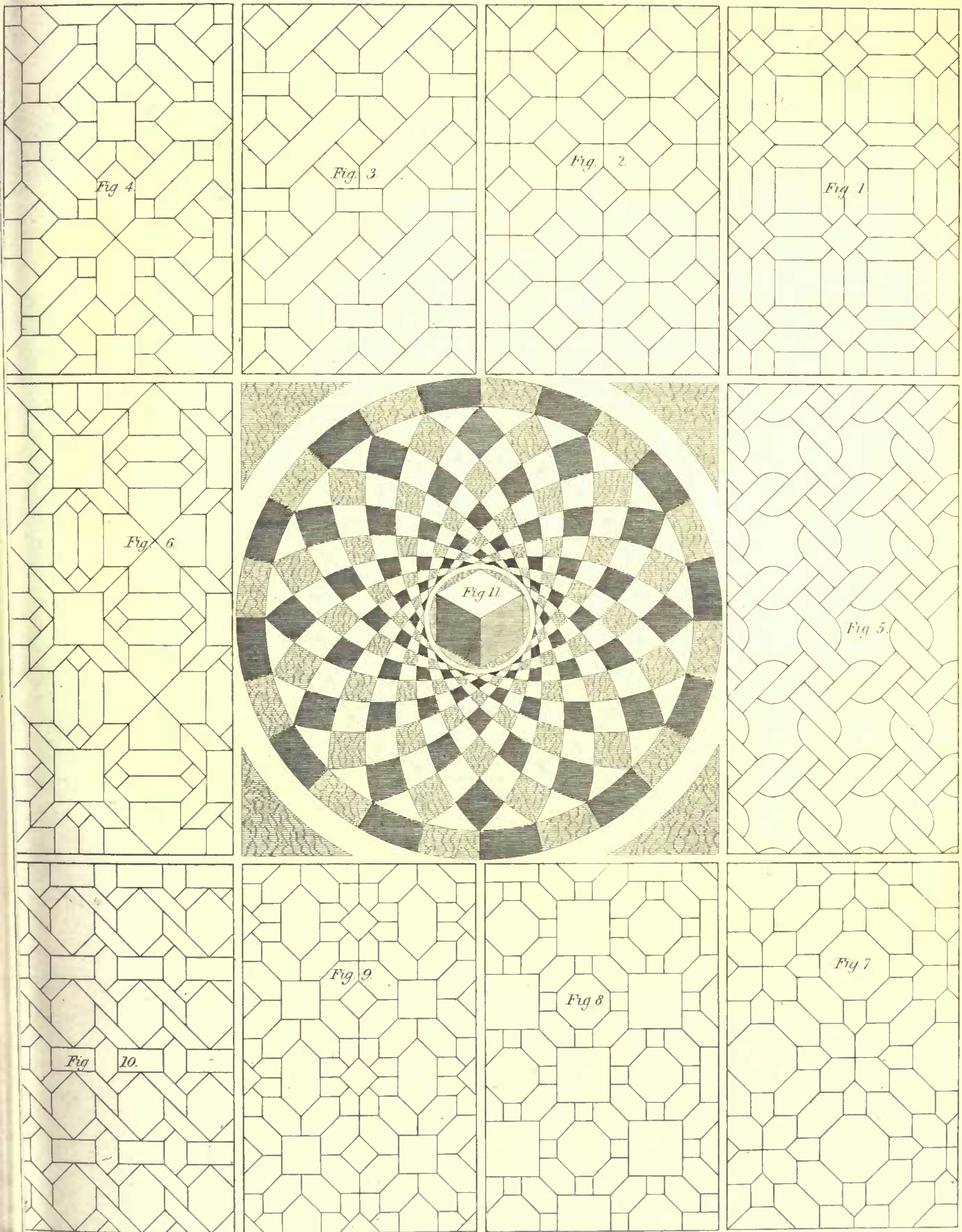
PAVEMENT.

PLATE II



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PAVEMENT.

Fig. 1.

Fig. 2

Fig. 3.

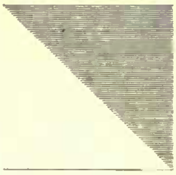

Fig. 4.

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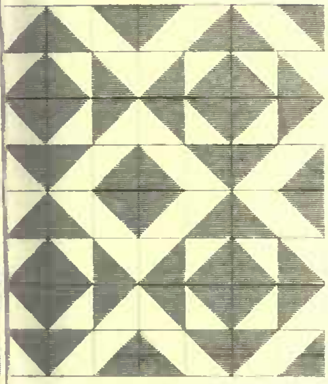

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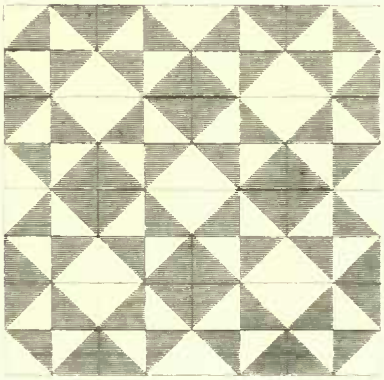

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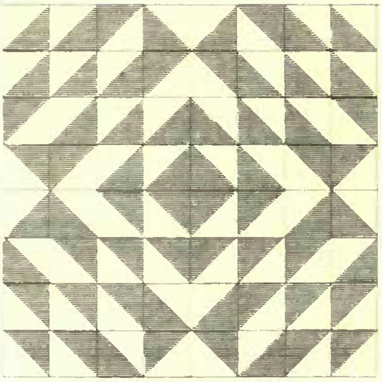

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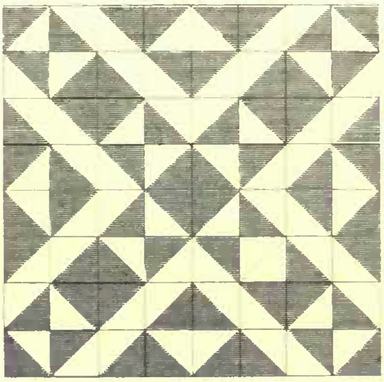

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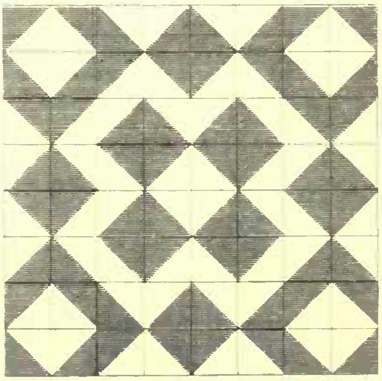

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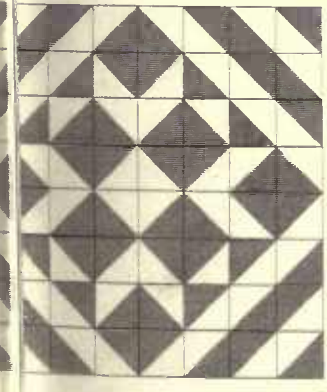

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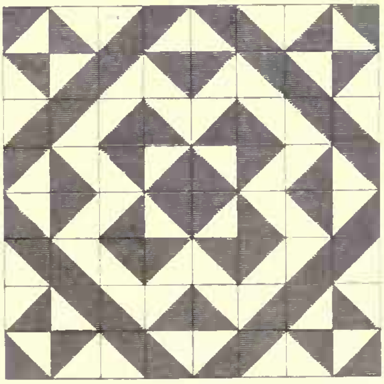

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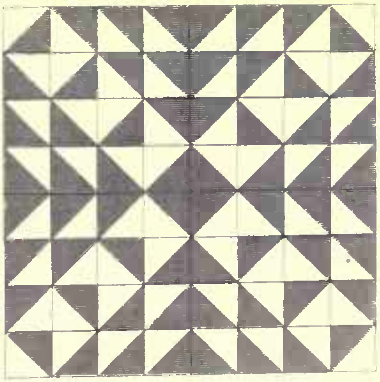


squared and bedded in lead. Those on wood, called by the Latins, *pavimentum contignata*, are either stones with beds for bridges, tiles for ceiling of rooms, or lays of mortar made of cement and lime, with flints or bricks laid flat, as is still practised by eastern and southern nations on the tops of houses. All those pavements which lie open, were called by the Latins, *pavimenta subdialia.*

Pavement, Diamond, those pavements of which the stones, flags, or bricks, are laid with their diagonals parallel and perpendicular to the sides of the apartment.

PAVILION, (French, from the Italian, *padiglione, a tent;* derived from the Latin, *papilio*) in architecture, a kind of turret, or building usually insulated, and contained under a single roof; sometimes square, and sometimes in form of a dome; and thus called from the resemblance of its roof to a tent.

Pavilions are sometimes also projecting parts, in the front of a building, marking their middle. Sometimes the pavilion flanks a corner, in which case it is called *an angular pavilion.* The Louvre is flanked with four pavilions. They are usually higher than the rest of the building.

There are pavilions built in gardens, popularly called *summer-houses*, *pleasure-houses*, &c. Some castles or forts consist only of a single pavilion.

PAUTRE, ANTONY LE, in biography, an eminent French architect, born at Paris in 1614, who distinguished himself by his taste in the decoration of buildings. Several edifices from his designs were erected in the capital and its neighbourhood, of which the most noted were the wings of St. Cloud, the church of the nunnery of Port-Royal, and the hotels of Gevres and Beauvais. He was appointed architect to the king's brother, and afterwards to the king himself. He was a member of the Academy of Architecture from its first institution, and published a work on that art, intitled *Les Œuvres d'Architecture d'Antoine le Pautre*, of which the first edition appeared in 1652. He died in 1691. His son Peter was eminent as a sculptor.

PAX, a small tablet, generally of metal, with a handle used for the *osculum pacis*, or kiss of peace.

PEDESTAL, (from the Latin, *pes, pedis, foot*, and *ςυλος, column*) in architecture, the lowest part of an order of columns; being that which sustains the column, and serves it as a foot to stand on.

The pedestal, called by the Greeks *stylobates*, and *stereobates*, consists of three principal parts: viz., a square trunk, or dye, which makes the body; a cornice, the head; and a base, the foot of the pedestal.

The pedestal is properly an appendage to a column; not an essential part thereof; though M. Le Clerc thinks it is essential to a complete order.

The proportions or ornaments of the pedestal are different in the different orders: Vignola, indeed, and most of the moderns, make the pedestal, and its ornaments, in all the orders, one-third of the height of the column, including the base and capital: but some deviate from this rule.

M. Perrault makes the proportion of the three constituent parts of pedestals the same in all the orders, viz., the base one-fourth of the pedestal; the cornice an eighth part; and the socle, or plinth, of the base, two-thirds of the base itself. The height of the dye is what remains of the whole height of the pedestal.

Pedestal, Tuscan, is the simplest and the lowest of all. Palladio and Scamozzi make it three modules high; Vignola five. Its members, in Vignola, are only a plinth, for a base; the dye; and a talon crowned, for a cornice. This has rarely any base.

Pedestal, Doric, Palladio makes four modules five minutes high; and Vignola, five modules four minutes.

In the antique, we not only do not meet with any pedestals, but even not with any base, in the Doric order.

The members in Vignola's Doric pedestal are the same with those in the Tuscan, with the addition of a mouchette in its cornice.

Pedestal, Ionic, in Vignola and Serlio, is six modules high; in Scamozzi five; in the temple of Fortuna Virilis it is seven modules twelve minutes. Its members and ornaments are mostly the same with those of the Doric, only a little richer. The pedestal now usually followed, is that of Vitruvius, though we do not find it in any work of the antique. Some, in lieu hereof, use the attic base, in imitation of the ancient.

Pedestal, Corinthian, is the richest and most delicate of all. In Vignola it is seven modules high; in Palladio five modules one minute; in Serlio six modules fifteen minutes; in the Coliseum, four modules two minutes.

Its members, in Vignola, are as follow: in the base are a plinth for a socle, over that a tore carved, then a reglet, a gula inverted and enriched, and an astragal. In the dye are a reglet, with a conge over it; and near the cornice a reglet, with a conge underneath. In the cornice is an astragal, a frieze, fillet, astragal, gorge, and a talon. See each under its proper article.

Pedestal, Composite, in Vignola, is of the same height with the Corinthian, viz. seven modules; in Scamozzi six modules two minutes, in Palladio six modules seven minutes, in the Goldsmiths' arch seven modules eight minutes.

Its members, in Vignola, are the same with those of the Corinthian; with this difference, that, whereas these are most of them enriched with carvings in the Corinthian, they are all plain in the Composite. Nor must it be omitted, that there is a difference in the profiles of the base and cornice, in the two orders.

The generality of architects, Daviler observes, use tables, or panels, either in relievo or creux, in the dyes of pedestals, without any regard to the character of the order. Those in relievo, he observes, only fit the Tuscan and Doric; the three others must be indented; but this, he adds, is a thing the ancients never practised, as being contrary to the rules of solidity and strength.

Pedestal, *Square*, that whose height and width are equal; as that of the arch of the lions at Verona, of the Corinthian order; and such some followers of Vitruvius, as Serlio, Philander, &c., have given to their Tuscan orders.

Pedestal, *Double*, that which supports two columns, and is larger in width than height.

Pedestal, *Continued*, that which supports a row of columns without any break or interruption; such is that which sustains the fluted Ionic columns of the palace of the Tuileries, on the side of the garden.

Pedestals or Statues, are those serving to support figures or statues.

Vignola observes there is no part of architecture more arbitrary, and in which more liberty may be taken, than in the pedestals of statues; there being no laws prescribed for them by antiquity, nor any even settled by the moderns.

There is no settled proportion for these pedestals; but the height depends on the situation, and the figure they sustain. Yet, when on the ground, the pedestal is usually two-thirds, or two-fifths, of that of the statue; but always the more massive the statue, the stronger must be the pedestal. Their form, character, &c., are to be extraordinary and ingenious, far from the regularity and simplicity of the pedestals of columns. The same author gives a great variety of forms—oval, triangular, multangular, &c.

PEDIMENT, in architecture, a kind of low pinnacle, serving to crown porticos, or finish a frontispiece; and placed as an ornament over gates, doors, windows, niches, altars, &c.

The pinnacles of the ancient houses, Vitruvius observes, gave architects the first idea of this noble part; which still retains the appearance of its original.

The parts of the pediment are, the tympanum and its cornice. The first is the panel, naked, or area of the pediment, enclosed between the cornice, which crowns it, and the entablature, which serves as a base, or socle.

Architects have taken a great deal of liberty in the form of this member; nor do they vary less as to the proportion of the pediment. The most beautiful, according to Daviler, is that where its height is about one-fifth of the length of its base. The pediment is usually triangular, and sometimes an equilateral triangle; this is also called a *pointed pediment.* Sometimes it is circular; though Pelibien observes, that we have no instances of round pediments in the antique, beside those in the chapels of the Rotunda. Sometimes its upper cornice is divided into three or four sides, or right lines; sometimes the cornice is cut, or open at top, which is an abuse introduced by the moderns, particularly by Michael Angelo. For the design of this part, at least over doors, windows, &c., being chiefly for the purpose of sheltering those underneath from the rain, to leave it open in the middle is evidently to frustrate its end.

Sometimes the pediment is formed of a couple of scrolls or wreaths, like two consoles joined together. *See* CONSOLE.

Sometimes, again, the pediment is without base, or its lower cornice is cut out, all but what is bestowed on two columns, or pilasters, and on these an arch or sweep, raised in lieu of an entablature; of which Serlio gives an instance in the antique, in a Corinthian gate at Foligny, in Umbria; and Daviler, a more modern one, in the church of St. Peter at Rome.

Under this kind of pediments, also come those little arched cornices, which form pediments over doors and windows, supported by two consoles, in lieu either of entablature or columns.

Sometimes the pediment is made double, *i. e.* a less pediment is made in the tympanum of the larger, on account of some projecture in the middle; as in the frontispiece of the church of the great Jesus, at Rome: but this repetition is an abuse in architecture, though authorized by some very good buildings; as may be seen in the large pavilion of the Louvre, where the Caryatides support three pediments, one in another.

Sometimes the tympanum of the pediment is cut out, or left open, to let in light; as we see under the portico of the Capitol, at Rome.

In all the remains of Grecian architecture, the horizontal cornice is never interrupted or broken, nor is there any instance of a circular pediment, nor of any open at the top. The proportion of the tympanum is from one-fifth to one-ninth part of the span, in the pediments which remain of Grecian edifices. In the Doric tetrastyle portico at Athens, the height of the tympanum is about one-seventh part of its triangular base. The portico of the temple of Theseus is hexastyle; and the height of the tympanum of the pediment is about an eighth part of the span of its triangular base. The portico of the temple of Minerva is octostyle; and the height of the triangular tympanum, about one-ninth of its base. So that the higher the pediment, the less is the height in proportion. And thus the pediments of doors and windows ought to be still higher, as is verified in the frontispiece of the entrance-door of the Tower of the Winds, at Athens, where the height of the tympanum is only one-fifth part of the triangular base.

Vitruvius expressly disapproves of the use of dentils, modillions, or mutules, in pediments, for this reason; that as mutules and modillions were the representations of rafters, and dentils the representations of laths, and as these essential parts were always placed in the inclined sides of the roof from the ridge, to overhang the eves, it would certainly have been improper to use mutules, modillions, or dentils, in a situation where the originals themselves never existed.

Arches under pediments, is an abuse in architecture.

PELASGIAN, or CYCLOPEAN ARCHITECTURE. These titles are applied indiscriminately to a class of ancient buildings, to be found in various parts of Greece, which consist principally of walls and fortifications, such as the walls surrounding their acropoles. They are of colossal dimensions, and composed of immense stones, or rather masses of rock, from which circumstance they have obtained the title of Cyclopean, as also because structures of a similar description have been attributed to the labours of the Cyclopes by many of the Greek historians. The erections it is certain are of very early date, and are in all probability of Pelasgic origin, though whether the Pelasgi and Cyclopes are of the same race or not, it would be difficult if not impossible to decide. The Pelasgi, it is well known, were settled in Greece at a very early period, and were spread over the greater part of the country, until the arrival of the Hellenes: it is also very probable that they had emigrated originally from Asia across the Hellespont, and round the northern shores of the Ægean sea. It is true that this is somewhat opposed to the Greek traditions, which make the Peloponnesus the original seat of the Pelasgi; but this is probably but a national boast, and may be classed in the same category as the Athenian claim to the title of *αυτοκθενες*. This matter, however, as well as the whole of the early history of Greece, is involved in great obscurity, and has been the subject of much learned controversy, into which it is not our intention to enter in this place, nor is it at all requisite to the due consideration of the matter before us. There is also a striking similarity in the construction of these edifices, and of those described under CELTIC ARCHITECTURE; but here again it is next to impossible to tell what connection existed between the builders of Stonehenge and those of Argos or Mycenæ, although this circumstance, as well as others, would lead us to suppose that they had a common origin. The investigation of such subjects are interesting, but are attended with great uncertainty. We shall hereafter have occasion to call attention to a particular instance of the similarity existing between buildings of the two classes, which is very remarkable; one of the structures existing in Ireland, the other at Mycenæ.

The Pelasgian buildings are remarkable chiefly, as we have before stated, for the rudeness of their construction, and the enormous dimensions of the stones of which they are composed; indeed, they are little better than piles of rock heaped together, and sustained in their places by their own gravity without the assistance of any cementitious preparation. Mr. Hamilton divides the existing remains into four classes; the earliest and most rude being that in which vast masses of rock were piled one upon the other in the same state as they came to hand, without any squaring or other adaptation for the position they were to occupy. In such masonry, there must have been, of course, apertures of considerable size left between the separate masses, and these were filled up with smaller stones, so as to render the work solid and compact. Of the larger stones, some of the masses are of such vast dimensions, as to contain as much as 216 cubic feet. Of the description are the walls of Tiryns and Mycenæ, although the latter are probably of more recent date than the former, the sides of the stones being somewhat adapted to each other.

In the second method, the stones are somewhat smaller, and are of irregular size and figure, the different stones varying from each other in both respects; but the surfaces of each are adapted to the others with great nicety. It would seem as if the stones, when taken from the quarry, were worked according to the shape in which they happened to be detached from their beds, by reducing the sides to an even surface, but still preserving the general form of the mass. These polygonal stones were generally of seven or eight sides, but sometimes of as many as thirteen; they form a wall of considerable stability and strength.

In the third mode, the stones were laid in horizontal courses, but were of different dimensions, one stone occasionally rising above the level of the adjoining ones, so that the courses were somewhat irregular; the joints, too, were sometimes perpendicular, but at others inclined to the horizon at various angles.

The fourth method comprises walls composed of stones squared on all sides, and of the form of parallelopipedons, layed in regular horizontal courses. In all these methods, the stones were layed dry without any mortar, and yet they are so strong as to have resisted the vicissitudes of three thousand years. Sometimes we find more than one method adopted in the same structure, but this is probably owing to more recent additions or repairs.

Amongst the more noted examples of this mode of building, stand the walls of Tiryns and Mycenæ, and the treasury of Atreus, which we proceed to describe *seriatim;* but we must premise, that we are indebted for the descriptions to the accounts of Stuart and Hughes.

The ruins of Tiryns are probably the oldest and best examples now in existence, and are supposed to have been erected about fourteen centuries B. C. This acropolis is built on a small mount about 50 feet above the level of the plain, and the foundations of the enclosure are still perfect. It had entrances from the east and west, and one at the south-eastern angle. That at the east is still in tolerable preservation, and is approached by an incline, 15 feet wide, along the eastern and southern sides of a tower 20 feet square, and 40 feet high, passing at the end of the second side under a gateway composed of immense blocks of stone; the stone forming the architrave being 10½ feet long. It is thought that there was formerly a triangular stone above the architrave of this portal, forming a kind of pediment; the fragments are now lying on the spot, but without any appearance of having been sculptured. The walls are generally 25 feet thick, and are formed of three parallel ranks of stones, five feet thick, which separate two ranges of galleries in the walls, each five feet broad, and about twelve feet high; the sides of the galleries are formed of two courses of stone, and the covering of other two horizontal courses, which project until they meet.

The roof is pointed when seen from below, the lower surfaces of the stones being cut at an angle of 45 degrees. That part of the gallery which is now uncovered, is about 90 feet long, and has six openings or recesses towards the east, one of which is a kind of window or door, which probably communicated with some exterior building, of which there are still some traces of the foundation in existence; the space between these niches varies from 10 feet 6 inches to 9 feet 8 inches, and the niches themselves are from 5 feet 6 inches to 5 feet 10 inches wide. These galleries probably continued all round the citadel; but they are only accessible at present where the walls are least perfect, at the southern part of the enclosure. They were probably constructed for shelter of the garrison in case of siege, as no loopholes or other apertures open from them into the plain, which would have been the case had they been constructed for any defensive purpose. If the inner gallery received light from the arched area, the exterior must have remained almost dark.

No remains of the south-eastern portal remain: it appears to have been connected with the eastern gate by an avenue enclosed between the outer wall and the inner curtain, yet it is not easy to conjecture the use of this singular place. Others of a similar kind are met with at Argos, and in some other ancient cities of Greece.

The northern point of the hill is less elevated than any other, and its wall is composed of stones of a smaller size than those employed in the galleries. All the exterior walls are composed of rough stones, some of them 9 feet 4 inches in length, and 4 feet thick—their usual size is from 3 to 7 feet. The wall, when entire, must have been about 60 feet high. On the eastern side, the wall has been entirely destroyed, probably by the Argives, about 460 years before Christ, that the city might be left entirely unprotected.

There is a small entrance-gate, in the *pointed* form, 6 feet 1 inch wide, situated in the recess of the western wall; it is defended by a wall projecting in a curve.

The whole length of the citadel is about 660 feet, and the breadth about 180 feet; and the walls are constructed upon a straight line, without any reference to the sinuosities of the rock.

"The Propylæa, or massive portal of the Acropolis of Mycenæ, is one of the most interesting antiquities which time has spared. It is of Cyclopean architecture, constructed with blocks of surprising magnitude, the architrave consisting of a single stone, 15 feet in length, by 4½ in height: two parallel walls, composed of huge masses, piled up in an uncouth manner, which nothing but their size and weight would ever have kept firm, project from the gateway, and form an oblong court about 50 feet deep." "Over the architrave of this portal is one of the most ancient pieces of sculpture existing perhaps in the world; it is cut in high relief upon a triangular stone, the base of which is 11 feet, and the perpendicular height 10, being very similar in appearance to an armorial shield. The subject is an inverted column resting upon a portion of its entablature, between two lions rampant for supporters; each animal stands on a columnar plinth, at equal distances from the pillar, whose inverted pedestal is decorated with a kind of beaded string, consisting of four spherical balls; there is also seen on the frieze of the entablature immediately under the capital of the column, an elliptical excavation, and half the same device appears under each of the plinths on which the lions stand."

To the south of the gate of the lions, the wall of the capital is much ruined. In one part something like a tower is visible, which being perpendicular, while the curtain inclines a little inward from its base, there remained a projection at the top sufficient for an archer to defend the wall below. The blocks of the superstructure are in general of large dimensions, while those of the foundation are considerably smaller.

With the exception of the gates, the whole circuit of the citadel is constructed of rough masses of rock, very accurately adjusted and fitted to each other, though the smaller stones which filled up the interstices have generally disappeared: this style of building has commonly been called Cyclopean. It certainly appears that the walls of the most ancient cities of the Peloponnesus, whether attributed to the Cyclops or not, were of this construction. Tiryns and Mycenæ differ from other acropoles in their galleries and gates, so that perhaps the ponderous method which so nearly resembles the style used by the Egyptians, of which the gate of the lions is the best specimen in Europe, is the real Cyclopean; while the remainder of the circuit is the work of the natives. These fortifications were reputed to be impregnable, and were so in ancient times. At the siege of Mycenæ by the Argives, these warriors found themselves unable to destroy the city, but they forced the inhabitants to surrender through famine. Mycenæ was demolished by the Argives at the time of the destruction of Tiryns; the buildings were overthrown, and the city for nearly 3,000 years has been desolate.

The southern ramparts of the citadel and all the other walls follow the natural irregularity of the precipice on which they are founded. At its eastern point it is attached by a narrow isthmus to the mountain. It is a long, irregular triangle, standing nearly east and west; the walls are mostly constructed of the second style of well-jointed polygons, although the rough construction is occasionally seen.

So small a fortress seems unworthy of the Tirynthian hero; but though the space it occupies is so circumscribed, the walls are truly herculean; their general thickness is 21 feet, in some places they are 25; their present height, in the most perfect part, is 43 feet. In some places there are square projections from the walls, in form of towers; but the projection is very slight: the most perfect of these is at the south-east angle, its breadth is 33 feet, and its height 43 feet.

The construction of the lateral walls is nearly regular, differing from the walls which constitute the peribolus, or boundary, of the acropolis, which are irregular polygons; they are of the hard breccia stone found on the spot, but the block ornamented with the lions resembles in its appearance the green basalt of Egypt. The back or inner part of the gate of the lions is highly interesting, as it exhibits two styles of construction totally differing from each other; that side which is towards the plain of Argos is of the rough Cyclopean masonry, while the other side is regularly constructed like the front of the gate and two lateral walls which diverge from it. It would appear that the gate had been made some time after the original Cyclopean structure. Without presuming to decide whether the regular as well as the irregular or polygonal construction were not sometimes employed at the same period, there are indeed reasons for believing, that while the walls of acropoles, or citadels, and other strong places, were composed of Cyclopean masonry, the temples, sepulchres, and sacred edifices were formed of a more regular construction; as the former were principally adapted to resist the impulse of warlike engines, while the sanctuaries of the gods, and the chambers of the dead, were regarded with reverential awe even by enemies.

A magnificent wall, composed of irregular polygons, closely united and carefully smoothed, supports the terrace on which the gate of the lions is situated.

The area of the acropolis is a long irregular triangle, standing nearly east and west. On the northern side, the declivity also is very steep, and there is a gate which consists of two stones, covered by a third. The opening is 5 feet 11 inches wide at bottom, and 5 feet 4 inches at top. Above the architrave is a large stone approaching the form of a triangle, with which the ruin is about 14 feet high. The gates folded, and were secured by bars. The access to this entrance was by an artificial terrace, which was completely commanded by the wall. A curtain nearly in a right line extends from this gate to that of the lions; and it is very probable that certain holes in the earth above this wall, which are shown by the natives as cisterns, are actually connected with galleries similar to those of Tirynthus. After entering the gate, there was a road, commanded by a wall, which traversed the hill almost to the opposite side before it turned to the summit; so that the acropolis was defended by at least a triple enclosure: on the northern side is a small gate, with its lintel, entire. The structure is so disposed, that those who entered it would have their left arm, which was guarded by the shield, on the side of the acropolis, which is a deviation from the common rule followed in constructing ancient Greek fortresses of all ages. The grooves for the bolts in the jambs of the door are of large dimensions. A deep rocky glen separates the acropolis from the neighbouring hill: there was anciently a bridge over the ravine: one of the side-walls still remains, consisting in well-jointed polygons.

Of the treasury at Atreus, near Mycenæ, which is a very remarkable building, Mr. Hughes gives us the following description, which we would beg the reader to compare with the account of a structure at New Grange, near Drogheda, Ireland, given under CELTIC ARCHITECTURE. It is the opinion of many archæologists that the Titan Celtæ were of the same race as the Cyclops, who built the acropolis of Tiryns.

"Descending down a slope flanked by enormous walls, we arrived at a plain entrance, noble in its simplicity and magnitude; it is 10 feet in breadth by 18 in depth—one of the stones composing the architrave or lintel being a single block, 27 feet long, 16 broad, and 4 deep. Immediately over it is a triangular aperture, which probably contained sculpture appertaining to Egyptian rites; the pyramidal form of the triangle being considered an emblem of the fiery element. The chief apartment of this treasury is a dome, very similar in shape to an English bee-hive, constructed, like the galleries of Tiryns, with large blocks in horizontal courses, each course projecting over the one immediately below it, whilst the interior surface is cut into form by the chisel. The diameter of its area is 47 feet; and at the end of the first quadrant, to the right of the entrance, is a passage leading into an inner room, about 27 feet by 20 in dimensions, the walls of which are not lined with any kind of masonry. This vault, near 50 feet high, is finished at the top by a single stone, like the treasury of Minyas, at Orchomenos; however, it is not a key-stone, for the principle of the arch is unapplied to this peculiar mode of construction. The inner surfaces of the blocks are pierced with holes, from whence many bronze nails have been extracted, which are supposed, not without probability, to have fastened plates of that metal over the interior surface of the edifice, as at the Pantheon, Rome."

The approach to the treasury is 20 feet in width. The blocks of stone composing the larger chamber are laid in regular courses, of which there are thirty-four visible, each course being about two feet in thickness. The stones, however, are not all of equal dimensions, but are united with the greatest precision, and without the aid of cement; they are composed of the hard and beautiful breccia of which the neighbouring rocks almost entirely consist. The entrance to the inner chamber is $9\frac{1}{2}$ feet high, 4 feet 7 inches wide at the base, and 4 feet 3 inches at top: it has also a triangular cavity above, similar to that over the larger chamber. These triangular spaces have been thought by some to be a rude method of relieving the centre of the lintel stone, and throwing the weight upon its ends; but others suppose them to have some mystical allusion, which is not improbable.

Various other examples besides those just described s

PENDENTIVE CRADLING.

Fig. 1.

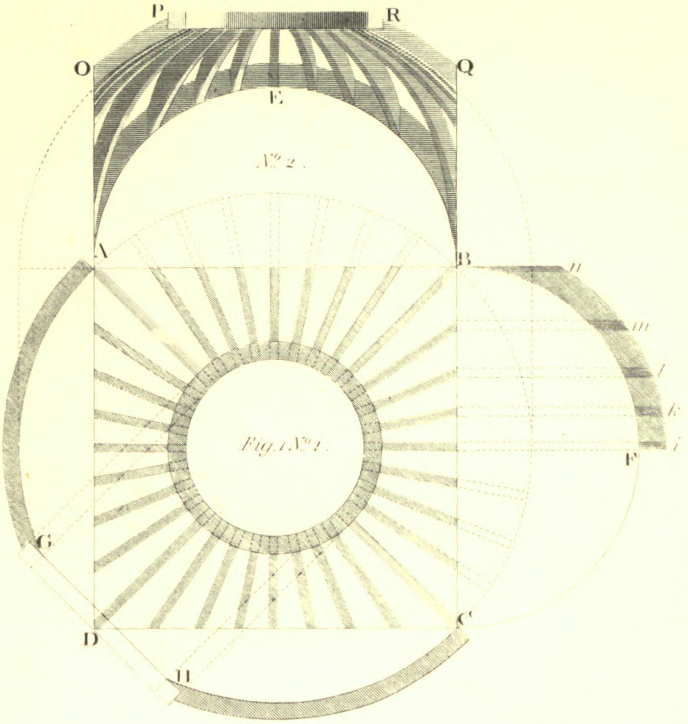
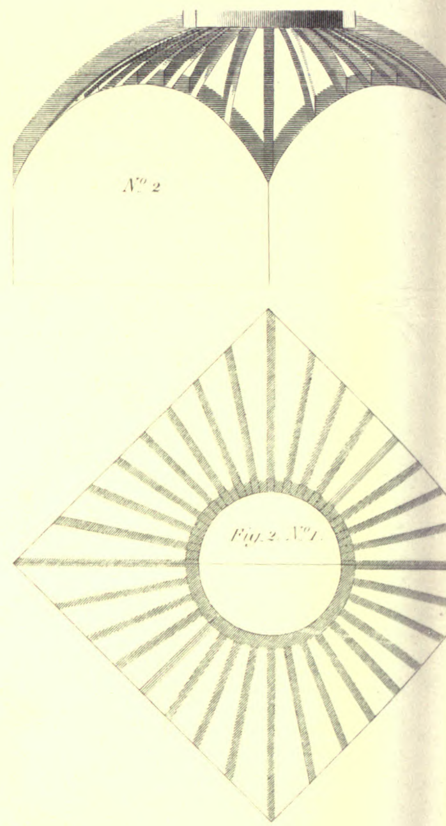
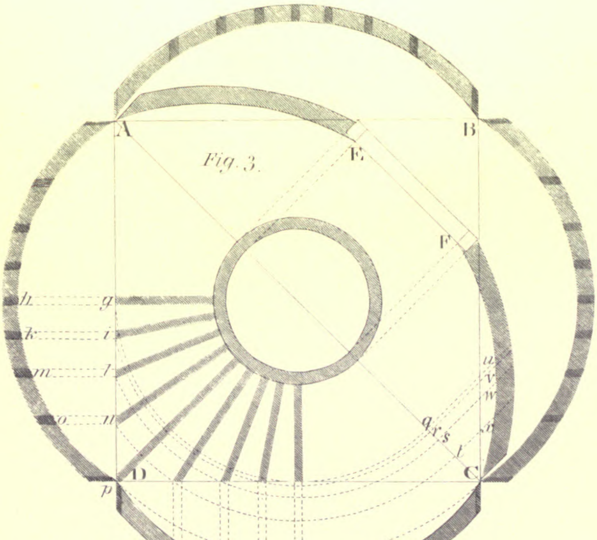
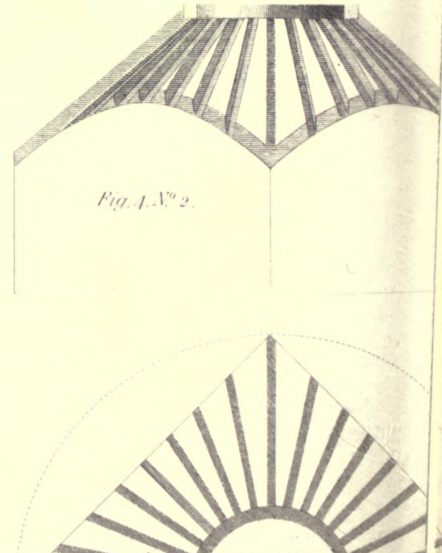


Fig. 2.







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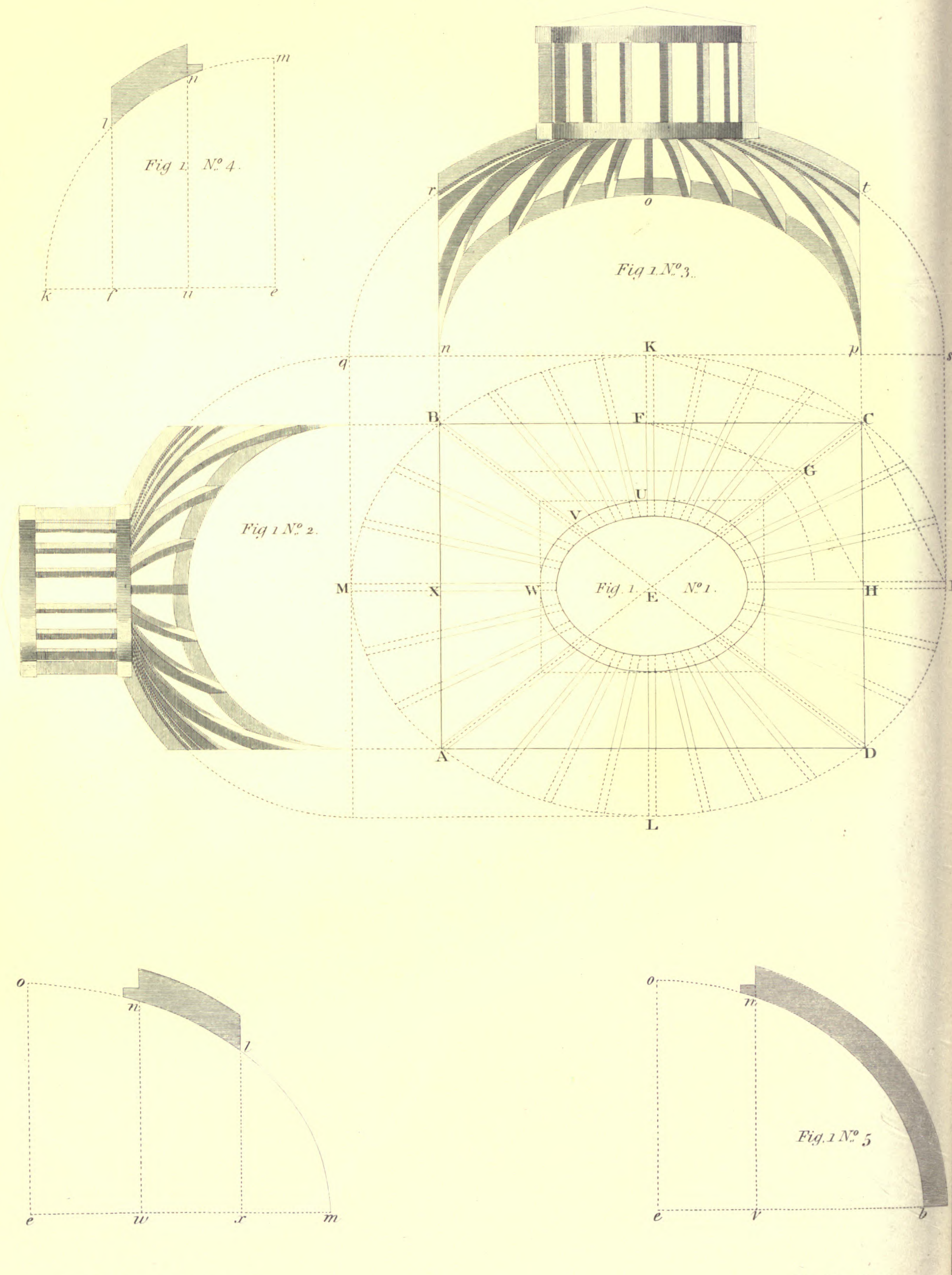
PENDENTIVE CRADLING.



Invented & drawn by P. Nicholson

Eng.d by R. Thew.

remain in various parts of Greece, in Bœotia, Attica, Argolis, and Phocis; also at Julis and Delphi; but the above will probably give a sufficiently explicit idea of their general character.

PELECOIDES, (from the Greek πελεκυς, *a hatchet*, and ειδος, *form*) a figure in the form of a hatchet. Such is the figure B C D A, contained under the inverted quadrantal arcs A B and A D, and the semicircle B C D.

The area of the pelecoides is demonstrated to be equal to the square A C; and that, again, to the rectangle E B. It is equal to the square A C, because it wants, of the square on the left hand, the two segments A B, and A D, which are equal to the two segments B C and C D, by which it exceeds on the right hand.

PEND, a vaulted roof without groining.

PENDENT, or Philosophical Bridge, a wooden bridge supported by posts and pillars, and sustained only by butments at the ends. *See* Bridge.

Pendent, an ornament not uncommon in the vaulted roofs of the late or perpendicular period of Gothic architecture. It consists of a boss of foliage, or other ornament, suspended from the summit of the vaulting at the end of ribs, which, converging from the soffit of the roof, meet at a point below, which is covered with the boss alluded to. Beautiful examples exist at Henry VII.'s chapel, Westminster.

Ornaments of a similar description occur also in the timber roofs of the same date, as likewise attached to the ends of the hammer-beams, or to the extremities of the ridge-pieces of a roof, to receive the ends of the barge-boards.

PENDENTIVE, in architecture, the whole body of a vault, suspended out of the perpendicular of the walls, and bearing against the arc-boutants.

Daviler defines it a portion of a vault between the arches of a dome, usually enriched with sculpture. Felibien, the main of the vault contained between the double arches, the forming arches, and the ogives.

The pendentives are usually of brick, or soft stone; and care must be taken that the joints of the masonry be always laid level, and in right lines proceeding from the sweep whence the rise is taken.

The joints, too, must be made as small as possible, to save the necessity of filling them up with slips of wood, or using much mortar.

Pendentive Bracketing, a cove bracketing, springing from the rectangular walls of an apartment upwards to the ceiling, so as to form the horizontal part of the ceiling into a complete circle, or ellipsis.

The proper criterion for such bracketing is, that if the walls are cut by horizontal planes through the coved parts, the sections through such parts will be portions of circles, or portions of ellipses, having their axes proportional to the sides of the apartment, so that each section will be a compound figure. Besides having four curvilinear parts, it will have four other parts, which are portions of the sides of the rectangular apartment; and the axis of the ellipsis will bisect each side of the rectangle.

Pendentive Cradling. The surface to be formed may be thus conceived. Let a square be inscribed within the circumference of the base of a hemisphere, and let the hemisphere be cut by four planes through the sides of the square, perpendicular to the plane of the base; then let this hemisphere be again cut by another plane parallel to the plane of the base, to touch the section of the four parts cut off; the surface of the remaining solid will then consist of a portion of the hemisphere, one entire circle, and four equal semicircles, each at right angles to the entire great circle. Therefore, if the ribs be fixed in planes passing through the axis of the sphere, and the two ribs, which stand upon the diagonals, will be entire semicircles; or, if a dome be perforated by a cylindric surface, of which the axis is that of the dome, the ribs will still have the same position at any springing, which is one of the semicircular arches.

Plate I. *Figure* 1.—The representation of the pendentive cradling of a dome. No. 1, A B C D, the plan; B F C the springing-line of a semicircular form, described on the diameter, B C. The shaded parts, at *i*, *k*, *l*, *m*, *n*, mark the places for the feet of the ribs to stand upon. G, H, sections of the curb, No. 2. The elevation, O P and Q R, the shortest ribs used; of these, there are four each, standing in the middle.

Figure 2. No. 1, 2.—Plan and elevation, representing the pendentive cradling of a dome.

Figure 3.—The geometrical construction of the pendentive cradling of a segment dome. This figure shows the portions of the ribs that must be used in the construction of the carpentry: thus, C *u*, C *v*, C *w*, C *x*, are the ribs which every eighth-part of the plan requires.

Figure 4. No. 1, 2.—The plan and elevation of the pendentive cradling of a cone.

Plate 2. *Figure* 1.—Plans, sections, and ribs of pendentive cradling.

To construct this cradling, let A B C D, No. 1, be the plan, which is an oblong figure. We must find the circumscribing plan of the spheroid, so that the length and breadth shall be in the same ratio as the two dimensions of the plan. For this purpose, draw the diagonals, A C and B D, cutting each other in E. Through the centre E, draw M I parallel to B C, or A D, cutting the plan at X and H; also, through E draw K L, parallel to B A, or C D, cutting the side B C, at F. From the centre, E, describe a quadrant, to touch the side of the plan at F, so that the portion of the circumference may be contained between K E and I E; bisect the arc, and through the point of bisection, draw a line parallel to B C, or any of its parallels, cutting the diagonal, A C, in G; join F G and G H, and draw C K and C I respectively parallel to G F and G H; make E L equal to E K, and E M equal to E I; then about the two axes, M I and K I, describe an ellipsis, which will be the base of the spheroid that will form the surface for the ribs.

When the plane of th figure to be covered is square, draw the seats of the ribs as in preceding examples. Also, draw the kirb for the skylight in the same proportion as the sides of the plan: then the rib which stands upon F U will be the portion of the quadrant of a circle, described with the radius E K, as at No. 4, where *e k*, No. 4, answers to E K, No. 1; *k f* to K F; and *f u* to F U; then, by drawing the perpendicular, *f l* and *u n*, No. 4, to cut the quadrant, *k m*, at *l* and *n*, *l n* will show the portion of the curve which will form the complete edge of the rib to cover the part F U.

Take half the transverse axis, M E, No. 1, and apply it in the straight line, *m e*, the left-hand figure at the bottom; draw *e o* perpendicular to *m e*, and make *e o* equal E K, No. 1; describe the quadrant of an ellipsis, *o n l m*; make *m x*, *x w*, respectively, equal to M X, X W, No. 1, draw the perpendiculars, *w n* and *x l*, then the portion of the ellipsis, intersected at *n* and *l*, will be the edge of the rib to cover X W on the plan.

In like manner *b n*, No. 5, is the edge of the ribs to cover the half of either diagonal, A C or B D.

No. 2, the transverse section and elevation.

No. 3, the longitudinal section and elevation, showing how the ribs are to be fixed.

PENETRALE, the most sacred chamber of a heathen temple.

PENETRALIA, chapels in Roman houses, in which the females or household gods were placed.

PENITENTIARY HOUSE. *See* Prison.

PENSTOCK, in engineering, a gate employed for ponding back-water; it works up vertically in a grooved frame.

PENTADORON, a Roman brick, whose length measures five palms. *See* Brick.

PENTAGON (from the Greek πενταγονος, *quinquangulus*, compounded of πεντε, *five*, and γωνια, *an angle*) in geometry, a figure of five sides and five angles.

If the five sides are equal, the angles are so too; and the figure is called a *regular pentagon*. Most citadels are regular pentagons.

The most considerable property of a pentagon is, that one of its sides, for example, D E, is equal in power to the sides of a hexagon and a decagon inscribed in the same circle, A B C D E; that is, the square of the side D E is equal to the sum of the squares of the sides D *a* and D *b*.

A pentagon, and also a decagon, may be inscribed in a circle, by drawing the two diameters, A P, *m n*, perpendicular to each other, and bisecting the radius *o n* at *q*. With the centre *q*, and distance *q* A, describe the arc A *r*; and with the centre A, and radius A *r*, describe the arc *r* B; then A B is one-fifth of the circumference; and A B, carried five times over, will form the pentagon; and the arc A B bisected in *s*, will give A *s*, the tenth-part of the circumference, or the side of the decagon.

If tangents be drawn through the angular points, they will form the circumscribing pentagon, or decagon. *See* Polygon, and Regular Figure.

Pappus has also demonstrated, that twelve regular pentagons contain more than twenty triangles inscribed in the same circle, lib. v. probl. 45.

The dodecahedron, which is the fourth regular body, consists of twelve pentagons.

PENTAGRAPH, or more correctly Pantagraph, or Parallelogram, an instrument for copying plans, maps, designs, &c., with expedition, even by a person unskilled in the art of drawing.

This instrument consists of four brass or wooden rulers, in the form of a parallelogram, with moveable joints at the angles; two of the rulers are extended beyond the parallelogram, one for the purpose of carrying a fixed socket, called C, with a metal tracer, in order to trace over the outlines of the original drawing or print; and the other, called B, for carrying a moveable socket; also called B, with a pencil, in order to trace out a drawing similar to the original. The parts, B and C, of the rulers thus extended, being upon the same side of one of the diagonals, the side of the parallelogram, called D, which adjoins the ruler with the moveable socket, has another moveable socket, also called D, in order to insert a vertical pin, which is fixed in a flat piece of lead; both of the moveable sockets, B and D, are clamped by means of a screw. As the metal tracer, C, the pin in the socket D, and the pencil in the socket B, are cylindrical, in fixing the instrument, the axes of the three cylinders must be set all in the same plane, and they will remain so throughout every movement of the instrument.

The pins which fasten the parallelogram at the angles being also vertical cylinders to the plane of the instrument, the axis of the metal tracing point, in the socket C, and those of the two pins in the sockets of B and D, must be in the same plane; also, the axis of the pin, in the socket D, and those of the ruler D at the joints, must also be in a plane. In order to make the movement of the instrument easy, it is provided with casters, or rollers, each of which turns on an axis in the same line with the axis at the joints or angles.

The extended part of the ruler B, on which the socket and pencil are carried, has several graduations, or divisions, which show the proportion of the drawing to be made to the original and thus calling the centre of the joint connecting the extended bars, the *apex of the instrument*, the first division on the extended part, B, is equally distant from the apex with the axis of the tracing point on the other extended part, C; and the ruler, D, which has the steel pin, has a corresponding division, exactly opposite the vertex, when the extended rulers, B and C, are brought into a straight line, and, consequently, the instrument is divided thereby into two equal parts; and thus it becomes necessary to have the two opposite sides of the parallelogram, which has the side marked D, longer than the other two sides, one of which has the extended part B.

The divisions upon the extended part, B, being fixed upon, and numbered from 1-1, 1-2, 1-3, 1-4, to 1-12; that is, 1, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, &c., towards the vertex, the other divisions upon the side of the parallelogram, D, are marked with corresponding figures, 1-1, 1-2, 1-3, &c., in such a manner, that when the extended sides are brought into a straight line, the division marked 1-2, on the side D, divides the instrument into three equal parts, from the division 1-2 on B, to the point C, on the axis of the tracing point on the other extended leg, C; and thus the distance from 1-2, on the side D, to 1-2 on the side B, will be half the distance between 1-2 on the side D and the point C, on the extended part C.

In like manner, the division marked 1-3, on the side D, divides the instrument into four equal parts, from 1-3 on B, to the tracer on C; and thus 1-3 on D will be distant from 1-3 on B, and one-third of the distance from 1-3 on D to the axis of the tracer on C.

The other proportions are found in a similar manner.

The fiducial edges of the clamps, which carry the socket for the steel pin, and the socket for holding the pencil, cross the rulers, to which they are attached, at right angles, and would, if produced, cut the axis of the cylindrical socket in each of the said rulers. The upper part of the cylindrical case, which holds the pencil, is provided with a cup, to contain shot, or a small weight, in order to make the pencil press sufficiently, so as to mark the paper. In order to prevent the pencil from tracing the same path it has already described a silk thread, or catgut string, connected with the pencil, passes through an eye at the vertex, returns to the hand of the operator, and being drawn tight, raises the pencil from the paper.

To use the instrument, suppose the drawing required to be one-half of the original; set the fiducial edge of the clamp B upon 1-2 in the extended part B, and the fiducial edge of the clamp D, upon 1-2 of the ruler D; slide the socket D upon the pin fixed into the lead weight, then having adjusted the original drawing, or print, under the tracer, and the paper under the pencil, trace over all the lines of the original, and the pencil at the remote extremity will trace out a similar figure.

Again, let us take another example: suppose the drawing required to be one-third of the original; set the fiducial edge of the clamp B upon 1-3 in the extended part B, and the fiducial edge of the clamp D upon 1-3 of the ruler D; slide the socket D upon the pin fixed into the leaden weight, then proceed as before. In the same manner the drawing may be reduced to $\frac{1}{4}$, $\frac{1}{5}$, &c. of the lineal dimensions, as shown by the graduations: but if any intermediate proportion is required, as between a third and a fourth; bring the fiducial edge of the clamp B to the intermediate point, and the fiducial edge of the clamp D in a straight line, then proceed as above. On the contrary, should it be required to enlarge the drawing, it is only necessary to change the pencil in the socket tube of the clamp B, for that of the metal tracer, and paper for the original, and proceed as before.

PENTASTYLE, (from πεντε, *five*, and στυλος, *a column*) . architecture, a work containing five rows of columns.

The portico begun by the emperor Gallienus, and which as to have been continued from the Flaminian-gate to the idge Milvius, *i. e.* from the Porto del Popolo to the Porte ole, was a pentastyle.

PENT-HOUSE, an open shed or projection placed over door, window, clock, statue, &c., to project them from e weather.

Pent-Roof, a roof consisting of two equally inclined sides eeting in a common apex, the former being that of a iangular prism.

PERAMBULATOR, (from the Latin, *perambulo*, to avel) an instrument for the measuring of distances, and in equent use for measuring distances on roads, for settling sputes concerning the charges of the drivers of hackney-rriages, and for other purposes. It consists principally of wheel, upon which it runs, and an index which shows the umber of turns of such wheel, reduced into miles, furlongs, les, and yards.

The carriage or stock is made of wood, and is about 3 et long. At one end is a handle for the person who uses and the other is furnished with sockets in which the axle the wheel turns; this end of the stock has the centre rt removed, by which are left two arms between which e wheel works. Upon the stock, and just in front of the ndle, is the dial-plate, with its two hands by which the stance is registered. The wheel is 8 feet 3 inches, or $\frac{1}{2}$ le in circumference. Upon one end of the axis of this eel is a small pinion, which works into a smaller pinion at e end of a rod, which passes up the stock or carriage to the rks beneath the dial-plate. Motion is communicated by eans of this rod to a worm or micrometer screw, which ras once round for each revolution of the carriage-wheel of e perambulator. This worm works into a wheel of 80 eth, which is moved forward one tooth for every $\frac{1}{2}$ pole, d carries a hand or index, which makes one revolution for poles or one furlong. On the axis of this wheel, is a ion of 8 teeth, which works into a wheel of 40 teeth, and the axis of this second wheel is a pinion of 10 teeth, ich moves a wheel of 160 teeth. This last wheel carries other hand, which makes one revolution for 80 of the mer. These hands are arranged in the same manner as hour and minute hand of a watch, so that the three cir-s on the dial-plate are all concentric. The first of these cles is divided into 220, and the second into 40, the number yards and poles contained in a furlong; the figures in these cles are read off by the first mentioned index, that which ttached to the wheel of 80 teeth. The third circle is ided into 80, the number of furlongs in 10 miles, and to s circle belongs the index attached to the wheel of 160 th. The distance is ascertained by reading off the figures the reverse order in which the circles are given above; ide the number on the first circle by 8, and you will e the distance required in miles, furlongs, poles, and yards. e instrument is furnished with a stop or strap, so that after distance is measured, the perambulator may be conveyed hout the index being altered.

Unlike the pedometer, it requires no regulating, and the y risk of its giving the distance incorrectly, if well con-ucted, is passing over rugged and uneven roads, which will course cause the index to show more than the true distance. general, however, for short distances, this error is very ling.

When about to commence a measurement, the wheel should turned round until the first mentioned index points to 220 the circle of yards. Some are provided with a click and racket, by which this may be done with much less trouble than by the wheel.

There are other instruments for the same or similar purposes, bearing different names, as *waywiser* and *odometer*, but the construction of all of them is very similar.

Waywiser is the name generally given to that form of the instrument which is applied to a carriage, in which, by a slight adaptation to one of the wheels of the carriage, the instrument is made to register the number of turns of such wheel, in the same manner as the perambulator.

PERCH, in land-measure, the 40th part of a square rood, containing $30\frac{1}{4}$ square yards; also used as a measure of length, being equal to $5\frac{1}{2}$ yards, or $16\frac{1}{2}$ feet, called otherwise a rod or pole.

Perch, a bracket or corbel, a small projecting beam near the altar of a church.

PERCLOSE. *See* Parclose.

PERIBOLUS, the enclosure surrounding a Grecian temple, which frequently contained a grove, and was adorned with altars, statues, &c.

PERIDROME, Peridromus, in ancient architecture, the space, or an aisle in a periptere, between the columns and the wall.

Salmasius observes, that the peridromes served for walks among the Greeks.

PERIMETER, (from the Greek περι, *about*, and περιφερω, *measure*) in geometry, the ambit or extent that bounds a figure or body.

The perimeters of surfaces, or figures, are lines; those of bodies are surfaces.

In circular figures, &c., instead of perimeter, we say *circumference*, or *periphery*.

PERIPHERY, (from the Greek περιφερω, *I surround*, or περι, *about*, and φερω, *I bear*, or *carry*) in geometry, the circumference or bounding line of a circle, ellipsis, parabola, or other regular curvilinear figure.

The periphery of every circle is supposed to be divided into three hundred and sixty degrees; which are again subdivided, each into sixty minutes, the minutes into seconds, &c.

The division of degrees, therefore, are fractions, whose denominators proceed in a sexigesimal ratio; as the minute $\frac{1}{60}$, second $\frac{1}{3600}$, third $\frac{1}{216000}$. *See* Sexigesimal.

But these denominators being troublesome, in their stead are used the indices of their logarithms; hence the degree, being the integer, or unit, is marked by °, the minute by ′, second by ″, &c. *See* Circle.

PERIPTERE, (from the Greek περιπτερος, formed of περι, *about*, and πτερων, *wing*, winged on every side) in ancient architecture, a building encompassed on the outside with a series of insulated columns, forming a kind of aisle, or portico, all round. Such were the basilica of Antonine, the septizon of Severus, the portico of Pompey, &c.

Peripteres were properly temples with columns on all the four sides, by which they were distinguished from prostyles and amphiprostyles, the one of which had no columns before, and the other none on the sides.

M. Perrault observes, that periptere, in its general sense, includes all the species of temples which have porticos of columns all round, whether the column be diptere, or pseudo-diptere, or simple periptere; which is a species that bears the name of the genus, and has its columns distant from the wall by the breadth of an intercolumniation. For the difference between periptere and peristyle. *See* Peristyle.

PERIPTERAL, surrounded by a periptere or continuous colonnade; the term is applied to a class of temples which answers to this description.

PERIRRANTERION, (from the Greek *περι, about,* and *ραινω, to sprinkle,*) lustral vases placed at the entrances of heathen temples, in which the priests washed their hands, and with which they sprinkled their worshippers.

PERISTYLE, (from the Greek *περιςυλος*, formed from *περι, about,* and *ςυλος, column,*) in ancient architecture, a place or building, encompassed with a row of columns on the inside; by which it is distinguished from the periptere, where the columns are disposed on the outside. Such was the hypæthral temple of Vitruvius, and such are now some basilicas in Rome, several places in Italy, and most cloisters of religious houses.

PERISTYLE is also used by modern writers for a range of columns, either within or without a building: thus we say, the Corinthian peristyle of the portal of the Louvre, &c.

PERISTYLION, (from the Greek *περιςυλιον,*) among the Athenians, a large square place, though sometimes oblong, in the middle of the gymnasium, designed for walking, and the performance of those exercises which were not peculiar to the palæstra.

PERISTYLIUM, a continued row or series of rows of columns all round a court or building, in contradistinction to porticos, in which the pillars do not surround a space, but are arranged in one or more parallel lines.

PERITHERIDES, the same as ANCONES.

PERITROCHIUM, (from *περι, about,* and *τροκιλος, a circle,*) in mechanics, a wheel, or circle, concentric with the base of a cylinder, and moveable together with it, about an axis. The axis, with the wheel and levers fixed in it, to move it, constitutes that mechanical power called *axis in peritrochio.*

PERPENDICULAR, (from the Latin *perpendicularis,*) in geometry, a line falling directly on another line, so as to make equal angles on each side; called also a *normal line.*

From the very notion of a perpendicular, it follows:—

1. That the perpendicularity is mutual; *i. e.*, if a line, as I O, be perpendicular to another, K H; that other is also perpendicular to the first.

2. That only one perpendicular can be drawn from one point in the same plane.

3. That if a perpendicular be continued through the line to which it was drawn perpendicular, the continuation will also be perpendicular to it.

4. That if there be two points of a right line, each of which is at an equal perpendicular distance from two points of another right line, the two lines are parallel to each other.

5. That two right lines perpendicular to one and the same line, are parallel to each other.

6. That a line, which is perpendicular to another, is also perpendicular to all the parallels of the other.

7. That perpendiculars to one of two parallel lines, terminated by those lines, are equal to each other.

8. That a perpendicular line is the shortest of all those which can be drawn from the same point to the same right line.

Hence the distance of a point from a line, is a right line drawn from the point perpendicular to the line or plane; and hence the altitude of a figure is a perpendicular let fall from the vertex to the base.

Perpendiculars are best described in practice by means of a square; one of whose legs is applied along that line, to or from which the perpendicular is to be let fall or raised.

A line is said to be perpendicular to a plane, when it is perpendicular to all right lines, that can be drawn in that plane, from the point on which it insists.

A plane is said to be perpendicular to another plane, when all right lines drawn in the one, perpendicular to the common section, are perpendicular to the other.

If a right line be perpendicular to two other right lines intersecting each other at the common section, it will be perpendicular to the plane passing by those two lines.

Two right lines perpendicular to the same plane are parallel to each other.

If, of two parallel right lines, the one is perpendicular to any plane, the other must also be perpendicular to such plane.

If a right line be perpendicular to a plane, any plane passing by that line will be perpendicular to the same plane.

Planes, to which one and the same right line is perpendicular, are parallel to each other: hence all right lines perpendicular to one of two parallel planes, are also perpendicular to the other.

If two planes, cutting each other, be both perpendicular to a third plane, their common section will also be perpendicular to the same plane.

PERPENDICULAR TO A CURVE, is a right line cutting the curve in the point in which any other right line touches it, and is also itself perpendicular to that tangent.

PERPENT-STONE, a long stone reaching right through a wall; a bond or thorough-stone.

PERPEYN-WALL, a projecting pier, buttress, or other support employed to sustain a beam or other weight.

PERRAULT, CLAUDE, an eminent architect, born at Paris in 1613. He was brought up to the medical profession, and took his degree as doctor of the faculty of Paris in 1641. He practised little, however, excepting among his friends and the poor; and having a decided taste for drawing and the fine arts, he turned his attention to the science of architecture, in which he became greatly distinguished. When the Academy of Sciences was founded, under the patronage of Colbert, in the year 1666, Perrault, who was one of the first members, was appointed to select a spot for an observatory; and he also gave a plan of the building which was to be executed. When it was resolved, under Louis XIV., to proceed in completing the palace of the Louvre, all the eminent architects were invited to give in designs of the façade; and that of Perrault was preferred. This is accounted the masterpiece of French architecture, and it would alone suffice to transmit his name with honour to posterity. It was in vain that persons, jealous of his reputation, endeavoured to make the public believe that the real designer was Le Veau; they entirely failed in their proof, and the glory of Perrault remained untarnished. When Colbert, after the king's first conquests, proposed to construct a grand triumphal arch to his honour, Perrault's design had the preference, and the edifice was commenced. It was, however, never finished. In its masonry, Perrault employed the practice of the ancients, of rubbing the surface of the stones together with grit and water, so as to make them cohere without mortar. Other works of this architect were, the chapel at Sceaux, that of Notre Dame, the church of the Petits Pères in Paris, the water-alley at Versailles, and most of the designs of the vases in the park of that palace. By the king's command, he undertook a translation of Vitruvius, with notes, published in 1673. All the designs for the plates of this work were drawn by himself, and have been esteemed as master-pieces of the kind. He afterwards published an abridgement of that author, for the use of students. He likewise facilitated the study of architecture by a work entitled *Ordonnance de Cinq Espèces de Colonnes selon la Méthode des Anciens.* In the preface to this work, he maintains that there is no natural foundation for the architectural proportions; but that they may be infinitely varied, according to taste and fancy—a opinion which gave much offence, though justified by the practice of the ancients themselves. A collection of the drawings of several machines, which he at different times invented, was published after his death in 4to. This excellent artist holds a respectable place among writers in his original profession, and, besides various memoirs on this subject, communicated to the Academy of Sciences, he published *Memoirs pour serviràl' Histoire Naturelle des Animaux*, in 2 vols. His other writings of this class are contained in his *Essais de Physique*, 4 vols. One of these volumes relates entirely to the organ of hearing, under the title of *Traité de Bruit.* Another relates to the mechanism of animals, in which he anticipated Stahl in some of his opinions respecting the functions of the animal soul. In other parts of these essays, he treats on the peristaltic motion of the intestines,—on the senses,—on nutrition, &c. He died in Paris in 1688, aged 75.

Perrault published a *Dissertation upon the Music of the Ancients*, in 1680. He had, indeed, given his opinion upon the subject very freely, in the notes to his translation of Vitruvius, in 1673; where, in his commentary of the chapter upon *Harmonic Music according to the doctrine of Aristoxenus*, he declares that "there is nothing in Aristoxenus, who was the first that wrote upon concords and discords, nor in any of the Greek authors who wrote after him, that manifests the ancients to have had the least idea of the use of concords in music of many parts."

PERRON, (French), in architecture, a staircase lying open, or withoutside the building; properly the steps before the front of the building, leading into the first story, when raised to a little above the level of the ground. Perrons are of different forms and sizes, according to the space and height they are to lead to. Sometimes the steps are round, or oval; more usually they are square.

PERRONET, JOHN RODOLPHUS, director of the bridges and roads of France, born in 1708. He was brought up to the profession of architecture in the city of Paris, and made great progress in the art. In 1745, he became inspector of the school of engineers, of which he was afterwards a director. France is indebted to him for several of its finest bridges and best roads, the canal of Burgundy, and other great works. He was, for his public services, honoured with the order of St. Michael, and admitted a member of the Academy of Sciences at Paris, of the Royal Society of London, and of the Academy of Stockholm. He died at Paris in 1794. He wrote a *Description of the Bridges* which he had constructed, 2 vols. 12mo.; and *Memoirs on the Method of constructing Grand Arches of Stone from* 200 *to* 500 *Feet in span.*

PERSEPOLIS, a town of Persia, formerly called Elymaïs, now known only by its ruins and monuments, which have been described by many travellers, from Chardin to Niebuhr and Franklin. They are situated at the bottom of a mountain, fronting the south-west, about 40 miles to the north of Shirauz. They command a view of the extensive plain of Merdasht; and the mountain of Rehumut encircles them, in the form of an amphitheatre. Here are many inscriptions, in a character not yet explained; but which Niebuhr seems to have represented with great accuracy. The letters somewhat resemble nails, disposed in various directions, in which singularity they approach to what are called the *Helsing Runes* of Scandinavia, but the form and disposition seem more complex. Behind the ruin, to the north, is a curious apartment cut in the solid rock, and a subterraneous passage, apparently carried to a very considerable extent. Situated about three miles and a half to the north-east of these ruins is the tomb of Rustan, the ancient Persian hero. The temple, or palace, at Persepolis, now called *the throne of Jemshid*, is supposed to have been erected in the time of Jemshid, and to have been posterior to the reign of the Hindoo monarchs. The figures at Persepolis differ from those of Elephanta, which are manifestly Hindoo; and Sir William Jones conjectures that they are Sabian, which conjecture is confirmed by a circumstance, which he believes to have been a fact, *viz.*, that the *Takhti Jemshid* was erected after the time of Cayúmers, when the Brahmans had migrated from Irán, and when their intricate mythology had been superseded by the simpler adoration of the planets and of fire. Chardin, who observed the inscriptions on these ancient monuments on the spot, observes, that they bear no resemblance whatever to the letters used by the Guebres, in their copies of the Vendidád; whence Sir William Jones inferred that the Zend letters were a modern invention; and in an amicable debate with a friend named Bahman, that friend insisted that the letters, to which he had alluded, and which he had often seen, were monumental characters, never used in books, and intended either to conceal some religious mysteries from the vulgar, or to display the art of the sculptor, like the embellished Cúfick and Nágari on several Arabian and Indian monuments. *See* NEXT ARTICLE.

PERSIAN or PERSEPOLITAN ARCHITECTURE, is that style of building employed by the ancient Persians; it is called Persepolitan from Persepolis, the capital of Persia, where also are found the principal remains of this style. The Persian architecture bears some resemblance to that of India and Egypt in general character, but differs from it considerably in matters of detail. In all three places we meet with excavated tombs and sepulchral chambers hewn out of the perpendicular face of the rock; yet beyond the circumstance of their position and method of formation, we find little in common between those of Persepolis and the other countries: in the latter, the excavations are usually of very great extent, and consist of one or more passages leading into a large number of different apartments; whereas those of Persia are very shallow, and consist mainly of an architectural façade or portico, richly adorned with sculpture and other embellishments. Such are those at Naksh-i-Rustam; also the tomb of Darius, at the foot of Mount Rachmed, near the ancient Araxes. Another similarity is to be found in their massive proportions; and although in the works of Persia there is less real massiveness than in those of Egypt, yet the similarity of appearance points to a common origin. The pyramidal inclination of their walls is another indication of the same fact; and great resemblance in this point and in others may be observed in their porticos or propylæa, which, besides the pyramidal form of the erection, present us with the same description of entablature which, in the ruins of Persepolis as well as in those of Egypt, consist of a lofty crowning hollow or concave member, ornamented with vertical ribs or leaves, and in both cases terminated with a large fillet. The sculpture of the two countries is also of similar character, stiff and formal, and, together with the arrow-headed characters which are found equally in both styles, presents a very fair argument in favour of their relationship.

The principal ruins of this style, as we have before mentioned, are to be found in Persepolis, in the great plain of Merdasht or Istakhr; but others are also existing at Shapur, where they cover an area of six miles in circumference, amidst rocks and precipices, many of which are decorated with sculpture. At Moorghab, forty-nine miles north-east of Istakhr, are other extensive ruins, amongst which a ruin, called by the natives Musjed-i-Madre-Solyman, is remarkable, being considered by some as the tomb of Cyrus the

Great. Somewhat nearer to the ruins of Persepolis are the Naksh-i-Rejib, and the Naksh-i-Roostan, both of which are supposed to be the tombs of regal personages. The ruins of the neighbourhood of Firoze-abad are very extensive, occupying a space of about 17 miles by about half the distance: other ruins exist at Darabgherd, and many in other places, of some of which we shall attempt to give a short description, and as the ruins of Persepolis are amongst the most remarkable and better-known examples, we proceed with their description forthwith.

These ruins are situated in the plains of Merdasht, at the foot of the mountain of Kuliraj-met, and stand upon an elevated terrace or platform, formed by levelling the surface of the rock. The platform is in the shape of a parallelogram, but somewhat irregular in its outline, which follows the profile of the rock; its dimensions are on the south face 802 feet, on the north 926, and on the west 1,425. On each of these sides the terrace is elevated above the general surface of the surrounding country, but on the east side the mountain rises above it; the vertical height of the three sides varies from 14 to 40 feet, the faces being formed of gigantic square blocks of a dark-grey marble, beautifully polished, and fitted to each other with the greatest exactness without the aid of cement. The surface of the platform is not on the same level throughout, those parts which were covered with buildings being somewhat elevated above the rest. On the west side, which may be considered the principal one, and at a spot about midway between the centre and the north-west angle, is the approach, which consists of two flights of steps in contrary directions, which return again to the upper landing-place. The height of the platform at this place is about 20 feet, and the flight on the north side consists of 55, and that on the south of 53 steps, the risers measuring 4 inches, and the threads 14; the width of the flights is 25 feet 7 inches, and the distance between them at the base 42 feet. The steps are cut out of immense masses of solid marble, sufficiently large to compose from 10 to 14 steps. The half space at the top of the first flight is 51 feet 4 inches between the flights, and that at the top of the upper flight 75 feet; the upper flights are separated from the lower by a wall.

Having arrived at the top of these steps, the first thing which presents itself to your notice is a portal or propylon, standing at about 42 feet east of the steps. This lofty mass, which is similar in all respects to the propyla of Egypt, forms an entrance to the ruins, and consists of a pyramidal mass of masonry, diminishing upwards on all sides, and crowned by a cavetto, or hollow cornice, having a large aperture, which forms a doorway or entrance. The interior faces of this propylon are sculptured into the forms of two colossal bulls, which are elevated on a pedestal five feet above the level of the platform. At a considerable height above their backs are three small compartments filled with inscriptions in the arrow-headed characters. Passing forward through this portal still in an easterly direction, we find the ruins of a fine group of columns, at a distance of 24 feet from the portal; there were originally 4 columns, which were all erect in Chardin's time, but when Sir Robert Ker Porter visited the place, two of them only remained. They are the most perfect examples among the ruins, and were placed equidistant from each other, at a distance of 22 feet apart. Their bases are buried in the ruins; their capitals are singular and beautiful, consisting, as it were, of three combined in one. The shaft gradually narrows towards the top, varied by 39 flutings near the cincture, each of which is four inches in breadth; the total height of the columns is 54 feet. A space of 24 feet separates these columns from a second propylon, resembling the former both in shape and dimensions, except that its length is 18 feet instead of 21. The remains of the first portal are 39 feet high, and of the second 28 feet; the base of the piers is 5 feet 2 inches high, and projects inwards, and the bases upon which the figures stand are 1 foot 2 inches high. The second propylon is sculptured on the inner faces similarly to the first, but the animals represented have the body and legs of a bull, an enormous pair of wings projecting from the shoulders, and the heads looking to the east, showing the faces of men. On the head is a cylindrical diadem, on both sides of which horns are clearly represented winding from the brows upwards, to the front of the crown; the whole being surmounted with a sort of coronet, formed of a range of leaves like the lotus, and bound with a fillet beautifully carved in roses. At the distance of 52 feet south-eastward from the second portal is a water-trough, cut out of a single stone 20 feet long, and 17 feet 5 inches broad, and standing three feet high from the ground. From hence to the northern wall of the platform is covered with fragments, and the remains of one column not channelled as the others are, which is 12 feet 4 inches high.

The propyla, in all probability, lead to some main court or building of which there are no remains, for it would seem unreasonable to suppose that these portals formed only an entrance to the Palace of Forty Pillars as it is termed, and which now forms the principal mass of remains; this palace is to the south of the portals, which are placed east and west of each other, and east of the staircase, or approach from below, so that to a person approaching from that quarter the Palace of Forty Pillars would be invisible, and it would be necessary to turn to the right immediately after passing under the first propylon. Owing to these difficulties, it has been suggested that the principal ruins are not those of a palace, but of a temple, and that the palace was eastward of them. This conjecture is somewhat confirmed by the nature of the court, which from its remains would seem to be too crowded with columns for a hall of entertainment; and further, it is precisely similar in arrangement to the Egyptian temples. If such be the case, it must be supposed that the ruins of the buildings of which the propyla formed the entrance, have been removed from the north-east portion of the platform. Be this as it may, at the distance of 172 feet from the propyla, in a southward direction, is the approach to the court, which consists of a staircase of two flights, one west and the other east, giving access to the platform on which the court is erected. "On drawing near the Chehel-minar, or Palace of Forty Pillars," says Sir Robert Ker Porter, "the eye is riveted by the grandeur and beautiful decorations of the flight of steps which lead up to them. This superb approach consists of a double staircase, projecting considerably before the northern face of the terrace, the whole length of which is 212 feet; at each extremity, east and west, rises another range of steps, and again, about the middle, projecting from it 18 feet, appear two smaller flights rising from the same point. Here, the extent of the range, including a landing-place of 20 feet, amounts to 86 feet. The ascent, like that of the great entrance from the plain, is extremely gradual, each flight containing only 32 steps, none exceeding 4 inches in height, in breadth 14 inches, and in length 16 feet. The whole front of the advanced range is covered with sculpture. The eye at first roves over it, lost and bewildered by the multitude of figures." Amongst these sculptures, the figures of the bull and the lion, and representations of the flower of the lotus, repeatedly occur; some of the figures exceed the natural size. The wall occupied by these sculptures extends for a length of 98 feet, and the sculptures are arranged in three rows, one above the other; the faces of the inner terrace walls were also decorated with bas-reliefs. The staircase itself is half-buried and the flights are of unequal height, the western consisting of 28 steps and the eastern, where the ground is higher, of only 18.

On arriving at the top of this staircase, another large platform presents itself, paved with large blocks of stone, and covered with fragments of pillars; it is of large extent, stretching north and south 350 feet, and from east to west 380 feet. The distribution of the columns comprised four divisions, consisting of a central phalanx of six deep every way, an advance body of twelve in two ranks, and the same number similarly disposed flanking the central body. At the distance of 22 feet from the parapet of the landing, are the most northern or advanced body of columns, originally 12 in number, but of which, in Sir R. K. Porter's time, only one remained. At 71 feet southward from these, stood the central phalanx of 36, at intervals of 22 feet 2 inches from each other, of which only 5 now remain: the bases, however, of all the others are in their places, though most of them much mutilated. To the east and west of this group are two other groups of 12 each, whereof 5 still remain in the eastern one, and 4 in the western. The form of the columns which compose the three smaller colonnades at the front and sides of the main body is the same in all. The total height of each column is 60 feet, of which the shaft from capital to base occupies 44; the circumference of the shaft is 16 feet. The base consists of a plinth 8 inches high, and 24 feet 6 inches in circumference, from which rises the pedestal in the form of the cup and leaves of a pendant or inverted lotus; above this is a torus one foot deep, and upon this again, a cincture connecting the base with the shaft only 2 inches deep. The total height of the base from the cincture to the plinth measures 5 feet 10 inches. The capitals consist of two demi-bulls, comprising the fore-part of two bulls with head and fore-legs overhanging the shaft on either side, the bodies connected in the middle, and sustaining a sort of abacus; the heads of the animals project very considerably beyond the shaft, and form a kind of bracket to sustain the entablature. The columns of the central group are only 55 feet high, and differ considerably from the others; the shafts are fluted, and about 35 feet in length, and the capitals which resemble those of the great portal, occupy a large proportion of the height, and are adorned with a series of small scrolls, one above another, beneath which, and immediately above the necking, the shaft presents a bulging appearance, widening rapidly at the lower part, and gathering in gradually towards the scrolls, then spreading out again in the shape of a calyx or cup to receive the scrolls.

Eastward of this hall, and towards the mountainous side of the platform is situate a large mass of ruins, consisting of portals, passages, &c., the plot of ground on which they stand is about 95 paces from east to west, and 125 paces from north to south. In the centre are scattered fragments of columns and other stones, and in the interior there seems to have been a group of 76 columns.

To the south-west of the hall of Forty Columns, is a building elevated on a platform about 8 feet above the plane of the colonnades, which measures 170 feet from north to south, and 95 from east to west. It is approached from the west by a double flight of steps, which appear to have been enriched with sculpture similar to those of the great platform; another flight on the south extends the whole width of the terrace, the landing place of which is 48 feet long by 10 wide: the east side is buried in fallen ruins. The platform outside the building is occupied with fragments of portals, colossal statuary, &c. "From the western landing-place two portals lead into a room 48 feet square; it has two doors on the north, two to the west, one to the south, and, originally, two to the east. On three sides of the room are several square-headed niches, each excavated in one solid stone to a depth of 3 feet, 5 feet high, and 6 feet wide; they appear to have been exquisitely polished within, while upright lines of cuneiform characters run along their edges. Four windows 10 feet high, open to the south. There is another apartment of the same building 30 feet by 48, open to the south."

South-east of this building is another large edifice covering a space of 160 feet from north to south, and 190 feet from east to west; the plan seems to have been very regular, and consists of a polystylar hall of 36 columns, arranged in 6 rows of 6 each, surrounded with no less than 10 portals. The ground is covered with fragments, and beneath the pavement has been discovered a subterraneous aqueduct. To the west of this, and 100 feet south of the previous building, have been found traces of columns belonging to a smaller structure, and amongst them Le Bruyn discovered a staircase leading to a subterranean apartment.

The above are the principal edifices of Persepolis; there are some others of smaller size, which we do not think necessary to describe; the entire area too, which is equal to nearly thirty acres, is covered with innumerable fragments of various descriptions. Excavated out of the rock at the east side of the platform are two tombs, which are probably of the same date as the structures we have been describing; they are about 400 yards apart, and each contains a chamber about 30 feet wide, 18 deep, and 10 or 12 high; the façades are richly sculptured in both cases.

About four miles from this place are the sculptured tombs, called by the natives Naksh-i-Rustam, the entrances to which are nearly 60 feet above the general surface of the ground. One of the tombs consists of a chamber 35 feet long, 7 broad at each end, and 8 in the middle; in the sides are three arched recesses cut out of the rock, and measuring 9 feet in length, by 5½ in breadth. The roof of the chamber is arched, and its height measures 10 feet at the highest point. Opposite these tombs is a square building about 24 feet wide, and 35 high, constructed of white marble. At about 11 feet above the ground is a small doorway, which gives access to a chamber about 12 feet square, and 20 feet high, the roof being composed of two immense slabs of marble. On the outside the walls are varied with many oblong recesses, and are surmounted by a cornice enriched with dentils, that on the north side being formed of a single slab 22 feet 6 inches in length.

A building somewhat resembling a pyramid exists amongst the ruins of Pasargadæ, and is thus described by Mr. Morier: "It rests upon a square base of large blocks of marble, which rise in seven layers pyramidically. It is in the form of a parallelogram, the lowest range of the foundation is 43 feet, by 37; and the edifice itself, which crowns the summit, diminishes to 21 feet by 16 feet 5 inches. It is covered with a shelving roof, built of the same massy stone as its base and sides, which are all fixed together by clamps of iron. Around it, besides a great profusion of broken marbles, are the shafts of 14 columns, once, perhaps, a colonnade, but now arranged in the square wall of mud which surrounds the whole remains." This monument contains a small and plain chamber; it is considered by some to be the tomb of Cyrus, but the Mohammedan writers call it the tomb of the mother of Solomon.

The fire-altars, which are of not unfrequent occurrence, consist often of a single upright stone about 12 feet high, and 3 or 4 feet square at the bottom, being slightly pyramidical, and therefore of somewhat smaller dimensions at the top, in which there is a deep hollow to receive the fire.

A rude, low wall of large stones forms an enclosure round the altar, having an entrance in one of its sides. Sir W. Ouseley observed several structures resembling those of the Druids in our own country; he mentions one at Darabgerd, which consisted of an irregular cluster of large, rude stones, some of which were from 20 to 25 feet in height. One, taller than the rest, stood in the centre, and another towards the west resembled a table or altar, being flat at the top; and under two or three others were recesses or small caverns.

It would be useless to attempt any description of the details of the style, with such slender information; some idea may be formed from the above descriptions, and for further information we must refer the reader to the writings of those travellers who have visited the spot, amongst whom we may mention Porter, Ouseley, Morier, Rich, Niebuhr, Le Brun, and Chardin.

PERSIANS, or PERSIC ORDER, in architecture a name common to all statues of men, serving instead of columns to support entablatures. They only differ from caryatides, in that the latter represent women.

The Persian is a kind of order of columns, first practised among the Athenians, on occasion of a victory their general, Pausanias, obtained over the Persians. As a trophy of this victory, the figures of men dressed in the Persian mode, with their hands bound before them, and other characters of slavery, were charged with the weight of Doric entablatures, and made to supply the place of Doric columns. Persian columns, M. le Clerc observes, are not always accompanied with the marks of slavery; but are frequently used as symbols of virtues, vices, joy, strength, valour, &c., as when made in the figures of Hercules, to represent strength; and of Mars, Mercury, Fauns, Satyrs, &c., on other occasions. *See* Caryatic Order.

PERSPECTIVE (from the Latin *perspicio*, to see,) the art of representing objects on a definite surface, so as to affect the eye when seen from a certain position, in the same manner as the object itself would, when the eye is fixed on the point in view.

The art of perspective owes its birth to painting, and particularly to that branch of it which was employed in the decorations of the theatre, where landscapes were principally introduced, and which would have looked unnatural and horrid, if the size of the objects had not been pretty nearly proportioned to their distance from the eye. The ancients must, therefore, have had considerable knowledge of this art, though the only ancient author from whom we can obtain any information relative to its antiquity is Vitruvius, who, in the proem of his seventeenth book, informs us, that Agatharcus, at Athens, was the first who wrote on this subject, on occasion of a play exhibited by Æschylus, for which he prepared a tragic scene; and that afterwards the principles of the art were more distinctly taught in the writings of Democritus and Anaxagoras, disciples of Agatharcus, which are no longer extant. The perspective of Euclid and of Heliodorus Larisseus contains only some general elements of optics, that are by no means adapted to any particular practice; though they furnish some materials that might be of service even in the linear perspective of painters. Geminus of Rhodes, who was a celebrated mathematician in the time of Cicero, hath likewise written on the subject. It seems probable that the Roman artists were acquainted with the rules of perspective, from the account given of their scenic representations; but of the theory of this art among the ancients we know nothing—perspective, no doubt, having been lost when painting and sculpture no longer existed. John Tzetzes, who lived in the twelfth century, speaks of perspective as if well acquainted with its importance; and the Greek painters, who were employed by the Venetians and Florentines in the thirteenth century, seem to have brought some knowledge of it into Italy. The disciples of Giotto are commended for observing perspective more than their predecessors had done; they lived in the beginning of the fourteenth century.

The Arabians were not ignorant of this art, as we may presume from the optical writings of Alhazen, who lived about the year 1100, cited by Roger Bacon, when treating on this subject. Vitellus, a Polander, about the year 1270, wrote largely and learnedly on optics; and our own Friar Bacon, as well as John Peckham, Archbishop of Canterbury, treated the subject with surprising accuracy, considering the times in which they lived.

The most ancient authors who professedly laid down rules of perspective, were Bartolomeo Bramantino, of Milan, whose book, entitled *Regole di Perspettiva, e Misure delle Antichita di Lombardia*, is dated 1440; and Pietro del Borgo, who is supposed to have died in 1443. He supposed objects to be placed beyond a transparent tablet, and endeavoured to trace the images, which rays of light, emitted from them, would make upon it. His work is not now extant; but Albert Durer constructed a machine upon the same principles, by which he could trace the perspective appearance of objects. In 1450, Leon Battista Alberetti wrote his treatise *De Pittura*, in which he treats principally of perspective.

Balthazar Peruzzi, of Sienna, wrote his *Method of Perspective*, published by Serlio in 1540. To him, it is said, we owe the discovery of points of distance, to which all lines that make an angle of 45° with the ground line are drawn. Guido Ubaldi, another Italian, soon after discovered that all lines parallel to each other, if inclined to the ground-line, converge to some point in the horizontal line; and that through this point, also, a line drawn from the eye, parallel to them, will pass. His *Perspective* was printed at Pessaro in 1600, and contained the first principles of the method afterwards discovered by Dr. B. Taylor. In 1583, a book was published by Giacomo Barozzi, of Vignola, commonly called Vignola, entitled, *The Two Rules of Perspective; with a learned Comment, by Ignotius Dante*. In 1615, the work of Marolois was printed, in Latin, at the Hague, and engraved and published by Hondius. And in 1625, Sirigatti published a treatise of perspective, which is little more than an abstract of Vignola's. The art of perspective has been gradually improved by subsequent geometricians, particularly by Professor Gravesande and Dr. Brook Taylor. The latter did not confine his rules, as his predecessors had done, to the horizontal plane only, but made them general, so as to affect every species of planes and lines, whether parallel to the horizon or not; and thus the principles were made universal. Farther, from the simplicity of his rules, the whole tedious process of drawing out plans and elevations for any object is rendered entirely useless, and therefore avoided; for by this method, not only the fewest lines imaginable are required to produce any perspective representation, but every figure thus drawn will bear the nicest mathematical examination.

Vanishing points, in every position, were known to Guido Ubaldi; and Gravesande not only understood the use of vanishing points, but the use of directors also, in the representation of a point, prior to the appearance of any thing published by Brook Taylor; but the latter has extended his theory not only to vanishing points, but to the vanishing lines of planes in every situation, which, when once ascertained, the representation of an object is found by the same means in each plane, consequently with the same facility. Hamilton seems to be the first writer who introduced the

›ractice of setting the radial, or parallel of the original line ›rom the vanishing point, upon the vanishing line, and the ›riginal line from the intersecting point upon the intersecting ine, in order to ascertain the representation of any point, or ıny part or parts of the original line, and to find the origi-ıals from the representations given. This author is the first who has applied the harmonical division of lines to perspec-ive. Noble's *Perspective* contains several inventions; par-icularly his methods of drawing indefinite representations o inaccessible vanishing points, both by scales and other neans. Thomas Malton's treatise on this subject is also an ıble performance.

In the following list will be found the names of some of he principal writers on perspective, with the dates of their performances, down to a comparatively modern period. Some of these authors have been already mentioned; but in ıddition, several mathematicians of eminence have written on perspective; the latter have treated the art as the subject of pure geometry, as it really is. The performances of Dr. Brook Taylor, Gravesande, Wolf, De la Caille, and Emerson, especially, are truly valuable, from the perspicuous simplicity and universality with which they have treated the subject.

FOREIGN AUTHORS.

	Dates.		Dates.
Guido Ubaldas	1600	Andrea Pozzo — two treatises	1700 & 1707
Maroloi	1615	Bernard Lamy	1701
Marolois - Vredeman - Friese, the Jesuit	1619	Gravesande	1711

ENGLISH AUTHORS.

Humphrey Ditton	1712	Ware	1768
Moxon	1712	Priestley	1770
Brook Taylor — two treatises	1715 & 1719	Edward Noble	1771
Langley	1730	Thomas Malton	1775
Oakley	1738	Bradberry	1775
Hamilton	1738	Shiraton	1775
Sirigath (translated by Ware)	1754	Wood	1797
Kirby	1760	Douglas	1805
Highmore	1763	Edwards	1806
Fournier	1764	W. Daniel	1810
Cowley	1765	D. Cresswell	1811
Ferguson	1765	Milne	1812
		Hayter	1813

Within the last few years, writers on perspective have ›een so numerous, that it is impossible, as indeed it is un-ıecessary, to enumerate them.

We shall now proceed to describe the art of perspective, ı such a manner as will, we trust, be found a very easy vay of acquiring a general knowledge of the subject. Let he student place himself in a darkened chamber, and then et him make a small hole, not larger than a pea, in the door r window, opposite to some remarkable objects, such as ouses or trees, the distance of which should be at least qual to their height, and may, with propriety, be two or ıree times that distance; and the experiment will be most greeably conducted, when the sun shines strongly on the ırfaces facing the hole. If a sheet of paper, or any white reen, be placed within the room before the hole, an image the external objects opposite the aperture will be depicted pon it. The image will be beautiful, although the outline the objects will not be very well defined, nor their colours ery distinct, for reasons which the study of optics will fully plain. The instruction, however, to be derived from the periment, will, for the present object, be the same. It ill be observed that the images of all objects are inverted; and, to understand this, the student must be reminded of the rectilinear motion of light. The image on the screen can, of course, be formed only by those rays of light which enter the chamber at the aperture, and it will be admitted that the rays from the top of the external objects cannot proceed in a right line to the screen, unless they proceed to the bottom of the screen, and the objects on the left hand will be on the right of the image. That the rays of light from the objects cross each other at the aperture, and spread afterwards as they advance, may be proved by varying the distance of the screen; the size of the image upon which is enlarged by drawing it back, and lessened by placing it nearer the aper-ture. The student must further be informed, that if he could trace the image on the screen exactly as it is there delineated, he would, on reversing the screen, have an out-line of the external objects in accurate perspective. As the proportions of the several parts, therefore, are not altered by the inverted position of the image, they may be contemplated and compared with the original objects, as if no inversion took place. Suppose the front of a single house to be paral-lel to the surface of the screen, and its centre very nearly opposite to the centre of the aperture, its image upon the screen will be of the same shape as the front itself is known to have, and its dimensions will be obtained by a rule easily discoverable; for the image will be very nearly as much less than the original as the distance between the original and the aperture. This estimate of the proportion between the image and the object, would not require the qualifying term *nearly*, but would be correct, if the aperture were exactly opposite the centre of the front of the house; but we have supposed the aperture to be nearer one side of the building than the other, in order that the rays from the nearest gable of the house may pass through the aperture. This being attended to, there will be an image of the gable end upon the screen; and the size and shape of this part of the image must be particularly noticed. It will be found, that, though the gable may be in reality as broad as the front, its image is extremely narrow; that its ground-line, instead of being level with that of the front, inclines more and more towards the top as it recedes from the eye, and that the further edge of the inclined roof inclines to this line with a greater degree of inclination than the original is known to have: thus, besides the narrowness in point of breadth, the height of the most distant corner of the gable is in the image shorter than the hithermost corner. This visual contraction of surfaces is called fore-shortening.

To understand how it happens, let the student suppose a thread stretched from any given point in the most distant angle or vertical edge of the gable to its image on the screen, or spot on which it would fall by taking a rectilinear course; let another line be supposed to be drawn from an opposite point of the nearest angle of the gable, and it will be per-ceived that as these lines, like the rays of light, cross the aperture, they will, at the screen, form but a very narrow opening; and as the breadth of the image cannot be greater than this opening, the breadth of the gable must be incon-siderable on the screen. It will be obvious at the same time, that the more nearly the gable is taken in front, the greater will be the breadth of its image, while that of the apparent extent of the front will be proportionally contracted. The incli-nation of the ground-line of the gable will be explained, by sup-posing lines to be drawn from the four corners or limits of the gable, to their respective places on the screen; for the line which bounds the further side of the gable must have a less image on the screen than the hithermost, because it is more distant, and at an intermediate distance, any vertical line in the gable must have an intermediate height; therefore, there must be in the picture a gradual rising of the ground-line towards a point horizontally opposite the place of the aperture:—Now the whole art of perspective consists in observing rules which teach us to discover the diminutions of all objects seen obliquely, like the gable-end of the house. To render this experiment, and the inferences drawn from it, perfectly clear, it ought to be tried and fully considered. It will then speak to the eye, and the object to be obtained by perspective can scarcely be misunderstood, whereas the impression of mere words is speedily effaced.

To prevent any incorrect inference, we shall, however, refer to fig. 1, where, let C D represent the window-shutter of the darkened chamber, and *g* the aperture in it, A B an external object, and E F the screen which receives its image. It must be observed, that the darkened chamber is used only as a means of separating the rays which form an image from any other; and that if the direction of the rays could be ascertained as much before the shutter, as they are here behind it, an image of the original object would be obtained of the same size as that upon the screen, and in its erect position, because the rays have not crossed. Accordingly in the practice of perspective, the rays of light from an object are always supposed to be intercepted as they converge to the eye at some point, as at *h*, between the original object and the eye. In the experiment, therefore, the aperture in the window-shutter must be considered as representing the pupil of the eye, the darkened chamber of the eye, and the screen the retina, or as a means of rendering visible the pictures which the eye receives of visible objects. We need not observe, that a larger aperture, with a convex glass set in it, would, in fact, form a camera obscura, and a very distinct image would be painted on the screen, at the focus of the glass, but the experiment would then be less simple, and the direction of the rays not so evident. Without a glass, the distinctness of the picture is sufficient to be agreeable, when the eye has been sometime in the chamber.

To consider the foundation of perspective in another point of view, let A B C D, fig. 2, represent a house, seen by the eye at N. The eye N, is supposed to be opposite the corner *q* of the house; its distance from which is equal to N *q*, and its height five feet from the ground. The situation of the eye corresponds to that of the hole in the window-shutter of the former experiment, and the picture of the house formed in the eye itself corresponds to that which the screen received. In this situation, as in every other, straight lines drawn from every part of the house to the eye, represent the direction of the rays which form the images of those parts respectively, and thereby render the house visible. The eye, it must be understood, is fixed upon the point *q*, directly before it, and in order that no sensible deviation may be possible, we may suppose it to be looking through a very small aperture in a piece of thin brass, *g*. If now a transparent plane, for example a pane of glass, K L, be interposed between the house and the eye, at a short distance from the eye, the whole of the house will be seen through the transparent plane, although the latter is, comparatively with the house, of very small dimensions, because the rays, in proceeding to their point of convergence at the eye, have approached each other in a proportion inversely as the distance; that is, at half the distance from the object, they only extend over half the space contained between the points of emission; at one-fourth of the distance from the eye, they only take up one-fourth of the space; and the same proportion for other distances. Suppose the pane of glass to be within arm's reach of the eye at N, and that it is coated with gum-water or isinglass, so as to receive the marks of a pencil, without having its transparency destroyed; trace the outlines of the house upon the glass, by observing and following exactly the direction in which they are seen through the small aperture in the piece of brass. When this is done, it will be found that the real or measured extents, forming the different external surfaces of the house, are represented by extents modified by the distance and obliquity of these surfaces to the eye; in short, as shown in the figure, a representation of the house in true perspective will be obtained, in the given situation of the eye. To young persons, the difficulty of understanding an explanation of this kind is occasioned by their indistinct perception of the relation between the rays and lines from a real object, and the projection of those lines upon a flat surface, as a sheet of paper. It appears confusing to them to say that the eye is opposite to the corner *q* of the house, and yet to represent it at N on one side. Unless this difficulty be overcome, and the mind can form a distinct image of the direction which the line shown on paper would have if drawn from a real object, perspective diagrams will be contemplated with pain, and the remembrance of them will soon be effaced. We shall therefore propose a little experiment, which we recommend to be tried by those who feel the difficulty alluded to.

Let a small model of a house be made of wood, and to every corner of it which can be seen in any one situation, affix a thread of silk, two or three times as long as the model of the house is high. These threads will represent the rays of light proceeding from the corners A B C D, *f k l m* of the house in *Figure* 2. Let the threads be drawn through a hole in a piece of thin brass, just large enough to admit them to be moved freely. The hole in the piece of brass will represent the eye. Let small weights be attached to the extremities of the threads which have been passed through the hole in the brass; the threads being thus stretched, will form a right line from the house to the brass, and the apparatus will be ready for elucidating the nature of perspective. Whil the model of the house remains stationary, let the position o the brass be varied, sometimes placing it higher, sometime lower, at different distances, and towards different sides and let the angles formed by the threads in each situation b attentively considered, by the observer placing himself behin the brass, and supposing himself to regard the house as if h saw it through the hole. Let him after each remove of th brass, suppose that the threads representing the rays of ligh without altering their direction, were to pass through a shee of paper, interposed at any distance between the brass an the house, and he would find that by drawing lines to joi the points thus obtained, an outline representation of th house would be produced, and this representation would b in true perspective. For any one situation, it would n be a troublesome matter to perforate a piece of paper, to b slipped upon the threads without distorting them; and f other situations, a good idea of what the representation wou be, or, in other words, of the perspective space between a given points, would be obtained by measuring the openin between the threads at equal distances from the brass. Aft the trial and proper consideration of this experiment, it w be easy to form a tolerably correct idea of the perspecti appearance of any object, or assemblage of objects, and n difficult to exhibit that appearance on paper. In perspect diagrams, lines must be drawn to represent the rays, t direction of which in this experiment is indicated by threa and as the view of an object varies from the point in wh it is seen, the situation of the eye, both in height and distan must be laid down upon paper, on which the perspect drawing of an object is to be made, unless we propose to l at the object itself as through a transparent plane. question then occurs, how shall the position of the eye esignated on paper? It can no way be represented so clearly s by placing it on one side, as shown in the figure, or by lacing it vertically beneath the object to be drawn, as re-resented in *Figure* 12.

By whatever means the representation *t u*, *Figure* 2, of an bject A B C D, is obtained, if the outline be accurate, and ewed at a proper distance, it is plain it will make an out-ne of the same form in the eye as the object itself; and if e colouring were equally perfect, the eye might mistake the gure for the original. But even when colours are not em-loyed, correct dimensions give the whole a pleasing ap-earance, and constitute the first great requisite to every good cture.

Having thus endeavoured to explain the nature of perspec-ve, we may next advert to the limits of vision. We may onsider the eye, in whatever direction we look, as situated the centre of a sphere, which we may suppose to be repre-nted by the circle E K F I, *Figure* 3. The hemisphere E L F behind the eye, and therefore obviously invisible; and it is so certain, that the eye, looking forward horizontally to K, annot take in at once the whole of the hemisphere E K F. o far from this, it cannot take in a larger angle than S R T, hich is but half a hemisphere, or equal to 90 degrees. And s the rays which the eye takes in, extend all round to an qual distance from the central ray K R, it follows that the hole of the rays which enter the eye at once, will be in the orm of a cone, of which the apex is at the eye; and of such cone of rays, S R T may be considered as the profile. It is owever found, that to have an agreeable view of large ob-ects, such as buildings, the angle of vision should not exceed 0 degrees, or one-third of an hemisphere; in other words, at we cannot distinctly see the whole of an object, unless s distance from the eye be at least equal to its height; and e appearance of a picture will be more agreeable, if not ade to comprehend above 45, or at most 50 degrees; in-eed, for small objects, or such as do not exceed the length f a foot in any of their dimensions, it is not advisable to xceed an angle of 30 degrees. As a picture therefore should ever comprise more than the eye can easily take in at one iew, a distance of 25 degrees on either side of the point of ight, may be considered a standard limit. Fifty degrees to e eye at B, are comprehended in the angle *x* R *y*; and we eed scarcely observe, that the measure of an angle, is the pace it takes up on the circumference of a circle, which has e point of the angle for its centre; a circle being always pposed to contain 360 degrees. Hence, if the lines form-g the angle *x* R *y* were extended, the angle *v* R *t* would still e only one of fifty degrees, because, whatever were the ze of a circle drawn from the point R, through its two gs, if that circle were divided into 360 parts, the number those parts enclosed by the angle, could not be more an fifty.

We shall now proceed to the definition of the terms used treating of perspective, and then show the method of put-g into perspective, those forms which may be considered the elements of all others.

DEFINITIONS.—1. An *original object* is any object what-er, which is rendered the subject of a picture.

2. *Original planes* or *lines* are the surfaces or lines of iginal objects.

3. *Perspective plane* is the surface on which a picture is lineated. It may be here observed, that painters regard e frame of a picture merely as an aperture through which iginal objects are seen; and they therefore consider the rspective plane to be transparent, to admit of this view. s on this account that the perspective plane is frequently led the *transparent* plane.

4. *Ground-plane* is the earth or surface on which stand the objects to be delineated, as well as the spectator.

5. *Ground-line* is the line on which the perspective plane is supposed to rest.

6. *Visual rays* are those which, passing through the transparent plane, render original objects visible.

7. *Principal visual ray* is that which passes through the axis or centre of the eye, and the course of which, therefore, from the perspective plane, is shorter than any other, because it is perfectly direct. Its height above the ground-line is, of course, always the same as that of the eye.

8. *Point of sight* is that fixed point from which the spectator looks upon the perspective plane, when any original object is delineated.

9. *Centre of the picture* is that point of the perspective plane which is exactly opposite the point of sight, that is, where the principal visual ray enters the transparent or perspective plane. It must, therefore, be carefully distinguished from the measured centre of any picture, as it can never exceed the height of the eye from the ground-line.

10. *The distance of the picture*, or *point of distance*, is the distance between the eye and point of sight, and the centre of the picture.

11. *Vanishing points* are those points to which all lines inclined to the picture appear to converge, and which those lines meet when produced. Vanishing points have no place in a finished picture; they are used to facilitate drawing in perspective.

12. *The horizontal line* is a line parallel with the horizon, at the height of the eye,—that is, it passes horizontally through the centre of the picture.

Distance of a vanishing point is the distance upon the vanishing point on the picture to the eye of the spectator. It may also be proper to remind some, of the difference between a perpendicular and a vertical line or plane: a vertical line points directly to the centre of the earth; it is therefore at right angles to the plane of the horizon, and is the same with the direction of a plumb-line: a perpendicular line is any line which is at right angles to another; it may therefore be sometimes a vertical line, sometimes a horizontal one, or in any other position, according to the direction of the line or surface with which it forms a right angle.

Methods of putting squares into perspective.—Suppose a square to be traced upon the ground at some distance before us; that we find, upon admeasurement, the length of each side to be 8 feet, and that we are opposite the centre of the nearest side, at the distance of 18 feet. We know, that if we wish to obtain what is called a ground-plan of this square, we must represent it by a square upon paper, as in *Figure* 4, and thus we shall have its real appearance, supposing the eye to be looking down upon it, just over its centre; but looking upon it obliquely, as we have stated, and with the eye at the height of 6 feet from the ground, we are convinced, from the nature of perspective, as before explained, that the side nearest to us will make a longer line upon the retina than any of the rest. The question is, therefore, to obtain the true appearance of the whole square,—that is, the true form of the image it makes on the retina. In the first place, determine the scale to be observed,—that is, what space shall correspond to a foot of the original. For example, suppose one-tenth of an inch; then draw a line, A B, *Figure* 5, eight-tenths of an inch long, and another line, H D, parallel with this base-line, at the height of six-tenths of an inch from it. Raise a perpendicular from the centre of the line A B, and the point C, in which cuts the horizontal line, will be the centre of the picture. From C on the horizontal line, set off the distance at which the square is seen, which will here be eighteen-tenths of an inch, and the point of distance D will be obtained. From A, draw the line A C; and from B, the line B C; then from A, draw the line A D, and to the point *h*, in which A D intersects B C, draw a line *g h*, parallel with the ground-line A B; then will A *g* D *h* form the perspective outline of the square required. Let it be supposed that the square above described is viewed by an eye situated opposite one of its corners, as in *Figure* 6. Draw a base-line, B L, as before, and on each side of any assumed point, *k*, set off half the measured length of the diagonal of the square, viz., half the distance between the corners *y* Z, *Figure* 4. Parallel to the base-line, at the height of six-tenths of an inch from it, draw the horizontal line P H D, and raise from *k* the perpendicular *k* C. From F, draw the line F C, and from G, the line G C. On each side of the centre C, set off on the horizontal line the points of distance P D, and from each side of them draw lines to the centre of the base *k;* then from *a*, draw the line *a* P, and from *b*, the line Z D, and the diagonal view, *a b f k*, of the square, will be completed.

We shall give one more example respecting squares:—Suppose we have a square pavement, composed of equal alternate pieces of black and white marble; the total number of small pieces to be 144, and each of them 1 foot square, as—

Here there will be six black and six white pieces on each side of the square. Suppose the spectator to stand opposite the middle of the third square on the left, and that, for greater clearness, the scale be two-tenths of an inch to a foot, with the eye 5 feet above the ground, but at the distance of 18 feet, as before. Draw a base line *r k*, and divide a part of it into as many equal divisions as there are squares on one side of the original, as 1, 2, 3, 4, &c. These divisions, by the scale now adopted, will each be two-tenths of an inch. Draw the horizontal line at the distance of 5 feet (according to the scale) from the base. From the middle of the space between 2 and 3, raise a perpendicular, and to the point C, in which it cuts the horizontal line, draw lines from the commencement and the termination of the divisions on the ground-line, viz., *r* C and 12 C. From C, set off the distance C D, 18 feet, for the distance of the eye. Draw the line *r* D; and from *e*, where it intersects the line 12 C, draw a line, *e f*, parallel with the base-line *r k;* then will *r f e* 12, give the boundaries of the pavement. To obtain the reticulations, draw lines from each of the divisions, 1, 2, 3, &c., on the base-line, to the centre of the picture C, and from each of the same divisions to the point of the distance D. The lines drawn from the divisions to C, from the right and left sides of the small squares, and the lines drawn from the divisions to D, give the points on the line C 12, from which the horizontal lines may be drawn to form the other sides of the squares. Or, after all the lines are drawn from the divisions on the ground-line to the centre C, and also the line *r* D, the remaining sides of the squares may be obtained by drawing parallel lines through the various points in which the part *r e*, of the line *r* D, intersects the lines drawn to the centre C.

It is often thought by those who are commencing this study, that representations such as the one now given, have no resemblance to the originals; but if they be examined, as every picture ought to be examined, opposite to the point of sight, and at the distance for which they are drawn, the idea of their incorrectness will disappear; to render the illusion the more complete, the figure should be viewed through a small tube or aperture, to prevent the intrusion of surrounding objects. It must also be observed, that diagrams upon paper have frequently, for the sake of convenience, a vanishing point so near, that the eye has not the power of distinct vision at the distance for which they are drawn. Such designs, therefore, although correct in principle, will not appear correct to the eye unless enlarged.

To put a circle into perspective.—The perspective or oblique view of a circle, is an ellipse, and it is usually obtained by drawing a square of a size just sufficient to contain the circle, and dividing it into small circles, then putting the divided square into the perspective, and drawing within it a line through the corresponding parts of the small squares, and this line will be an ellipse. Thus, to obtain the perspective of a circle E F G H, fig. 8, draw round it the square A B C D. Divide the square into small squares, the number of which should be increased in proportion to the exactness with which the perspective curve must be obtained; draw also the diagonals, C B and A D. Throw the square and reticulations into perspective, as represented in fig. 9, where C is the centre of the picture, and D the point of distance; then draw the curve by hand through the parts corresponding to those through which the circle passes in fig. 8. The perspective view of a circle will be an ellipse, whether the square opposite the middle of one of its sides, as in fig. 9; or even with one of its angles, as in fig. 10, where D C is the line of sight; or at a distance on one side, as in fig. 11, where L C is the line of sight. The point of distance, in figs. 10 and 11, is the same as in fig. 9, though in fig. 11 it could not be drawn without extending beyond the limits of the plate.

To put a triangular prism into perspective.—To represent in perspective a triangular prism or solid, standing vertically upon one of its ends, and viewed by an eye just opposite one of its angles; draw by admeasurement a plan of a prism, as *a b c*, fig. 12; then draw the line G K across the outermost boundary of the triangle, and make E F parallel with G K. From *e* let fall the line *e d*, perpendicular to G K. On *c d* set off the measured distance of the eye from the prism, and mark the place of the eye at *d*. From *a* and *b*, draw lines meeting each other in *d*. From *d*, draw the line *d m* parallel with *a c* of the triangle, and on the other side of the line *d l* parallel with *b c*. From *e* raise the perpendicular *e f* to the measured height of the nearest angle of the prism to which the eye is opposite. On *e f*, measure the height of the eye from the ground-line G K, and draw the horizontal line H H. Take the distance *c m*, set it off on each side from *n*, and it will give the vanishing points V P and V. Draw the lines *e* V P and *e* V. Then from *o* and *p*, where the lines from *a* and *b*, in proceeding to the eye, cut the line E F, draw the lines *p q* and *o s*, parallel with *e f*. Draw the lines V *x f* and *f w* V P, and the perspective outlines *w f x r e z*, of the prism, whose base is equal to the triangle *a b c*, will be obtained, and may be finished by shading it according to the direction in which the light falls upon it. This mode of drawing from a ground-plan is extremely useful, and well calculated to show the difference between the visual and real dimensions of objects. The outlines of the house A B C F in fig. 2, were obtained by it; it should be rendered familiar by frequent practice on figures in different positions.

To put a cube and cylinder into perspective.—As the base of a cube is a square, it may, when viewed as in the present example, opposite one of the angles, be put into perspective by the same process as the square in fig. 13, and figs. 9, 10 and 11, will explain the manner in which the perspective of a square, seen in other positions, may be obtained. Having then obtained the base, we shall find that when H is the horizontal line, P D the points of distance, and *a b* half the measured length of the diagonal of the cube, the perspective of the base will be represented by *a f d g*. Make the height of *a c* equal to the measured length according to the scale, of one of the sides of the cube, then draw the lines C D and *e*

PERSPECTIVE PLATE 1.

Fig. 1.

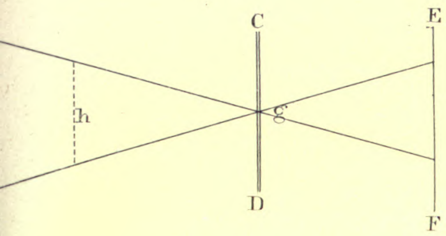


Fig. 2.

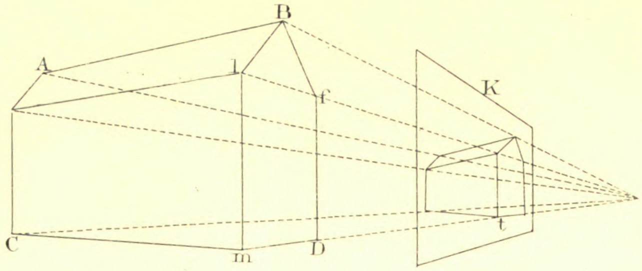


Fig. 3.

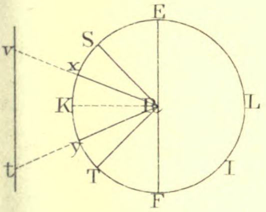


Fig. 4.

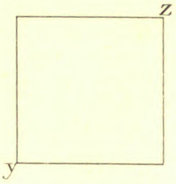


Fig. 5.

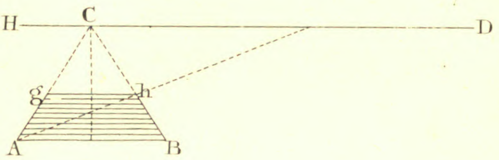


Fig. 6.

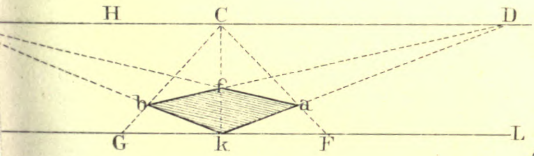
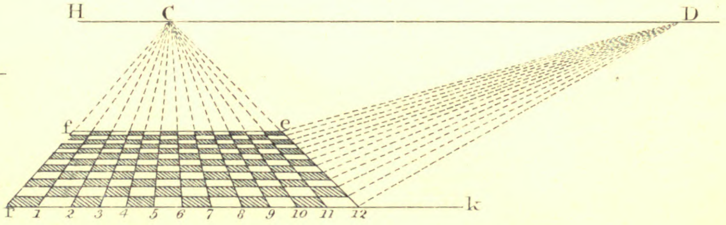


Fig. 7.



8.

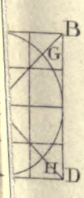


Fig. 9.

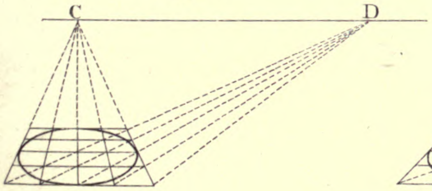


Fig. 10.

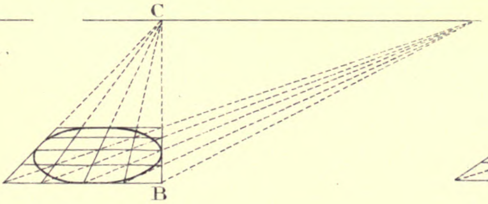


Fig. 11.

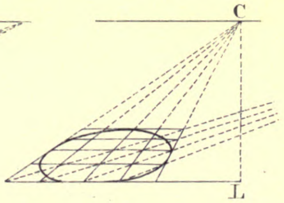


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Fig. 12.

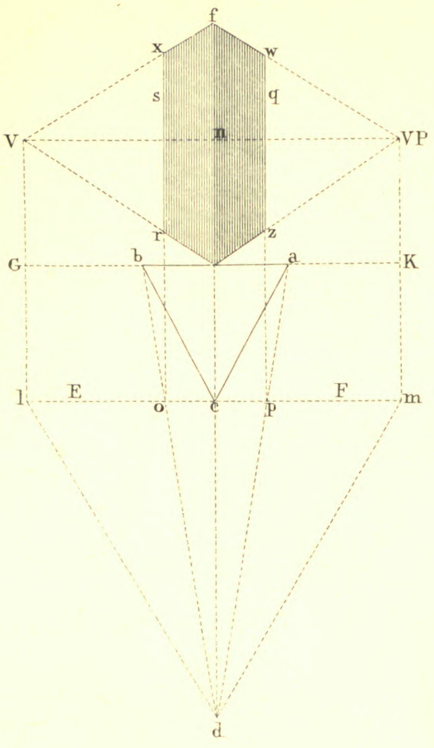


Fig. 13.

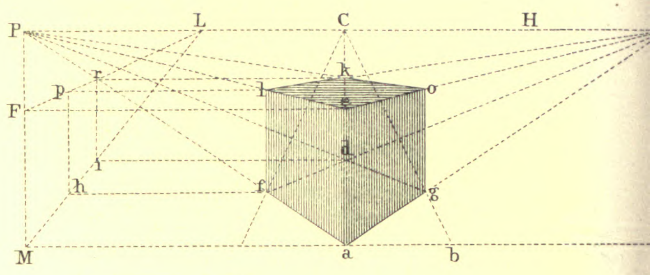


Fig. 14.

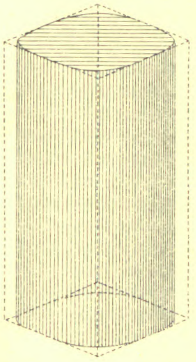


Fig. 15.

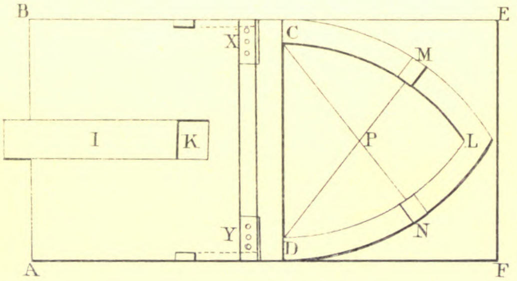
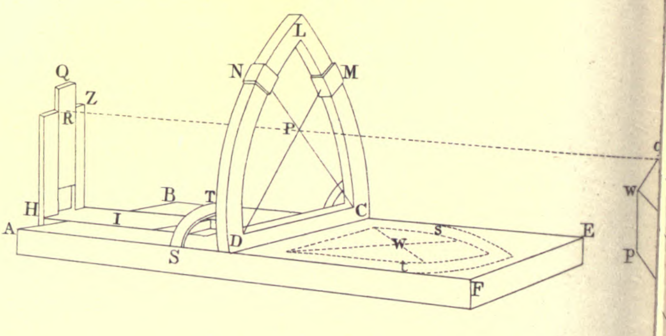


Fig. 16.



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From *f* and *g* draw lines parallel with *a e*, for the sides of the figure; draw the line *e* F to a perpendicular let fall from the horizontal line at P to M. From F draw a line to any part of the horizontal line, as to L, and draw from M a line to meet this in L. To *f* draw the line *f h*, and to *d* the line *i d;* then from *h* and *i* raise perpendiculars to intersect F L, and from the points of intersection draw the lines *p l* and *r k;* thus will be obtained the perspective outline of the cube *k l f a g o e.* If the cube had not been viewed directly opposite one of its angles, the points of distance would not on each side have coincided with the vanishing points, and the vanishing points would have been best obtained as for the triangular prism, fig. 12.

The procedure of a parallelopiped, is essentially the same as for a cube. To put a cylinder into perspective, first proceed as for a cube or parallelopiped, draw on the perspective of each, and such an ellipse as it will admit; let the longer or conjugate axes be equal, and join the opposite extremities of these axes by two parallel lines, as shown in *Figure* 14. Having thus obtained the perspective of the cylinder, it only remains to erase the lines which belong to the cube or parallelopiped.

Of shadows, and description for drawing perspective.—Having now shown the mode of putting into perspective those elementary forms which enter into the composition of drawings of every description, we shall be obliged to be concise with the remainder of the subject. The student must be aware how much difference of position affects the visual appearance of objects. And that by a proper attention to this circumstance, the few rules which have been given, may be applied to subjects of considerable complication. To acquire a knowledge of the principles of perspective, it is recommended not merely to compare the plates with the printed page, but to copy the diagrams, and, for the sake of greater perspicuity, to do this on as large a scale as may be convenient. Afterwards, some treatise especially devoted to the subject may be perused, and perhaps Brook Taylor's and Matton's may be the best; for although these authors will require considerable attention, they have the merit of being sure guides.

With respect to shadows, the proper distribution of which give such life to perspective drawings, it may be useful to remark, that the shadow cast by any object, covers the precise space which that object would prevent the eye from seeing, if the eye were in the place of the luminous body. The position, therefore, of the luminous body must always be ascertained, and the shadow to be assigned to any object in a picture, will be a perspective view of the space which the eye would be prevented from seeing, if in the place of the luminous body. A few experiments with a candle at night will be an easy mode of gaining a little acquaintance with this subject; it must, however, be observed, that the shadow from a candle is every way larger than that part of the object which intercepts the rays; but in point of breadth, this never happens with the shadows of the sun. The reason is, that the rays from the candle considerably diverge, while those from the sun, on account of the immense distance of that luminary, have no perceptible deviation from parallelism. It must be remembered also, that strong reflections from surrounding objects will diminish the intensity of shades, and that not only the quantity of light which falls on an object, but the quantity which can be reflected to the eye, must be considered.

As it frequently happens that persons have occasion to draw in perspective, who have acquired no theoretical knowledge of the art; for the use of such, a great variety of machines have been constructed. Most of these machines are on optical principles; the camera obscura, which we have already described, is one of them, and the camera lucida is another. In praise of the latter, much has lately been said; but although it must be admitted to be a very portable and beautiful instrument, the acquisition of the proper art of using it is extremely difficult to all, and to some impossible. Its chief use will be, that of affording the means of contemplating the real perspective appearance of objects, and perhaps to obtain the position of a few points; but for very minute delineation, it is of little value. For general use we may venture to recommend an instrument described by Ferguson, to whom the knowledge of it was communicated by Dr. Bevis. It has the advantage of other machines in two points; it may be constructed at a small expense by any tolerably skilful artisan in wood, and the use of it will constantly tend to render the practice of perspective drawing more easy, by the manner in which it produces the measure of surfaces or angles. It will therefore, better than most other instruments for the same purpose, supply the want of a more extended essay.

The machine in question is represented at *Figures* 15 and 16. *Figure* 15 is a plan, and *Figure* 16 a view of it on a larger scale. The same letters refer to the corresponding parts in both figures. A B E F is an oblong board, and X Y are two hinges on which the part C L D is moveable. This part consists of two arches or portions of arches, C M L, and D N L, joined together at the top L, and at the bottom to the cross bar D C, to which one part of each hinge is fixed, and the other part to a flat board, half the length of the board A B E F, and glued to its uppermost side. The centre of the arch C M L is at D, and the centre of the arch D N L is at C.

On the outer side of the arch D N L is a sliding piece, N, (much like the nut of the quadrant of altitude belonging to a common globe) which may be moved to any part of the arch between D and L; and there is such another slider O, on the arch C M L, which may be set to any part between C and L. A thread C P N is stretched tight from the centre C to the slider N, and such another thread is stretched from the centre D to the slider O; the ends of the threads being fastened to these centres and sliders. It is plain, therefore, that by moving the sliders on their respective arches, the intersection P of the threads may be brought to any point of the open space within those arches.

In the groove K is a straight sliding bar I, which may be drawn farther out, or pushed further in, at pleasure. To the outer end of this bar I, *Figure* 16, is fixed the upright piece H Z, in which is a groove for receiving the sliding piece Q. In this slider is a small hole R, for the eye to look through in using the machine; and there is a long slit in H Z, to let the hole R be seen through when the eye is placed behind it, at any height of the hole above the level of the bar I.

Suppose a house, *q s r p*, to be at a considerable distance beyond the limits of the plate, to obtain a perspective representation of it, place the machine on a table, with the end E F, of the horizontal board A B E F towards the house, so that, when the arch D L C is set upright, the middle part of the open space (about P) within it, may be even with the house when the eye is placed at Z, and looking at the house through the small hole R; and then fix the corners of a square piece of paper with four wafers, on the surface of that half of the horizontal board which is nearest the house.

To complete the arrangement of the apparatus for drawing, set the arch upright, as in the figure, which it will be when it comes to the perpendicular side T, of the upright piece S T, fixed to the horizontal board behind D. Then placing the eye at Z, look through the hole at R at any point of the house, as *q*; and move the sliders N and O, till the intersection of the threads at P, is directly between the eye and the point *q*; then put down the arch flat upon the paper on the board, as *s t*, and the intersection of the threads will be at W. Mark the point W on the paper with the dot of a blacklead pencil, and set the arch upright again as before; then look through the hole R, and move the sliders N and O, till the intersection of the threads comes between the eye and any other point of the house, as *w*; this being done put down the arch again to the paper, and make a pencil-mark thereon at the intersection of the thread as before; obtain the point *p* in the same manner, and draw a line from that mark to the one at *w*. The line *p w*, thus obtained, will be a representation in true perspective of the corner *p q* of the house.

By thus bringing the intersection of the threads successively between the eye and other points of the outlines of the house, as *r s*, &c., and putting down the arch to mark the corresponding points, on the paper, at the intersection of the threads, then connecting these points by straight lines, the entire perspective outline of the house will be obtained. In like manner, find points for the corners of the doors, windows, &c., and draw the finishing lines from point to point. The perspective drawing thus produced, may then be completed, by shading it according to the manner in which the light is observed to fall on the original.

Great care must be taken, during the whole of the time, that the position of the machine be not shifted on the table; and to prevent such an accident, the table or support employed should be perfectly steady, and the machine fixed down upon it by screws or clamps.

It is obvious that a landscape, or any number of objects within the field of view through the arch, may be delineated, by finding a sufficient number of points, and connecting them by straight or curved lines, as they appear in the original objects.

The arch ought to be not less than a foot wide at the bottom, that the eye at Z may have a large field of view through it; and the eye should be then at least ten inches and a half from the intersection of the threads at P, when the arch is set upright. If the eye be nearer, the boundaries of the view at the sides near the foot of the arch will subtend an angle at Z of more than sixty degrees, which will not only strain the eye, but will cause the outermost parts of the drawing to have a disagreeable appearance. To avoid this it will be proper to draw back the sliding bar I till Z be fourteen inches and a half distant from P; then the whole field of view through the foot-wide arch, will not subtend an angle to the eye at Z of more than forty-five degrees: which will give a more easy and pleasant view not only of the objects themselves, but of their representations upon the paper on which they are delineated. Hence, whatever may be the width of the arch, the distance of the eye from it should be in this proportion: as twelve is to the width of the arch, so is fourteen and a half to the distance of the eye (at Z) from it.

If a pane of glass, previously coated with thin gum-water, and dried, be fixed in the arch, a person who looks through the hole at R, may delineate upon the glass the objects which he sees at a distance, and the delineation may be afterwards transferred to paper. By this means will be saved the trouble of putting down the arch to take the position of every point, but it will not be so easy to obtain a correct representation.

Perspective of Shadows.—The shadow of an object is no more than the projection of its contour upon one or more planes, from a given luminous point, and is therefore the dark space upon these planes, occasioned by the intervention of the object, which hides the rays of light from proceeding in straight lines. To avoid difficulties, the luminary, whether the sun or artificial light, is considered as a point, and the sun's rays are considered as parallel.

Problem.—*Given the vanishing line of a plane, the image of a line insisting upon that plane, and its vanishing point; also the vanishing point of the sun's rays; to find the shadow of the line.*

Plate I. *Figure* 1.—Let A B be the vanishing line of the plane, *a b* the image of the line, V its vanishing point, and S the vanishing point of the sun's rays; join V S, and produce it to meet A B in *s*: join *b s* and *a* S, cutting each other in *c*, then *b c* is the shadow of the line required.

For the vanishing point of the line, and that of the sun's rays, are in the vanishing line of the plane of shade; therefore V S *s* is the vanishing line of the plane of shade; but the shadow is occasioned by the intersection of the plane of shade with the original plane, whose vanishing line is given; therefore the point *s*, the intersection of the vanishing line of the plane on which the line insists, with the vanishing line of the plane of shade occasioned by the line, is the vanishing point of the shadow.

Example to find the shadow of a cube.

Figures 2 and 3.—A B being the vanishing line of the plane of its base, and of the surface on which it rests; the edges *g d*, *b a*, *m n*, being supposed to be perpendicular to the base; then, if the picture be perpendicular to the original plane, the vanishing line of a plane of shade occasioned by the vertical arrises, will be perpendicular to the vanishing line A B; therefore let S *s* be the vanishing line of the plane of shade occasioned by the vertical edges, S being the vanishing point of the sun's rays, and *s* the intersection of the vanishing line of the plane of shade with that of the plane on which the shadow is to be thrown.

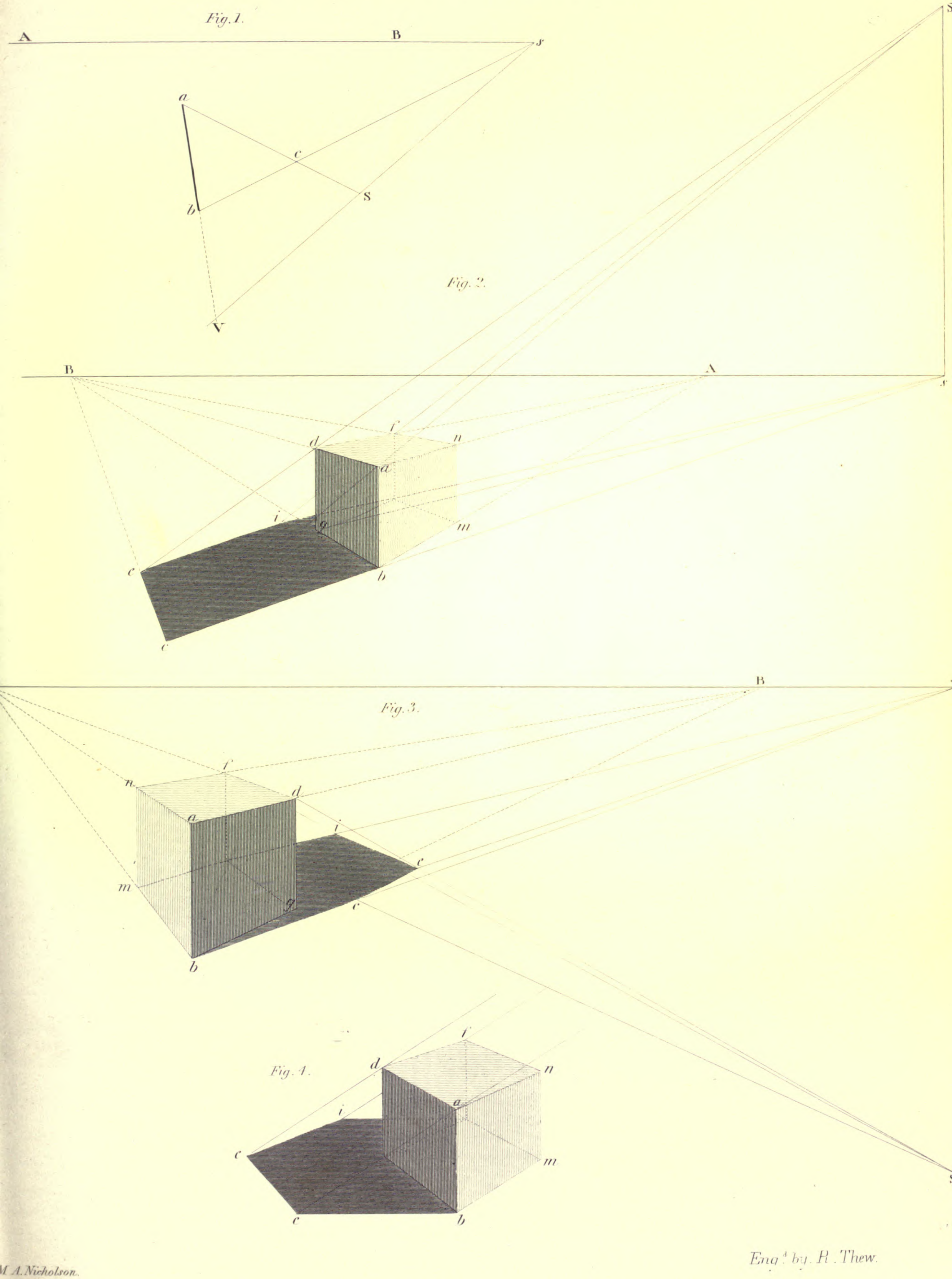
Join *b s* and *a* S, cutting each other in *c*; then *b c* is the shadow occasioned by the edge *b a*; join *c* B and *d* S, cutting each other in *e*, or, if necessary, produce them to cut in *e*, and *c e* is the shadow occasioned by the edge, *a d*, parallel to the plane of its base; also join *e* A and S *f*, cutting each other in *i*, or, if necessary, produce them to cut each other in *i*; then *e i* will be the shadow of the edge *d f*; lastly draw *i s*, which will complete the shadow of the cube, as required.

Figure 2 shows the shadow when the sun is before the picture: *Figure* 3 shows the shadow when the sun is behind the picture; and *Figure* 4, the shadow when the sun is in the plane of the picture.

Many more examples of the shadows of objects might be given, but if the principles here shown are understood, the student will not be at a loss to find the shadow of any right-lined object whatever. To find the shadow of any right-lined object, is no more than to find the shadow of the lines, or arrises, formed by the meeting of the sides, and those only of the lines forming the contour; if a circle be given, the circumference may be divided by parallel lines into parts, and the shadows of the points of division may be found by finding the shadows of the intercepted parts, then drawing a curve round the extremities. If it were required to find the shadows upon several planes; first, find the shadow in the plane on which the object rests; then, observe where the shadow meets the next plane; then, having the vanishing line of this second plane, observe where the vanishing line of the plane of shade cuts the vanishing line of the second plane; then the point of intersection is the vanishing point of the shadow in this second plane. See more of shadows under the article Projection, where the principles apply as well to perspective as to orthographical projection.

PERUZZI, BALDASSARE, in biography, was born at Accajano, in the territory of Sienna, in 1481, in poor and dis-

PERSPECTIVE OF SHADOWS, PLATE I.



M A. Nicholson.

Eng.d by. R. Thew.

tressed circumstances; his father having been reduced from a state of comparative affluence, by the civil wars which ravaged Florence and its territory. Baldassare exhibited his genius at a very early age; first by imitation of the works of others, and afterwards by original productions in the city of Volterra, where his family resided. Thence he went to Rome, where he placed himself with the father of Maturino; and becoming conspicuous for ability, he was at length employed by pope Alexander VI., and also in many churches and convents in that city, in which he produced pictures justly entitled to exalted praise.

Together with painting, he studied architecture; and practised it with considerable success. He was also renowned for his knowledge of perspective; and the works he produced in imitation of architectural projections, excited even the surprise and admiration of Titian. But his highest renown is founded upon works of a much more elevated class; viz., his paintings in fresco and in oil; in which he exhibited a taste and style not unworthy of Raphael. There is at Wilton a picture of his of the Four Evangelists in Glory, with their peculiar characteristic accompaniments, which bears ample testimony to the truth of this remark; and perhaps it is the only real specimen of his pencil in England. He wrote a treatise upon the antiquities of Rome, and a commentary on Vitruvius, but did not live to publish them; being poisoned by some who were probably envious of his reputation and talents, in 1536, at the age of 55.

PEST-HOUSE, a lazaretto, or infirmary, where goods, persons, &c., infected, or suspected to be infected, with some contagious disease, are disposed, and provided for.

PETER OF COLECHURCH, an architect and priest, who built the late London Bridge, in the reigns of Henry II. and his sons Richard and John.

PEW, or Pue, a wooden seat or bench used in churches, of sufficient length to contain several persons. The term has, of late years, been particularly applied to the closed boxes provided with doors, but is equally applicable to the open seats of a previous age, which are now again happily superseding the closed pews. We have many beautiful examples of such benches, some very richly carved; they consist, for the most part, of a low seat and back, fixed into a standard at each end, which is either plain or carved, and is sometimes finished at the top with a finial, boss, or poppy-head.

PHALANGÆ, a term applied by Vitruvius to wooden rollers employed to transport heavy weights from place to place.

PHAROS, or Phare, a lighthouse, or pile raised near a port, where a fire is kept burning in the night, to guide and direct vessels near at hand. The pharos of Alexandria, built in a small island at the mouth of the Nile, was anciently very famous, insomuch as to communicate its name to all the rest. It was so magnificent a structure, being built by the celebrated architect Sostrates, a native of Cnidos, or, as some say, by Deiphanes, the father of Sostrates, that it cost Ptolemy Philadelphus eight hundred talents. It had several stories, raised one over another, adorned with columns, balustrades, and galleries, of the finest marble and workmanship; to which some add, that the architect had contrived to fasten looking-glasses so artificially against the highest galleries, that in them could be seen all the ships that sailed in the sea for a great way; instead of which noble structure, there is now only a kind of irregular castle, without ditches, or outworks of any strength, the whole being accommodated to the inequality of the ground on which it stands, and which, it seems, is no higher than that which it should command. Out of the midst of this clumsy building rises a tower, which serves for a lighthouse, but possessing nothing of the beauty and grandeur of the old one. The colossus of Rhodes also served as a pharos. *See* Eddystone, and Lighthouse.

PHEASANTRY, a building or place constructed for the purpose of breeding, rearing, and keeping pheasants, which should always be near to, and well covered with, plenty of wood, in different states of growth; the whole being enclosed with a high fence, that the young may, as soon as possible, run freely through it, and pick up their food, &c.

PHENGITES, in the natural history of the ancients, the name of a very beautiful species of alabaster. It is a very rude and irregular mass, very friable, yet of a brightness superior to that of most of the other marbles, and excelling them all in transparency; it is in colour of an agreeable pale yellowish white, or honey colour; the yellowish is more intense in some places than in others, and sometimes has an obscure resemblance of veins. It is very weak and brittle in the mass; and when reduced to small pieces, easily crumbles between the fingers into loose, but considerably large angular pieces, some perfect, others complex, irregular, or mutilated, and all approaching to a flat shape.

The ancients were very fond of this species in their public buildings; and the Temple of Fortune, built wholly of it, has long been celebrated. Its great beauty is its transparency, from which alone this temple was perfectly light when the doors were shut, though it was built without a window, and had no other light but what was transmitted through the stone walls. It was anciently found in Cappadocia, and is still plentiful there: it is also met with in Germany and France, and in our own kingdom in Derbyshire, and some other counties. It takes an excellent polish, and is very fit for ornamental works, where no great strength is required.

PHIALS, vases used by the ancients in the construction of vaults; they were made of a slightly conical form, so as to fit into each other, and were manufactured of a light material, so as to ease the weight and thrust of the vault.

PHIDIAS, in biography, an Athenian, the most celebrated sculptor of antiquity. His distinguishing character was grandeur and sublimity; and he particularly studied optical effect. To this purpose it is related, that having, in competition with Alcamenes, made a statue of Minerva to be placed on a column; the work of the latter appeared so finished when viewed on the ground, that it was universally admired, whilst that of Phidias seemed to be a mere rough sketch; but when both were seen from their destined situations, the beauties of the first were lost, while the second produced the most striking effect. After the battle of Marathon, he converted a block of marble, which the Persians had brought for a trophy of their expected victory, into a fine statue of Nemesis, the goddess of Vengeance. His reputation was so high at Athens, that Pericles regarded him as his particular friend, and appointed him superintendent of all the public edifices with which that city was decorated. One of his greatest performances was a colossal statue of Minerva, in the temple called Parthenon. In this work he displayed his skill in minute sculpture, no less than his grandeur of conception in the main figure. On the convexity of the goddess's shield was represented the battle of the Amazons, and on its concave surface the combat of the gods with the giants; whilst her slippers were adorned with the fight of the Centaurs and Lapithæ. On her breastplate was a Medusa's head. The base contained the birth of Pandora, with twenty figures of the gods. He is said to have been the first who brought the bas-relief to perfection. His fame and fortune excited envy, and several accusations were brought against him, which he was enabled to repel. At length, he was charged with having introduced the portraits of himself and Pericles in the battle of the Amazons; and this being regarded as a kind of profanation, he was thrown into prison, where, according to Plutarch, he died. Others, however, affirm, that he escaped to Elis, where he afterwards executed his Olympian Jupiter, the most remarkable piece of sculpture in all antiquity. It was a colossal statue, sixty feet high, of incomparable majesty and dignity in its attitude and expression. The name of the artist was engraved on the base. The Eleans, in gratitude for this extraordinary work, settled upon his descendants a perpetual office, the sole duty of which was to preserve the lustre of the statue.

PIACHE, or Piazza, a covered arched walk, or portico. *See* Piazza and Portico.

PIAZZA (from the Italian *piache*) a portico, or covered walk, supported by arches. The word literally signifies a broad open place, or square; whence it also became applied to the walks, or the porticos around them. *See* Portico.

PICTS' WALL, in antiquity, a remarkable piece of Roman work, begun by the emperor Adrian, A.D. 124, on the northern bounds of England, to prevent the incursions of the Picts and Scots.

At first it was made only of turf, strengthened with palisadoes, till the emperor Severus, coming in person into Britain, repaired it, as some say, with solid stone, reaching eighty miles in length, from the Irish to the German sea, through Carlisle and Newcastle; with watch-towers garrisoned, now called *castle-steeds*, at the distance of a mile from each other.

It does not appear with sufficient evidence, that Severus's wall was formed of stone: Bede expressly asserts the contrary, though Spartian intimates that Severus built both a *murus*, *i.e.* a wall of stone, and a *vallum*, or a wall of turf. Bede relates, that "Severus, after several great and difficult engagements, thought it necessary to separate that part of the island, which he had recovered, from the other nations that were unconquered; not with a *murus*, as some think, but with a *vallum*. Now a *murus*," continues he, "is of stone; but a *vallum*, such as they made round a camp, to secure it against the attacks of the enemy, is made of turf, cut regularly out of the ground, and built high above ground, like a wall, with the ditch before it, out of which the turf has been dug; and strong stakes of wood all along the brink." Severus, therefore, drew a great ditch, and built a strong earthen wall, fortified with several turrets from sea to sea. The learned Camden adopts this opinion; and adds, that Severus's wall is expressed by no other word than *vallum*, either in Antoninus or the *Notitia*.

This wall was ruined several times by the Picts, and often repaired by the Romans. At last Aëtius, a Roman general, ordered it to be rebuilt of stone, about the year 420; but the Picts ruining it in the year following, it was thenceforward regarded only as a boundary between the two nations. The wall was eight feet thick, and twelve high, from the ground: it ran on the north side of the rivers Tyne and Irthing, up and down several hills: the tract, or remains of it, are to be seen to this day in many places, both in Cumberland and Northumberland.

The inhabitants of the country pretend, that there was a brazen trumpet, or pipe, so artificially laid in the wall between each castle and tower, that, upon the apprehension of danger at any one place, by the sounding of it, notice might be given to the next, and then to the third, &c., whence it derived the ancient name *cornage;* and in the inside a sort of fortified little town, now called Chester, the foundations of which appear, in some places, in a square form.

PICTS' HOUSE, a name given to the remains of some ancient buildings not uncommon in the Scottish isles, the erection of which is attributed to the Picts. They are composed of large stones uncemented, built up in a conical form, and are of various sizes. Some consist of only a single chamber, with one external wall, others have an outer and inner wall, about two feet distant from each other, the space between being occupied by a winding stair. There is an example at Kirkwall, the form of which is that of a truncated cone, the height being about 14 feet, and its circumference at the base, 384 feet. "It is probable," says a writer on the subject, "that it was surrounded by two walls, but the quantity of rubbish rendered this circumstance difficult to ascertain. Internally, it consists of several cells or apartments, the principal one of which is in the centre, built with large flat stones without cement, the one immediately projecting over that below, so as gradually to contract the space within as the building rises, till the opposite walls meet at the top, when they are bound together by large stones laid across. Six other apartments of a similar form and construction, but of little more than half the dimensions, communicate with the central one, each by a passage of about two feet square, on a level with the floor. There does not appear to have been any contrivance for the admission of light. The earth at the bottom of the cells, as deep as could be dug, was of a dark colour, of a greasy feel, and of a fetid odour, plentifully intermingled with bones both of men, of birds, and of some domestic animals. In one of the apartments, an entire human skeleton in a prone attitude was found, but in the others the bones were not only separated from one another, but most of them divided into small fragments. From their appearance, some have supposed the inhabitants to have been cannibals."

PICTURE (from the Latin *pictura*), an imitation, or representation by lines and colours of any natural object. Such representations are also called *paintings*, from the name of the art by which they are produced; which, being capable of general application, and of great influence upon the mind, has, at all times, since men have cultivated their intellectual powers, been regarded with peculiar interest.

The subject of a picture may be represented in colours, on canvass, wood, or the like; and enclosed in a frame.

Pictures or paintings in oil are preserved by coating them with some transparent or hard substance, as a varnish, in order to secure the colours from the injuries of the air or moisture; and to defend the surfaces from scratches or any damages the painting might receive from slight violence. The substances that have been, or may be used for this purpose, are gum-arabic, dissolved in water, with the addition of sugar or sugar-candy to prevent its cracking; glair or whites of eggs, mixed with a little brandy or spirit of wine, in order to make it work more freely, and a lump of sugar to prevent its cracking; isinglass, used as either of the former, or mixed with a fourth or fifth of its weight of honey or sugar, and varnishes formed of gum resins dissolved in spirit of wine, or oil of turpentine; which last are called *oil-varnishes.*

Paintings in miniature are preserved by plates of glass, or the talc called *isinglass*, placed before them in the frame. Paintings in distemper may be rendered more durable, and preserved from foulness, by varnishing them with hot size, boiled to a strong consistence, in which a fifteenth or twentieth part of honey has been dissolved. Crayons must be preserved in the same manner as paintings in water-colours by plates of glass or isinglass.

When pictures are cut or torn, they may be repaired by laying them on an even board or table, carefully putting together the torn or divided parts with colour laid as a cement, in and over the joint, and keeping them in that situation till the cement is thoroughly dried. The protuberance of the cement may be easily reduced with a penknife, and the repaired part properly coloured so as to correspond with the picture. When part of the cloth is destroyed, a piece of canvass, somewhat bigger than the vacant space, is to be plastered over on the outside of the cloth with white or any other colour, and when it is thoroughly dry, the inequality of the picture in this part is to be filled up with the same matter, properly reduced and coloured.

The art of cleaning pictures and paintings is of great consequence in order to their preservation: in this operation great skill and care are requisite, so that the menstruum used for taking off any foulness may not dissolve the oil in the painting itself, or disorder its colours, and that each sort of varnish with which paintings are coloured may be taken off without injury to the painting. The first and most general substance used for cleaning pictures is water, which will remove any foulness arising from many kinds of glutinous bodies, as sugar, honey, glue, &c., and any varnish of gum-arabic, glair of eggs, or isinglass, without affecting the oil that holds the colours together. Olive oil or butter will dissolve pitch, resin, and other substances of a like kind, without injuring the oil of the painting. Pearl-ashes, dissolved in water, form a proper menstruum for most kinds of matter that foul paintings; but they must be very cautiously used, as they will corrode the oil of the painting, if there be no varnish of the gum resins over it. Soap is of the same nature, and should be cautiously applied, and only to particular spots, that elude all other methods. Spirit of wine will dissolve all the gums and gum resins, except gum arabic, and is therefore very necessary for taking off from pictures varnishes composed of such substances, but it also corrodes the oil of the painting. This is also the case with oil of turpentine, and essence of lemon, spirit of lavender, and rosemary, and other essential oils. With regard to paintings that are varnished with gum-arabic, glair of eggs, or isinglass, the varnish should be taken off when they are to be cleaned. This may be easily distinguished by wetting any part of the painting, which will feel clammy, if varnished with any substance soluble in water. This kind of varnish may be taken off with hot water and a sponge, or by gentle rubbing with a linen cloth dipped in warm water. If paintings, on this trial, appear to be varnished with gum resins, or such substances as cannot be dissolved in water, they may, in some cases, be sufficiently cleaned by a sponge with warm water; and any remaining foulness may be removed by rubbing the painting over with olive oil made warm, or with butter, which should be wiped off with a woollen cloth; and if the picture require farther cleaning, wood-ashes or pearl-ashes may be used in the following manner: take an ounce of pearl-ashes, and dissolve them in a pint of water; or take two pounds of wood-ashes, and stir them well in three quarts of water, once or twice in an hour for half a day. Then pour off the clear fluid, and evaporate it to a quart or three pints; wash the painting well with a sponge dipped in either of these leys, and rub gently any foul spots with a linen cloth till they disappear. If this method fail, recourse must be had, first to spirit of wine, then to oil of turpentine, and if these are ineffectual, the essence of lemons: with either of which the foul spots should be slightly moistened, and the part immediately rubbed gently with a linen cloth. After a little rubbing, if oil of turpentine or essence of lemon has been applied, olive oil should be put upon the spot; and water, if spirit of wine has been used; which should be taken off with a woollen cloth; repeating the operation till the foulness be removed. When paintings appear to have been varnished with those substances that will not dissolve in water, and, after the use of the above means, retain their foulness, the following method will succeed; place the picture or painting in a horizontal situation; and moisten, or rather flood, by means of a sponge, the surface with very strong rectified spirit of wine: keep the painting thus moistened, by adding fresh quantities of the spirit, for some minutes; then flood the whole surface copiously with cold water; wash off the whole without rubbing; and, when the painting is dry, repeat the operation till the whole varnish is taken off.

The art of removing paintings in oil from the cloth or wood on which they are originally done, and transferring them to new grounds of either kinds of substance, is of great use. For those on cloth or canvass, the method is as follows: let the decayed picture be cleansed of all grease that may be on its surface, by rubbing it very gently with crumb of stale bread, and then wiping it with a very fine soft linen cloth. It must then be laid, with the face downwards, on a smooth table covered with fan-paper, or the India-paper: and the cloth on the reverse must be well soaked with boiling water, spread upon it with a sponge, till it appears perfectly soft and pliable. Turn the picture with the face upwards, and, having stretched it evenly on the table, pin it down with nails at the edges. Having melted a quantity of glue and strained it through a flannel, spread part of it, when a little stiffened, on a linen cloth of the size of the painting, and when this is set and dry, lay another coat over it; when this becomes stiff, spread some of the glue, moderately heated, over the face of the picture, and lay over it the linen cloth already prepared in the most even manner, and nail it down to the picture and table. Then expose the whole apparatus to the heat of the sun, in a place where it may be secured from rain, till the glue be perfectly dry and hard; when this is the case, remove the picture and linen cloth from the table. Turn the picture with the face downwards, and let it be stretched and nailed to the table as before; then raise round its edge a border of wax, as in the etching of copper-plates, forming a kind of shallow trough with the surface of the picture; into which pour a proper corroding fluid, as oil of vitriol, aquafortis, or spirit of salt, but the last is to be preferred: dilute either of these with water to such a degree, determined by previous trials, that they may destroy the threads of the original canvass or cloth of the picture, without discolouring it. When the corroding fluid has answered this purpose, drain it off through a passage made at one end of the border of wax, and wash away the remaining part by repeatedly pouring quantities of fresh water on the cloth. The threads of the cloth must be then carefully picked out till the whole be taken away. The reverse surface of the painting, being thus wholly freed from the old cloth, must be well washed with water by means of a sponge, and left to dry. In the mean time prepare a new piece of canvass of the size of the painting; and having spread some hot glue, purified as before, and melted with a little brandy or spirit of wine, over the reverse of the painting, lay the new canvass evenly upon it while the glue is hot, and compress them together with thick plates of lead or flat pieces of polished marble. When the glue is set, remove these weights, let the cloth remain till the glue is become perfectly dry and hard. Then the whole must be again turned with the other side upwards, and the border of wax being replaced, the linen cloth on the face of the painting must be destroyed by means of the corroding fluid; particular care is necessary in this part of the operation, because the face of the painting is defended only by the coat of glue which cemented the linen cloth to it. The painting must then be freed from the glue by washing it with hot water, spread and rubbed on the surface by a sponge. The painting may afterwards be varnished as a new picture; and if the operation be well conducted, it will be transferred to the new cloth in a perfect state.

When the painting is originally on wood, it must first be detached from the ceiling of the wainscot where it was fixed; and the surface of it covered with a linen cloth, cemented to it by means of glue, as already directed. A proper table being then provided, and overspread with a blanket, or thinner woollen cloth, laid on in several doubles; the painting must be laid upon it with the face downwards, and fixed steady: and the board of wood on which it was done must be planed away, till the shell remains as thin as it can be made, without damaging the paint under it. The process is afterwards the same as that in the case of paintings on canvass, till the painting on wood be in like manner transferred to a cloth or canvass.

PIEDROIT (French) in architecture, a pier or square kind of pillar, part of which is hid within the wall. It only differs from a pilaster in having no regular base and capital, which the other has. *See* Pilaster.

This term is also used for a part of the solid wall annexed to a door or window; comprehending the door-post, chambranle, tableau, leaf, &c.

PIER (from the French *pierre*, a stone) a mass of stone, &c., opposed against the force of the sea, or great river, for the security of ships that lie at harbour in any haven.

Piers are also used in architecture for a kind of pilasters, or buttresses, raised for support, strength, and sometimes for ornament.

Piers, *Circular*, also called *massive columns*, are with or without caps, and are frequently seen in Norman architecture.

Piers of a Bridge, the supports of the arches over the openings, when more than one, not including the supports at the extremities, which are called *abutments*. *See* Bridge.

M. Belidor observes, that when the height of the piers is about six feet, and the arches are circular, it is sufficient to make their thickness the sixth part of the width of the arch, and two feet more; but when the arches become of a great span, the thickness of the piers may be reduced to the sixth part; but then the depression of the two feet does not take place at once; that is, in an arch of about forty-eight feet, three inches are taken off for every six feet of increase of the width of the arch. The thickness of the piers supporting elliptic arches is greater than in the former proportion: thus, in an arch of seventy-five feet wide, the thickness of the pier, whose height is about six feet, should be 13.5 when the arch is circular, and fifteen feet when it is elliptical. The same author makes the abutments one sixth part more than the piers of the largest arch; and Mr. Muller has calculated a table, containing the thickness of the piers of bridges.

Rectangular piers are seldom used except in bridges over small rivers; in all others they project from a bridge by a triangular prism, which presents an edge to the stream, in order to divide the water more easily, to prevent the ice from sheltering there, as well as vessels from running foul against them. This edge is terminated by the adjacent surfaces at right angles to each other at Westminster Bridge; but those of the Pont-royal, at Paris, make an acute angle of about 60 degrees. Engineers, however, in their later constructions, make this angle to terminate by two cylindric surfaces, whose bases are arcs of 60 degrees.

PIGGERY, the place where hogs or swine are lodged.

PIG-STY, the name of the place where hogs are kep[t]. Buildings of this kind should always be large and com[]modious.

PILA, or Pile. *See* Piles.

PILÆ, according to Vitruvius, square blocks placed upo[n] the epistylia, immediately over the columns, to support th[e] timbers of the roof.

PILASTER, (from the French, *pilastre*, or Italian, *pila[s]tro*,) in architecture, a square column, sometimes insulate[d] but more frequently let into a wall, and only projecting wit[h] a fourth or fifth part of its thickness.

The pilaster borrows the name of each order, and has th[e] same proportions, capitals, members, and ornaments, wit[h] the columns themselves.

The pilasters in the Attic order are sometimes at equ[al] distances, and sometimes coupled; but this depends on th[e] intercolumniation of the order below. If the Attic order b[e] straight, and immediately over it, it must partake of the sam[e] distances, and stand over the column in the lower order.

Pilasters are made, usually, without either swelling or d[i]minution, as broad at top as at bottom: though some of th[e] modern architects, as M. Mansard, &c., diminish them at to[p] and make them swell in the middle, like columns; partic[u]larly when placed behind columns.

Pilasters, M. Perrault observes, like columns, become o[f] different kinds, according to the manner in which they ar[e] applied to the wall. Some are wholly detached, and calle[d] by Vitruvius *parastatæ;* others have three faces clear out o[f] the wall; others two; and others only one: these are a[l] called by Vitruvius *antæ*.

Insulated pilasters are but rarely found in the antique[.] The chief use they made of pilasters was at the extremitie[s] of porticos, to give the greater strength to the corners.

There are four principal things to be regarded in pilasters[,] viz., their projecture out of the wall, the diminution, the di[s]position of the entablature, when it happens to be commo[n] to them and to a column, and their flutings and capitals.

1. The projecture of pilasters, which have only one fac[e] out of the wall, is to be one-eighth of their breadth; or, a[t] most, not above one-sixth. When they receive impost[s] against their sides, their projecture may be a quarter of thei[r] diameter. They are made to project in different proportion[s] to their diameters, as one-eighth, one-fourth, one-half, an[d] three-fourths; but are never used gracefully quite square[,] except at angles; and then only in massive buildings, as th[e] portico at St. Paul's, Covent Garden.

2. Pilasters are but seldom diminished, when they hav[e] only one face out of the wall. Indeed, where they stand i[n] the same line with columns, and the entablature is continue[d] over both, without any break, the pilasters are to have th[e] same diminution with the columns; that is to say, on the fac[e] respecting the column; the sides being left without any dim[i]nution. When they are diminished, they have an ill effect[,] where it becomes necessary to make them correspond wit[h] the lines of the columns at top, as is sometimes the case i[n] porticos and returns, then it is better for the architect t[o] make them entirely of the smallest diameter of the colum[n] to which they are opposed.

3. Pilasters are sometimes fluted, though the column[s] they accompany are not so; and, on the other hand, th[e] columns are sometimes fluted, when the pilasters that accom[]pany them are not. The flutings of pilasters are always od[d] in number, except in half pilasters, meeting at inward angles[,] where four flutings are made for three, &c.

4. The proportions of the capitals of pilasters are the sam[e] as to height with those of columns, but they differ in widt[h;] the leaves of the former being much wider; because pila[sters]

ers, though of equal extent, have only the same number of leaves for their girt, viz., eight. Their usual disposition is to have two in each face in the lower row, and in the upper row one in the middle, and two halves in the angles, in the turns whereof they meet. Add to this, that the rim of the vase, or tambour, is not straight, as the lower part is, but a little circular, and prominent in the middle. In pilasters that support arches, the proportions, Palladio shows, must be regulated by the light they let in; and at angles, by the weight they are to sustain. For which reason, says Sir Henry Wotton, a rustic superficies best becomes them.

Pilaster, *Demi*, or Membretto, a pilaster that supports an arch: it generally stands against a pier, or column.

Pilasters, in ship-building, flat columns, or ornaments, made of deal, fluted or reeded, with moulded caps and bases, and placed in the middle of the munnions, which part the lights of the stern and quarter-galleries; also on the munnions of the bulkheads of the captain's cabin, &c.

Pilaster-Masses, in Gothic architecture, piers of a rectangular plan capped with impost mouldings.

PILE. *See* Piles.

Pile, a word used among architects, for a mass or body of building.

Pile-Driver, a machine for driving piles into the ground, of which there are many kinds; some are worked by a great number of men, who raise a heavy weight to a small height, and then let it fall upon the pile, till, by reiterated blows, they drive it to the required depth. This machine is extremely simple. A long thick plank of wood is fixed up close to the pile, having a mortise through the upper end, in which a pulley is fitted; a rope goes over this to suspend the rammer, which is a large block of hard wood, properly hooped, to prevent it from splitting. In rising and falling, it slides against the face of the plank, and is guided by irons, which are fixed to the ram, and bent round the edges of the plank, in the manner of hooks. The plank, when placed upright, is secured by guy-ropes, in the manner of the mast of a ship; the end of the great rope which suspends the ram, has ten or twelve small ropes spliced into it, for as many men to take hold, and work it by; they raise the ram up two or three feet by pulling the ropes all together, and then letting them go, the ram falls upon the pile-head. When the pile becomes firm enough to cause the ram to rebound, they take care to pull the ropes instantly after the blow, that they may avail themselves of the leap it makes.

This is the simplest form of the machine. Others, instead of a plank, have two upright beams attached together, at such a distance as to leave an opening between them for the reception of a piece of wood which is affixed to the ram, and by this means it is guided. Instead of guy-ropes, these are usually fixed upon a base, consisting of a triangular frame, on one angle of which the uprights are erected; and from the other two angles, braces arise, inclined so as to reach the uprights at one-half or two-thirds of their height, to steady them. This plan is very convenient for driving piles in corners; but for driving in rows, it is more advantageous to have the uprights fixed at the middle of one side of the triangular base, and have stays from all the three angles. A machine of this kind, with a ram of beech, four feet long and one foot square, may be worked by ten or twelve men, at the rate of twenty-four blows per minute, and fixes the pile very quickly. To estimate the force of the rammer, its weight ought to be multiplied into the velocity it acquires in falling. Thus, if a rammer weighing 500lbs. drop from four feet, it will fall in half a second, and have at the time of percussion a velocity capable of carrying it uniformly eight feet in half a second, without any farther help from gravity; so that we must multiply 500 by 16, or its weight by the number of feet it would fall in a second, and the product, 8,000, gives the momentum of the stroke. If a capstan, pulley, or windlass, be made to raise the rammer to a considerable height, and then, by an easy contrivance, loosen it at once from its hook, the momentum of the stroke will always be as the square root of the height from which the rammer fell.

Notwithstanding the momentum, or force of a body in motion, is as the weight multiplied by the velocity, or simply as its velocity, when the weight is given or constant; yet the effect of the blow will be nearly as the square of that velocity; the effect being the quantity the pile is driven into the ground by the stroke. For the force of the blow, transferred to the pile, being destroyed in some certain definite time by the friction of the part within the earth, which is nearly a constant quantity, and the spaces in constant forces being as the squares of the velocities; therefore, the effects, which are those spaces sunk, are nearly as the square of the velocities, or, which is the same thing, nearly as the heights fallen by the ram or hammer to the head of the pile.

For large works, such as bridges, &c., the piles are driven by a different kind of machine: this has a very heavy iron ram, with mechanical powers, by which it is raised to a very considerable height, and then let fall, instead of continually repeating small blows. These are sometimes worked by horses, or steam-engines.

Figures 1 and 2.—A, A, the uprights, erected on the frame, B, and supported by the braces, C; connected by the cross feet, *a*, at bottom, and the piece, D, at top; in this the pulley, *b*, for the rope, *d*, is fitted. Fillets of iron are fixed withinside the uprights, A, A, and enter grooves made in the edges of the great iron ram, E, which is thereby guided as it rises and falls: F is a piece, called *the follower* (see *Figures* 3 and 4) consisting of a wooden block, sliding between the uprights, and mortised to receive the iron tongs, *e*, which take hold of an eye on the top of the cast-iron ram: the rope is attached to the follower by an iron hoop, *f*, through which the centre pin of the tongs passes. On the base, *a* B, of the machine, an iron frame is bolted, to contain the windlass, G, on which the rope, *d*, winds. On the end of the windlass a cog-wheel, *g*, is fixed, and a pinion upon the axis, *h*, engages its teeth. Motion is given to the spindle, *h*, by the winches, *k*, fixed to each end of it, and the fly-wheel, *l*, regulates its motion, when turned by two men at each handle. The pile is of course included in the space between the two uprights, A, A, before it is driven down; and the ram, being engaged by the tongs, *e*, is drawn up by turning the handle, *k*, till the tails, *n*, of the tongs come to the inclined planes, *m*, *Figure* 1: by these they are closed together, which opening the lower ends, disengages them from the eye of the ram, and it falls upon the head of the pile immediately. The men at the handles shift the spindle, *h*, endwise, which disengages the pinion from the wheel, and then the weight of the follower, F, runs back the windlass, G, and descends till its tongs take hold of the ram, ready to take it up again. The inclined planes, *m*, are not fixed to the uprights, A, A, but are connected together by pieces of wood, which embrace the uprights, and these have holes through them to receive iron bolts, which also pass through the uprights. By this means the inclined planes can be shifted, to set them at any required height, that they may, by discharging the ram at the proper height, give a blow proportioned to the pile to be driven. The tongs are sometimes made with rollers in the ends, *n*, *n*, as shown in *Figure* 12, that they may act more easily in the inclined planes. Other machines have a kind of latch, shown in *Figure* 11, instead of the tongs; in this, *f* represents the iron loop for the rope;

the centre pin of which, passing through the latch, *r s t*, catches the eye of the ram by the hook, *t*, and is discharged by the line *r*, when the men snatch it. The weight, *s*, is to cause the hook to catch; and the loop, *f*, is attached to the wooden follower, which guides it between the uprights.

Machines of this kind are frequently actuated by steam-engines. A pulley, fixed on the end of the spindle, *h*, in place of the handle, *k*, receives an endless rope from some wheel put in motion by the engine; one man then attends it, to throw the spindle endwise at the proper time, to permit the descent of the follower; but we have seen one in which levers, and a connecting rod from the inclined plane, *m*, were used to disengage the spindle the moment after the follower discharges the ram; by adopting these means much expense of labour would be saved, as the steam-engine which is afterwards to be employed in pumping the water out of the coffer-dams, would drive the piles for them and for the foundations.

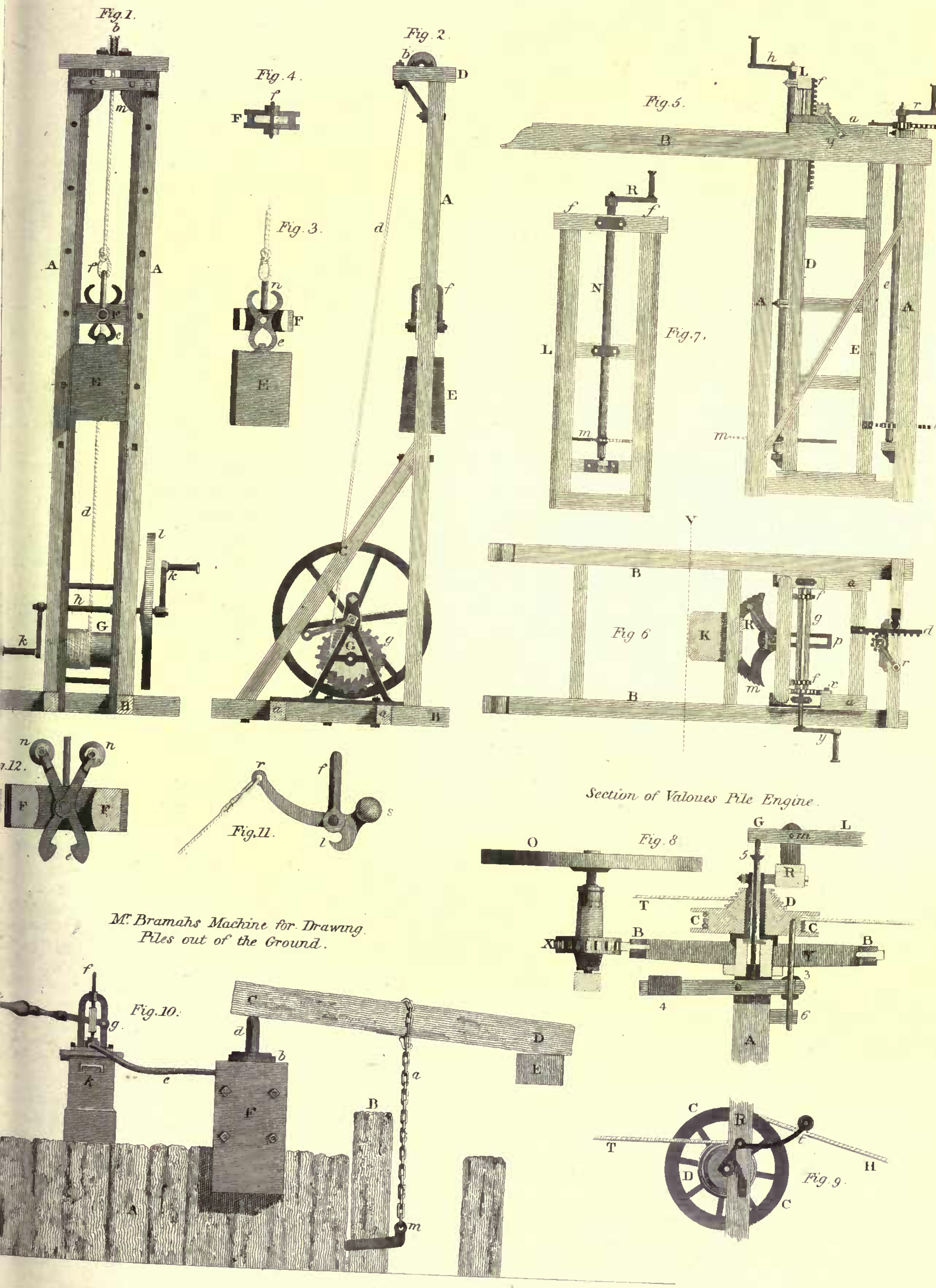
The piles of the works of Westminster-bridge, whilst it was building, were driven by a horse-machine, invented by Mr. Valoue. A pair of the uprights, such as represented in *Figures* 1 and 2, but thirty feet high, were erected at one end of a frame, which supported a vertical shaft, turned round by the horses, and the framing was of course large enough to admit a circular walk of sufficient size for them to work in, when they drew the ends of arms or levers projecting from the vertical shaft. The whole was erected upon a platform, which was built over a barge in the manner of a deck. The vertical shaft had a wheel or drum upon it, to wind up the rope of the follower, and it was in the construction of this part that the invention lay. A section of the upper part of the vertical shaft and drum is given in *Figure* 8, and a plan in *Figure* 9. Here A is the great upright shaft, or axle, turned by the horses attached to the levers, which are not shown. The cog-wheel, B, turns the pinion, X, having a fly, O, at the top to regulate the motion, and to act against the horses, and keep them from falling, when the ram is disengaged. The drum, C, is loose upon the axle of the shaft, A, but is locked to the wheel, B, by the bolt, Y. On this drum the great rope, H, is wound, one end of it being fixed to the drum, and the other to the follower, passing over proper pulleys. In the follower are contained the tongs, which take hold of the ram, by the staple for drawing it up, as described in *Figure* 2; D is a spiral, or fusee, fixed to the drum, C, on which winds the small rope, T: it goes over a pulley, and has a small counterpoise hung to the end of it, which hinders the follower from accelerating as it goes down to take hold of the ram; for, as the follower tends to acquire velocity in its descent, the line, T, winds downwards upon the fusee on a larger and larger radius, by which means the counterpoise acts stronger and stronger against it; and so allows it to come down with only a moderate and uniform velocity. The bolt, Y, locks the drum to the great wheel, being pushed upwards by the small lever, 3, which passes through a mortise on the shaft, A, and turns upon a pin; the lower end of the bolt is guided by passing through a piece of wood, 6, fixed into the great shaft, and the upper end passes through an arm of the wheel; the lever, 3, has a weight, 4, which always tends to push up the bolt, Y, through the wheel into the drum; G L is the great lever, turning on the centre, *m*, and resting its end, G, upon the forcing bar, 5, which goes down through a hollow in the shaft, A, and bears upon the little lever, 3. The other end of the lever, L, is long enough to reach the uprights, and has there a small rope, extended from its end up to the inclined planes, so that the follower, when drawn to the highest, pulls this rope, and raises the long end, L, of the lever, depressing the other, and forcing the bar, 5. By the horses going round, the great rope, H, is wound about the drum, C, and the ram is drawn up by the tongs in the follower, till they come between the inclined planes, which, by shutting the tongs at the top, open them below, and so discharge the ram, which falls down between the uprights and the pile, and drives it by a few strokes as far into the ground as it can go, or as is desired; after which, the top part is sawed off close to the mud, by an engine for that purpose. Immediately after the ram is discharged, a piece upon the follower takes hold of the rope, which raises the end L, of the lever L G, and causes its end, G, to descend, and press down the forcing-bar, 5, upon the little lever, 3, which, by drawing down the bolt, Y, unlocks the drum C, from the great wheel, B; and then the follower being at liberty, comes down by its own weight to the ram; and the lower ends of the tongs slip over the eye of the ram, the weight of their heads causing them to fall outwards, and fasten upon it: then the weight, 4, pushes up the bolt, Y, into the drum, which locks it to the great wheel, and so the ram is drawn up as before. As the follower comes down, it causes the drum, C, to turn backward, and unwinds the rope from it, while the horses, the great wheel, the pinion X, and the fly, go on with an uninterrupted motion; and as the drum is turning backward, the counterpoise is drawn up by its rope, T, winding upon the spiral fusee, D.

There are several holes in the under side of the drum, and the bolt, Y, always takes the first that it finds, when the drum stops by the falling of the follower upon the ram, till which stoppage the bolt has not time to slip into any of the holes. But the same effect is more certainly produced by a crooked lever, *t*, *Figure* 9, fixed on the framing, R, over the end of the vertical shaft; one end of this has a roller, which is pressed upon by the great rope, H, while the other end holds down the catch, 5, of the forcing bar, but as soon as the great rope slackens, it retires, and gives liberty to the small lever, 3, to push up the bolt. As long as the great rope has a tension upon it, to support the weight of the ram, or follower, the crooked lever is kept in close contact with the forcing-bar, and when that is depressed (to discharge the bolt, Y) by locking over its catch, 5, the crooked lever keeps it down, till the follower touches the ram; the great rope then slackens, and the spring, *v* H, discharges the crooked lever from the catch of the forcing-bar, and gives liberty to the small lever, 4, to push up the great bolt, and to lock the drum to the great wheel, when the ram is drawn up again, as before.

The peculiar advantages of this engine are, that the weight of the ram, or hammer, may be raised with the force of horses instead of men; that when it is raised to a proper height, it readily disengages itself, and falls with the utmost freedom; that the forceps, or tongs, are lowered down speedily, and instantly of themselves again lay hold of the ram, and lift it up; on which account this machine will drive the greatest number of piles in the least time, and with the fewest labourers.

The piles at Westminster bridge, when driven by the above machine till they were quite firm, were cut off, under water, by a machine to a level with the surface of the ground, to build the piers upon. This machine consisted of a framing adapted to fit upon the upper part of the pile, and fixed fast thereto. The lower part of this frame formed guides for the saw, which reciprocated horizontally at a certain depth beneath the top of the pile, and had weights to cause it to advance up to the cut. The saw was put in motion by ropes from each end, which were conducted, over proper pulleys, to two men standing on a float or raft at the surface. After fixing the machine, before the sawing wa

PILE DRIVING MACHINE.



begun, the whole machine was suspended by a tackle, which therefore took up the top part of the pile with the machine as soon as it was cut off. This was the invention of Mr. Etheridge, carpenter to the works at Westminster bridge; it was very effective, as the time employed in cutting off a fir pile of 14 or 16 inches square, in 10 feet depth of water, was seldom more, and often less, than a minute and a half. A machine, more convenient than this in its application, and not less effective, was also invented by Mr. Foulds, to whom the Society of Arts presented a gold medal for the invention; see *Figures* 5 and 7, where A A B is the external frame, consisting of four parallel rails, A, framed into two others, B, at right angles, with proper cross pieces to unite them, and inclined to strengthen the whole: within this frame a second, or internal frame, D E, is situated; like the other, it has four parallel pieces, D and E, connected together into one frame by cross pieces; at the top it has two pieces, *a*, *a*, which rest upon the beam, B, and suspend its weight, and on these it is capable of sliding backwards and forwards between B B, always preserving its parallelism, because it is moved by the racks, *d*, *d*, affixed to it, one at top, and the other at the bottom; the pinions for both are fixed on a vertical axis, *e*, supported in the external frame; therefore, by turning the handle, *r*, the internal frame with the saw is advanced to the pile, as at K, *Figure* 6. The saw itself is sustained in a frame, L, *Figure* 7, which fits, in the manner of a sash-frame, between the two beams, D, of the internal frame, and has racks, *f*, *f*, (dotted) behind it, which work in pinions on an axis, *g*, extended across the frame, and by the handle, *y*, it is capable of being drawn up and let down, or detained at any height by a ratchet-wheel and click, *x*; the saw, *m*, is fixed upon a spindle N, supported in bearings on the frame, L, and turned by the handle, R, at the top; the saw is connected with the spindle by a piece of iron, *p*, having a mortise through it for the reception of the spindle, to which it is fastened by a nut beneath; by this means the edge of the saw may be advanced as the work goes on.

In using this machine, the beams, B, are fixed across a barge, which is ballasted till they are horizontal, and the spindle of the saw is therefore vertical in this state; it is moored with her side against the pile, K, to be cut off, as shown by the dotted line, V, *Figure* 6; then, by the rack and pinion, *f g*, the saw is adjusted in height to the level where the pile is to be cut; by the handle, *r*, it is advanced to the pile, K, whilst, by the other handle, R, the saw is kept in continual motion backwards and forwards, till the pile is cut through, and the piece is taken into the barge; it then proceeds to cut off the next by the same means. By this machine, temporary piles, used in coffer-dams, may be cut off level with the bottom, when the work is finished, which is a very superior method to drawing them up out of the ground, as is the usual practice; because this must necessarily make a deep ditch or trench all round the pier or foundation, and tend to loosen the ground.

To draw piles out of the ground when they have been driven fast, requires a very great force. There are different methods of exerting this force: one for drawing them in water, is by having a very strong barge, with a windlass at one end to receive a strong chain, which is passed several times round the head of the pile, and made fast to the barge; two long beams are laid upon the barge, to form a railway for a small waggon to run upon from one end to the other, loaded with stones of several tons weight; when this is wheeled to one end of the barge, it will, of course, depress it in the water, elevating the other; then, in this state, the lowest end of the barge is chained to the pile, by putting a very large bolt through it, and passing a chain round the pile under this bolt a great many times; the carriage is then wheeled to the other end of the barge by a windlass and rope; this tends to raise the end to which the pile is fixed; and when the carriage is so far advanced that it exerts a sufficient power, it will draw up the pile, if the chain is properly fixed; and then the carriage is returned to draw another pile. A plan was adopted at Waterloo Bridge, for drawing the useless piles by one of Mr. Bramah's hydrostatic cylinders. This is represented in *Figure* 10, where A is supposed to be the top of a range of piles forming the coffer-dam, and B the pile to be drawn. A chain, *a*, is made fast to the pile, and carried many times round a large beam, C D, the end, D, of which rests upon a fulcrum, or support, E, consisting of a block, supported on the head of a neighbouring pile, &c. F is a block of two pieces of wood, screwed together in two places, and enclosing between them a cast-iron cylinder, *b*, into which is fitted the piston, or cylinder, *d*, the joining being made tight by a collar of leather; *e* is a small copper pipe, communicating with the cylinder, and also with a small forcing-pump, the piston, *f*, of which, is actuated by the lever, *g h*; the pump is fixed upon the top of a small cistern, *k*, to contain water. Now, by working the lever of the pump, water is injected into the cylinder, *b*, which protrudes the piston, *d*, from it with a force proportioned to the force exerted upon the lever, in the same degree as the areas of the pump to that of the cylinder multiplied by the proportions of the lever, *h*. By this means, the power of one or two men is increased to such a degree as to draw up the largest pile; the copper pipe, *e*, is made to unscrew at several joints, which are provided with leather, to make them tight; by which the pump is separated when the machine is to be removed. As it has no connection with the beam or lever, D, the cylinder is frequently employed in the manner of a hand-jack, for any purposes where enormous weights are to be lifted for a small space. The same figure also shows a very complete way of catching fast hold of the pile, instead of putting a bolt through the pile-head to stop the chain under: it is simply a strong iron ring, *l*, large enough to drop over the pile loosely, and having a strong shank or eye, *m*, projecting from it to run the chain through; when this is drawn, the ring jambs so forcibly upon the wood of the pile as to draw it out of the ground rather than slip off, for it holds faster in proportion to the force.

The theory of Mr. Valoue's engine depends on the following principles, viz.—1. If the resistance of the ground and the masses of the piles be equal, the depths to which they will be driven with a single blow will be as the product of the weight of the ram into the height through which it falls.

2. If the masses of the ram, and heights through which it falls, are both equal, the depths to which the piles will be driven will be in the inverse ratios of the masses of the piles into the superficies of that part of them which is already immersed in the earth.

3. If all these be unequal, the depths will be in a ratio compounded of the direct ratio of the heights through which the ram falls into its mass, and the inverse ratio of the mass of the pile into its immersed superficies.

4. If the weights of the ram be equal, and also the weights of the piles, the depths to which they will be driven will be as the heights through which the ram falls directly, and the immersed superficies of the piles. Or, because the immersed superficies are as the depths through which the piles are already driven into the earth, these depths are simply as the square roots of the heights through which the ram falls.

These principles are founded on the general supposition that the space through which the weight falls is estimated by the product of its mass into the square of its velocity, or into the height through which it falls.

Hence it is inferred, that the distance through which a pile will be driven by each succeeding blow, will be less and less, as the superficies of that part of the pile which is immersed in the ground increases; and, consequently, that there is a certain depth, beyond which a pile of a given mass and scantling cannot be driven; the mass of the ram and the height through which it falls at first being assigned.

At the close of the year 1843, a new method of sinking piles by atmospheric agency, was patented by Dr. Potts. In this invention the piles are of cast-iron, and hollow, and are lowered by drawing out the sand or soil through the centre by means of an air-pump. The pile is closed at the top with an air-tight cap, through which a pipe passes to a receiver, and from this again another pipe connected with an air-pump. By this means a communication is kept up between the pump and the interior of the pile, and by working the former the air is exhausted from the pile, the sand rises through the interior into the receiver, and the pile gradually sinks into the vacuity so produced. This method of piling has been successfully employed on the Goodwin Sands by the Trinity Board, the piles being driven through the sands to a depth of 75 feet, when they reached a solid foundation. These piles are especially adapted for such situations; they are attended, however, in many instances, with some disadvantage, for by removing the earth occupied by the piles, they lose that firmness of position which is ensured in the old method by its compression. This defect is somewhat compensated for by the injection by hydraulic pressure of certain chemical solutions, and hydraulic cements round the feet of the piles, to consolidate the earth on which they stand, and give them a firm bearing.

The most important of all inventions for this purpose is Nasmyth's steam-hammer, which consists of a steam cylinder, through a steam-tight aperture in the bottom of which the piston-rod passes, having the hammer, or "monkey," suspended from it. The steam admitted at the bottom of the cylinder raises the piston with the monkey attached to it, and in so doing, closes the induction and opens the eduction pipe, which reverses the motion, and the monkey falls with great force upon the head of the pile beneath. The following description of the action of this machine is extracted from a contemporary, and has especial reference to its employment at Morice Town, Devon.

"There are two features which most remarkably distinguish this important invention from all pile-driving machines. These consist, in the first place, in the direct manner in which the elastic power of the steam is employed to lift up the mass of iron by whose fall on the head of the pile it is driven into the ground; secondly, in the peculiar manner in which the block of iron and its guide-case and cylinder are made to sit, as it were, on the shoulders of the pile, so as to predispose and assist it in its descent into the ground. In this manner, the entire dead-weight of this part of the apparatus is rendered available, and made to act in a most important degree as a portion of the pile-driving agency, and as the entire part of the apparatus follows the pile down, it never ceases for one instant to yield a most important assistance towards the attainment of the desired object. The energy and rapidity of the blows, which are dealt out on the head of the pile at the rate of upwards of 70 per minute, is such, that, assisted by the dead-weight of the apparatus sitting upon the shoulders of the pile, it is seen to sink into the ground in steps varying from 6 feet to 3 inches per stroke,—the whole operation of driving the pile, 60 feet in length, occupying little more than from two and a half to four minutes,—in fact, such is the ease and rapidity with which these enormous piles are driven into the ground by these powerful machines, when compared with the old system, that the spectator is as much inclined to laugh at the ridiculous contrast, as to be astonished at its vast powers, and the perfect control under which it is placed. The whole movements are governed by one handle, regulating the supply of steam from the boiler to the cylinder and piston, which yields the requisite rising and falling motion of the monkey or hammer that drives the pile. We are particularly attracted by the simple and efficient contrivance which Mr. Nasmyth has adopted for carrying the steam from the boiler to the cylinder on the head of the pile, namely, by wrought-iron jointed pipes, which fold up in the most beautiful manner in a succession of joints or lengths, so as to accommodate the length of steam at all the various heights of the apparatus, which, having to descend through a perpendicular space of upwards of 50 feet in following down the sinking, double up or fold together in the most perfect yet simple manner. The same boiler which supplies the steam to the actual pile-driving apparatus, likewise supplies steam to a small engine, which is employed to give the requisite locomotive action to the whole apparatus in either direction, so as to cause it to move from pile to pile. The same small engine hoists and pitches the piles in the most perfect manner; also raises the pile-driving apparatus to the head of the highest pile, some of which are 66 feet in height, and places it on the shoulders of the pile with the utmost ease and exactness. Some idea of the performance may be formed when we state, that it drives a pile of 66 feet in length in four minutes, while, with the ordinary machines, upwards of 15 or 20 hours would be occupied in doing the same work, to say nothing of the entire absence of all damage to the head of the pile, which, in the case of the employment of Mr. Nasmyth's machine, is not in the slightest degree injured; while in driving such a pile by the ordinary machine, the head of the pile is so shattered by the repetition of its destructive and ineffectual blows, as to require to be cut off and reheaded several times during the operation. Practical pile-drivers will have some idea of the remarkable superiority in the action of Mr. Nasmyth's machine, when we inform them, that the iron hoop hitherto employed to preserve the head of the pile from being split into matches, is, in the steam pile-driver, entirely dispensed with, and the heads of the piles, after driving, bear scarcely any evidence of force having been applied to them."

Pile-planks, are planks whose ends are sharpened, to drive into any canal or water, close to each other, in order to form a dam, by which the water may be stopped and discharged. *See* Piles.

Pile-sheeting, the same with dovetail piling.

Piles, in hydraulic architecture, are beams of timber, or stakes of wood, driven firmly into the ground, for various purposes; as, for forming a foundation for buildings, piers of bridges, &c., in which cases they are driven quite down into the ground, or are cut off level with its surface, with a view of obtaining a solid bearing for the weight of the intended superstructure.

Amsterdam, and some other cities, are wholly built upon piles. The stoppage of the breach in the banks of the Thames at Dagenham, was effected by dovetail piles; that is, by piles mortised into each other by a dovetail joint.

Piles are not employed for foundations, unless the ground is suspected to be unsound, or when the weight to be borne is exceedingly great. They make the foundation solid, by reaching deep into the earth, down to a more substantial stratum than that of the surface. Indeed, the manner of fixing the piles, by driving them by repeated blows of a powerful machine till they will go no farther, ensures that they come to a good bearing.

Piles are also used for making the faces of wharfs, banks of rivers, piers for the sea, &c. For these purposes they are driven in rows, but only a sufficient depth in the earth to make them stand firm, and support the planking or framing which is fixed against them. These piles are usually driven rather in an inclined position. For temporary defence against the water, in laying the foundation of bridges, &c., piles are always required; they are employed in different ways to form an enclosure, or water-tight wall, called a coffer-dam, round the area where the work is to be laid, and from which space the water is drawn by pumps. This is the most difficult of all kinds of piling; because it must stand a great height above the ground, have sufficient strength to resist the pressure of water, and be perfectly close and tight. In navigable rivers detached piles are driven, and very firmly fixed, to mark the enclosures where barges are to lie, and to fender off others from them, as well as to moor them to.

Piles are in general formed of square timber, tapering if the tree happens to be so, cut to a sharp point at one end, and shod with iron to enter the ground. The other end is bound by a strong iron hoop, to prevent the pile-head from splitting by the violence of the blows which drive it down. When they are to be driven quite below ground, small trees, if sufficiently straight, may be used without squaring; but for coffer-dams, square piles are always used, except for filling up a row between such square piles. When they are to touch each other, flat ones, called *pile-planks*, are used; they are three or four inches thick, according to the depth of water, and have grooves formed in their adjacent edges, to receive tongues or slips of wood, which make the joints quite tight. This method is termed *sheet-piling*. To enclose an area for a coffer-dam, two rows, or walls of piles, are usually driven one within the other, at a distance usually equal to the depth of water where they are driven; or, if the current is rapid, once and a half. The space between these is filled with clay, so as to form a mound or rampart of that material, defended on the outside and inside by wooden walls of piles. To make these walls, large square piles are first driven, at a distance of ten or twelve feet asunder, in the line of the intended range of the dam; horizontal tie-beams are then extended from one pile to the next, on the inside, and sometimes on the outside also, each tie being notched into the piles, so that its outer edge is in a line with the inside of the groove for the plank-piles, which are to be driven down to fill up the spaces between the piles, and will be guided by these ties to stand exactly vertical, and in a straight line. The first plank-piles are fixed adjacent to the main piles, and thus they are continued from both ends of the interval, till the planks meet in the centre, where the last plank is inserted, and, being formed rather wedge-like, it makes all the rest tight. The pile-planks are cut inclined, or wedge-like, on one side only, to form the point, by which means the point is in the line of one of the edges of the plank. When a plank pile is to be driven adjacent to another, this edge is applied to the one already fixed, and then, as it is driven, the inclined or wedge-like edge entering the ground, causes the pile to approach, and press very close to its neighbour; and it is chiefly by this means they are made to fit water-tight. The fillets are made by spiking a ledge or ruler of wood fast upon the edge of one plank, and a groove of corresponding depth and width is ploughed in the edge of the adjacent plank to receive it.

The square *gauge* or *guide* piles, as they are termed, are usually composed of whole timbers from twelve to fourteen inches scantling, but the plank piles, or sheet-piling, as well as the horizontal ties or *walings* of half-timbers, being of the same width, but only half the thickness of the square piles.

Piles of cast-iron were first employed by Mr. Mathews in the formation of Bridlington harbour, in which work he made use of sheets of iron 8 or 9 feet long by 2 feet in width, and half an inch thick, so contrived at the sides, that each pile should form a dovetail joint with the adjoining one. Mr. Ewart, however, was the first who brought this kind of piling into general notice; he took out a patent for his invention in 1822. These piles consisted of plates of iron from 10 to 15 feet in length, $14\frac{1}{2}$ inches in width, and $1\frac{1}{2}$ inch in thickness; they have a flanch running down the centre, and one at each extremity, turned off at an acute angle with the face. To connect these together, he made use of a smaller pile only 6 inches wide, but having a flanch at each side corresponding with those at the sides of the larger plate, so as to form a dovetail joint with them. Where a greater length of piling was required, a method of lengthening them was adopted, by placing one above another, and securing the horizontal joints by means of dovetail cramps.

Mr. Ewart's piles have been extensively adopted, especially by Mr. Hartley, in the Liverpool docks, who has employed them successfully, and speaks favourably of their employment in such works as coffer-dams. He states, that considerable care is required in keeping the piles in a vertical position, as they are apt to shrink every blow, and drive slanting. They require to be driven between two heavy balks of timber to keep them in a straight line, as they expose very little section to the blow of the ram, and are so sharp, that they are easily driven out of a right line. There is another very necessary precaution to be taken, which is the keeping the fall of the ram in the same line as the pile; otherwise, the ram descending on the pile, and not striking it fairly, all parts equally, the chances are, that, if in a pretty stiff stratum, the head breaks off in shivers, and the pile must be drawn, which is sometimes no easy matter.

Mr. Mylne has also employed those piles to a considerable extent, especially in a large coffer-dam opposite the New River Company's establishment at Broken Wharf, where he succeeded in driving the larger and smaller piles or cramps simultaneously, the usual practice being to drive them separately.

A work on a much larger scale was constructed of the same material by Mr. Cubitt at the sea entrance of the Norwich and Lowestoft navigation; but the form of the piles was, in this instance, of a somewhat different description. The wall consisted exclusively of sheet piling without any guide-piles whatever, each pile being 30 feet long, 18 inches broad, and $1\frac{1}{2}$ inch thick, having a deep flanch in the centre, without any dovetail or other jointing at the sides; the perfectness of the joints depending entirely upon close and accurate driving. As some assistance to the driving, a pair of strong wrought-iron cheeks, projecting two or three inches beyond the edge of the pile, were riveted on to the lower end, which served as a guide or groove to keep the piles flush. The entire length of wharfing thus constructed was about 2,000 feet.

Another work of importance is that of Walker and Burgess at the Brunswick Wharf, in front of the East India Docks at Blackwall, of which we copy the following description, as given by Mr. Borthwick in the Transactions of the Institution of Civil Engineers.

"The first operation was to dig a trench two yards deep in the intended line, and this was immediately followed by the driving of the timber guide-piles. The deepening in front, which, to give the required depth of 10 feet at low water, was as much as 12 feet, was not done until near the conclusion of the work; to have effected it in the first instance would, without any countervailing advantage except some saving in the driving, have been attended with the double expense of removing the ground forming the original bottom between the old and new lines of wharfing, and afterwards refilling the void so left by a material that would require time to make it of equal solidity; and even if this had been otherwise, such an attempt would have endangered the old wall, or rather would have been fatal to it. The permanent piling was next begun, the main piles being driven first at intervals of seven feet, and the intermediate spaces or bays then filled in, working always from right to left, towards which the drafts of the sheet-piles were pointed. The ground is a coarse gravel, with a stratum of the hard Blackwall rock occurring in places, and some trouble was occasionally experienced from its tendency to turn the piles from the proper direction; but due attention being paid to the form of the points, the drawing was, on the whole, effected pretty regularly, but few of the bays requiring closing piles made specially for them, so that the work may be said to be nearly iron and iron from end to end; at the same time, the vertical joints of the piling being all covered, as will be noticed presently, any slight imperfection, in this respect, is no serious detriment to the work as a whole.

"The main piles are in two pieces, the lower end of the upper one being formed so as to fit into a socket on the top of the under length, and the joining made good by means of a strong screw-bolt; the only object of this was to insure a supply of truer castings, and lessen the difficulty of transporting such unwieldy masses from Northumberland and Staffordshire to London. Each sheet-pile is secured at the top by two bolts to the uppermost wale of the woodwork behind, and the edge of the end-ones of each bay, it will be observed, pass behind the adjoining main pile, while the other joints are overlapped by the bosses with which all the sheet-piles, except the closers, are furnished on one side. Besides adding to the perfection and security of the works, by breaking the joints, so that the water, if it penetrate, (as, even with the best pile-driving, it will,) cannot draw the backing from its place, these projections appear to me to relieve the appearance of the otherwise too uniform space, and a like effect is produced by the horizontal fillets on the lower edges of the plates above, which also mask the joints. These plates filling up the space over the sheet-piling, are bolted to the main piles and to each other, in the manner shown, and the joints stopped with iron cement. Where the mooring-rings come, the plates are cast concave, with a hole perforated in the middle, to allow a bolt to pass through, and this bolt is secured, as well as the land-ties, from the main piles to the old wharf, which was not otherwise disturbed, or to needle-piles driven adjoining to it. The backing consists of a concrete of lime and gravel, in the proportion of about one to ten, extending down to the solid bottom. The coping, with the water-channel in its rear, is of Devonshire granite; the water is conveyed from the channel at intervals by pipes extending from gratings in the bottom, in a slanting line, to the lowermost plate, and discharging themselves immediately above the sheet-piling. The main piles were originally proposed to be hollow, but this was given up on further consideration of the uncertainty of procuring sound castings of the intended form, and of the greater liability to break afterwards from a blow sideways.

"The solid form was therefore adopted, according to which the lower lengths weighed about 28 cwt., and that this was not too much, was shown by the circumstance of several of the piles, particularly the early ones, breaking in the testing, or driving, and showing in the fracture the danger of even a slight defect. The greater care subsequently taken at the foundry, and probably also greater experience in driving, made accidents of this kind of rare occurrence in the later stages of the work; and it may be mentioned as no bad proof of the care of all parties, that of upward of 600 piles, including both descriptions, only 16 broke in driving—7 being of one sort, and 9 of the other: the failure was in five cases attributed to strains in driving, and to imperfections of casting in the other eleven. The sheet-piles, which bear a considerable resemblance in their general outline to those used at Downes wharf ten years before, were proposed to be an inch thick, but it was found necessary to increase this dimension, and some of them was as much as $1\frac{1}{4}$ inch; the average, however, was not above $1\frac{1}{8}$ inch, and weight of each pile 17 cwt.; the length of the wharf is about 720 feet, and the whole weight of iron used, upwards of 900 tons.

"The crab engine was employed invariably, the heads of the piles being covered with a slip of three-quarter inch elm, to distribute the force of the blow equally over the iron, and so prevent jarring. The monkeys used, weighed from 13 to 15 cwt. each, and it was found necessary to limit the fall to a height of 3 feet 6 inches, and sometimes less; when the resistance proved more than usually great, the pile showed a tendency to turn from its straightforward course. The driving throughout was very hard, more especially at the west end, where the sheet-piles in four bays, could not be forced to the full depth, the space above being in two of them made up with two plates in height, and in the other two admitting only one instead of three, as in the rest of the work. Driving was the only means resorted to, or indeed practicable, in the gravelly soil that prevailed. Had the bottom been clay, or other similar substance, the plan of boring, to receive the points, might probably have been partially adopted in the main piles with advantage; but I should say, certainly not to the extent of depending mainly upon it for getting the piles home to their places."

Piles similar to the above have been employed in many situations, differing only in matters of detail, which we do not think it requisite more fully to describe.

Piling of cast-iron seems to be very well adapted for coffer-dams, wharf-walls, embankments, and such works, but is not to be substituted for timber when employed for foundations, for unless based upon a very firm stratum, they are not so secure against sinking when heavily loaded; nor, on account of their small sectional area, do they compress and consolidate the soil through which they pass to the same extent as timber pilings, and this compression greatly assists in forming a solid foundation for the superstructure. Another disadvantage which attends the use of this material, is the deterioration which it undergoes by the action of water upon it, and especially of sea-water.

The screw-pile introduced by Mr. Mitchell, is admirably adapted for loose and moveable strata, and has been found very useful in situations where all other means had failed. This pile consists of a spindle of the required length, with a broad cast-iron plate or disc, in a spiral or helical form, attached to the lower end, so as to form a screw by means of which the pile is secured in the ground. The following account of them is taken from a summary of a paper read by Mr. A. Mitchell, and published in a cotemporary.

"The origin of the screw-pile was the screw-mooring which was designed for the purpose of obtaining, for an especial purpose, a greater holding power than was possessed by either the ordinary pile, or any of the usual moorin anchors or blocks, of however large dimensions. It was proved by experiment, that if a screw with a broad spiral flange were fixed upon a spindle, and forcibly propelled by rotary motion to a certain depth into the ground, an enormous force would be required to abstract it by direct tension, and that the power employed must be sufficient to drag up a mass of the form of a frustum of a cone reversed, the base being at the surface of the ground, and the section of the apex being equal to the diameter of the screw. The extent of the resisting mass must of course depend upon the natural tenacity of the soil; even in this reasoning it must be evident that a vertical force was calculated upon, but as practically that seldom or never occurred, the angle of tension and the curve of the buoy-cable again gave the moorings greater power. This was found to be correct in practice, and the applications of these moorings became very extensive. An arrangement was made with the port of Newcastle-on-Tyne, by which, for the sum of £2,500, the right of fixing the moorings in the Tyne was given; and Mr. Brookes, the engineer, showed that last year, (1847,) whilst in the neighbouring port damage was done to the shipping to the extent of nearly £30,000, no injury was sustained in the Tyne, entirely owing to the sound holding of Mitchell's screw-pile moorings.

"It naturally occurred to Mr. Mitchell, that the same means of resistance to downward pressure might be used, and he proposed to apply it for the foundations of lighthouses, beacons, and other structures, which for maritime purposes it might be desirable to place upon sand and mud banks, where hitherto it had been considered impracticable to place any permanent edifices. In the year 1838, a plan for a structure of this nature for a lighthouse on the Maplin Sand, at the mouth of the Thames, was laid before the corporation of the Trinity House, supported by the opinion of Mr. James Walker, their engineer. The 9 iron piles, 5 inches in diameter, with screws 4 feet in diameter, were accordingly driven 22 feet deep into the mud, and, with proper precaution, they were allowed to stand for two years, before any edifice was placed upon them. The lighthouse was subsequently constructed, and, as was testified by Mr. Walker, had stood perfectly until the present time (March, 1848"). The plan of the piling in this instance was octagonal, one pile being driven in each of the angles of the octagon, and another in the centre, making in all 9 piles, which were fixed in their places in 9 consecutive days, being screwed to a depth of 22 feet in the bank. The piles were made of malleable iron, 5 inches in diameter, and 26 feet long, with a cast-iron screw, 4 feet in diameter, screwed to the foot.

"Another lighthouse was erected to point out the entrance to the harbour of Fleetwood on Wyre; and under the advice of Captain Denham, R.N., the screw-piles were adopted. The spot fixed on was the point of a bank of loose sand about two miles from the shore. Screw-iron piles, with screws of 3 feet in diameter, were forced about 16 feet into the bank, and upon them timber-supports, 48 feet in vertical height, were fixed, to carry the house and lantern. This structure was completed in six months, and it was said to have never required any repairs to the present time," (March, 1848.)

Another method of piling was invented by Dr. Potts, but as this is connected more especially with PILE DRIVING, it has been described under that article, and does not demand any further observation in this place.

PILLAGE, among builders, a word sometimes used for a square pillar, standing behind a column to bear up the arches; having a round base and capital, as a pillar has.

PILLAR (from the Italian *piliere*, or French *pillier*) a kind of irregular column, round and insulate; but deviating from the proportions of a just column.

Pillars are always either too massive or too slender for regular architecture. In effect, pillars are not restrained to any rules; their parts and proportions are arbitrary. Such, for instance, are the pillars which support Gothic vaults, and other buildings, &c.

A square pillar is a massive work, called also *pier*, or *piedroit*, serving to support arches, &c.

A butting-pillar is a butment, or body of masonry, raised to prop, or sustain, the thrust of a vault, arch, or other work.

It seems not impossible for stone to be cast into the shape of pillars. We find mention made in the *Philosophical Transactions* (No. 481, p. 328, in *note*,) of two pillars of stone at Fontevraud, in France, each about 60 feet high, all of one solid piece, which are said to have been run. Pillars of stone were anciently erected as sepulchral monuments, near the highways; and also in memory of some victory. We find traces of this custom in Cornwall and Wales, where these pillars are often found, and called *meinigwir*, a stone for play, perhaps in memory of funeral games; and sometimes *llech*, that is, *tabula saxea*.

Pompey's pillar is a famous monument of antiquity, constructed of red granite, and situated on a rock, about a mile without the walls of Alexandria, in Egypt. By the mensuration of Edward Wortley Montagu, Esq., the capital of the pillar, which is Corinthian, with palm-leaves, and not indented, is 9 feet 7 inches high; the shaft 66 feet $1\frac{1}{4}$ inch; the base 5 feet $9\frac{3}{4}$ inches; the pedestals 10 feet $5\frac{1}{2}$ inches; the height from the ground 92 feet: though Dr. Pococke, by the shadow, determined the whole height to be 114 feet; and its diameter 9 feet and an inch. It is perfectly well polished, and only a little shivered on the eastern side. Nothing can equal the majesty of this monument: seen from a distance, it overtops the town, and serves as a signal for vessels. Approaching it near, it produces, says Savary, an astonishment mixed with awe. One can never be tired with admiring the beauty of the capital, the length of the shaft, nor the extraordinary simplicity of the pedestal. This prodigious mass stands, as on a pivot, on a reversed obelisk; and was erected, as many have supposed, either by Pompey, or to his honour. But as no mention is made of it by Strabo, Diodorus Siculus, or any other ancient writers, Mr. Montagu concludes that it was not known before the time of Vespasian, and that it was erected to his honour. In proof of this opinion, he found within the circumference of the pillar a medal of Vespasian, in fine order.

Savary, on the authority of Abu'lfeda, who calls it "the pillar of Severus," ascribes it to this emperor; alleging, that he visited Egypt, gave a senate to Alexandria, and deserved well of its inhabitants. Accordingly, it is said that this column was a mark of their gratitude. The Greek inscription, half effaced, which is visible on the west side when the sun shines upon it, was legible, without doubt, in the time of Abu'lfeda, and preserved the name of Severus. Nor is this the only monument erected to him by the gratitude of the Alexandrians. In the midst of the ruins of Antinoë, built by Adrian, is seen a magnificent pillar, the inscription on which is still remaining, dedicated to Alexander Severus.

Denon has given a drawing of this pillar, with the marked dimensions of its various parts: he makes its whole height a fraction more than 92 feet; and the height of the shaft, which is of a single piece, 63 feet $1\frac{3}{10}$ inch. It acquired, as this author says, the name of Pompey's pillar in the 15th century. A monument, as he supposes, had been raised by

Pompey at Alexandria, but it had disappeared, and was thought to be recovered in this pillar or column, which has since been converted into a trophy erected to the memory of Septimius Severus. It is, however, placed on the ruins of the ancient city; and in the time of Septimius Severus, the city of the Ptolemys was not in a ruinous state. To support this column by a solid foundation, an obelisk has been sunk in the earth, on which is placed a very clumsy pedestal, having a fine shaft, and surmounted by a Corinthian capital of bad workmanship. If the shaft of this column, continues Denon, separating it from the pedestal and the capital, once belonged to an ancient edifice, it is an evidence of its magnificence, and of the skill with which it was executed. It ought, therefore, to be said, that what is called Pompey's pillar is a fine column, and not a fine monument; and that a column is not a monument. The earth about the foundation of this pillar having been cleared away by time, two fragments of an obelisk, of white marble, the only monument of that substance seen by Denon in Egypt, have been added to the original base, to render it more solid. After having observed that the column, entitled Pompey's pillar, is very chaste both in style and execution; that the pedestal and capital are not formed of the same granite as the shaft; that their workmanship is heavy, and appears to be merely a rough draft; and that the foundations, made up of fragments, indicate a modern construction; it may be concluded, says our author, that this monument is not antique; and that it might have been erected either in the time of the Greek emperors, or of the caliphs: since, if the capital and pedestal are well enough wrought to belong to the former of these periods, they are not so perfect but that art may have reached so far in the latter.

PINION, an arbor, or spindle, in the body of which are several notches to catch the teeth of a wheel that serves to turn it round. Or a pinion is a lesser wheel, which plays in the teeth of a larger.

PINNACLE, (from the Latin, *pinna*, or *pinnaculum*,) the top or roof of a house, terminating in a point. This kind of roof, among the ancients, was appropriated to temples; their ordinary roofs being all flat, or made in the platform-way. It was from the pinnacle that the form of the pediment took its rise.

But the term is more generally applied to the slender and spire-like terminations in Gothic architecture, which rise from the top of buttresses, roofs, and other parts of an edifice. They form a very beautiful enrichment to the more delicate carvings in screens, shrines, and other works of a decorative character.

PINNING, the fastening of tiles together with pins of heart-of-oak; for the covering of a house, &c.

Pinning-up, the process of driving the wedges in underpinning the upper work, so as to make a good bearing upon the work below.

PIPE, a tube for the conveyance of water, gas, steam, soil, &c., made of various materials, as lead, iron, earthenware, &c.

PISCINA, (from the Latin, *pisces*, *fish*,) a large bason in an open public place or square, where the Roman youth learned to swim; it was surrounded with a high wall, to prevent the casting of filth into it.

Piscina, was also used for the square bason in the middle of a bath.

Piscina, or Probatica, (from the Greek, *πραβατον*, *sheep*,) a pool or reservoir of water, near the court of Solomon's temple; here the cattle, destined for sacrifice, were washed. By this piscina it was, that our Saviour wrought the miraculous cure of the paralytic. Davilier observes, there are still remaining five arches of the portico, and part of th bason of this piscina.

Piscina, or Lavatory, among the Turks, a large baso placed in the middle of the court of a mosque, or under th porticos that encompass it. Its form is usually a long square It is built of stone or marble, furnished with a great numbe of cocks, wherein the Mussulmans wash themselves befor they offer their prayers.

Piscina, the perforated stone usually found in a niche on th right-hand side of the altar, in our ancient churches and cha pels, into which the water used in washing the hands of th officiating priests, and other sacred ablutions, was cast.

Piscinas were almost always placed on the south side o the altar, and usually in the south wall, but sometimes in th east wall. They were of various degrees of ornamentatior some being very plain, and others elaborately enriched; no unfrequently we find a double niche, and sometimes a singl niche, with a sink and shelf above it, which is supposed t have been used as a credence-table.

PISE, a term applied to a peculiar mode of forming build ings of different kinds, but more especially those designe for farm-purposes, with some sort of stiff earthy material of a loamy quality. It is an easy, economical, and convenien method, which had its rise on the continent, and has been ha recourse to in different parts of this kingdom, as in Bedford shire, Lancashire, &c.

The difference between this, and the common mud-walling consists in the earth being pressed in moulds, by which it i rendered much more compact, and is not subject to crack s readily in the drying.

PIT OF A THEATRE, all that space between the am phitheatre, or galleries, and the theatre, or stage; called, by th ancients, *orchestra*: and by the French, *parterre*. This bein the most commodious part, it was here the Roman senate wa placed. It has its name, *pit*, in Latin, *cavea*, from its bein sunk below the level of the stage.

PITCH, in building, the vertical angle of a roof, or th proportion between the height and span; as, when th height is one-fourth, one-third, or one-half of the breadth o the building. If the height is one-half of the breadth, th inclination of the planes, forming the vertical angle, is a rig angle.

In former times, the vertical angles of roofs were made s very acute, that the length of the rafter was three-fourt of the breadth of the building; but, in the present day, whe the coverings are mostly of slate, mansions and dwellin houses have the height of the roof one-fourth or one-thi of that breadth; though in some country-places, the practi still continues of making the rafters three-fourths of t breadth of the building, which they call *true-pitch;* but wh the length of the rafters is equal to the breadth of the buil ing, the pitch is denominated *Gothic*.

PITCHING-PIECE, in staircasing an horizontal piece timber, having one of its ends wedged into the wall, at t top of a flight of steps, to support the upper ends of t rough-strings.

PIX, the casket in which the consecrated host was p served for the use of the sick. It was usually of me placed upon the altar under a canopy, but was sometimes ma in the form of a dove, and suspended over the altar.

PLACARD, the decoration of the door of an apartme which is sometimes a cornice supported by consoles.

PLACE-BRICKS, were originally kiln-burnt red bri of a full size, now entirely disused in the metropolis; bu lieu of them, the soft insufficiently burnt bricks from the side of the clamps are called, by way of distinction f stock or hard-burnt bricks, *place-bricks*. These are of a red colour, and will easily break or crush to pieces. The particular manner in which place-bricks were formerly made, was by dipping the mould in water before the clay was put in; which made the outer surfaces, when burnt, very coarse and hard. *See* Brick.

PLAFOND, or Platfond, (French) the ceiling of a room, whether it be flat or arched; lined with laths and plaster, and sometimes also enriched with paintings, &c. *See* Ceiling.

Plafond is also more particularly used for the bottom of the projecture of the larmier of the cornice; called also *the soffit.*

PLAIN ANGLE, an angle contained under two lines, or surfaces, so called in contradistinction to a *solid angle.*

Plain Figure, that of which the surface is a plane, bounded by one or more lines.

Plain Tiles, or Plane Tiles, such as are intended to have their surfaces planes.

Plain Triangle, a triangle included under three right lines, or surfaces; in opposition to a *spherical*, and a *mixed triangle.*

Plain Trigonometry, the doctrine of plain triangles, their measures, proportions, &c.

PLAN, (French) a representation of something drawn on a plane. Such are maps, charts, and inchnographies.

Plan, in architecture, is particularly used for a draught of a building; such as it appears, or is intended to appear, on the ground; showing the extent, division, and distribution of its area into apartments, rooms, passages, &c.

To render plans intelligible, it is usual to distinguish the massives with a black wash. The projectures on the ground are drawn in full lines, and those supposed over them, in dotted lines. The augmentations, or alterations, to be made are distinguished by a colour different from what is already built; and the tints of each plan are made lighter as the stories are raised. In large buildings, it is usual to have three several plans for the first three stories.

The plan is the first device, or sketch, the architect makes; it is also called the *ground plot*, *platform*, and *ichnography*, of the building.

Plan, *Geometrical*, that in which the solid and vacant parts are represented in their natural proportion.

Plan, *Perspective*, one that is conducted and exhibited by degradations, or diminutions, according to the rules of perspective.

Plan, *Raised*, that where the elevation, or upright, is shown, upon the geometrical plan, so as to hide the distribution. *See* Elevation.

Plan of a Bastion, in the military art, the same with the *face of the bastion.*

Plan, in ship-building, the section of a ship, as designed upon paper, previously to the actual building, of which three are the chief, viz., the plan of elevation or sheer-plan; the horizontal or half-breadth-plan; the plan of projection or body-plan; these three compose the *sheer-draught.* But it must be observed, that the extreme length, breadth, and height must be determined; by which the three plans aforesaid may be delineated. These may be called *the outlines*, and the several parts contained within them may be delineated so as to answer the intended purpose; and likewise have a distinct view of the whole design, so that any inconveniencies attending such a disposition may be easily remedied, and the true dimensions of every particular may then be had upon the draught. The delineating of a ship upon a plan is called *drawing*, and the representation is called *draught.*

PLANCERE, the soffit of the corona of a cornice.

PLANE, (from the Latin, *planus*,) a tool used by artificers who work in wood, to produce straight, flat, and even surfaces upon that material.

Almost all trades which fabricate articles of wood, employ planes at times; but as joiners make a greater use of these tools than any others, they are usually considered as joiners' and carpenters' tools. Planes have been of late years used by some artists to produce flat surfaces in metals. A plane operates to cut off a thin chip, or shaving, from the wood on which it is applied, by the sharp edge of a steel cutter, or broad chisel, called, very improperly, the *plane iron:* this is fixed in a hole made through a wooden block, called the *plane stock*, and the edge of the iron projects in a very small degree through the lower side of the stock, called the *face of the plane;* the surface of which face is made a perfectly true plane.

The iron is fixed in an inclined position in the hole through the stock, by means of a *wedge* driven in before it, to jamb it fast in the hole, which being wider than the thickness of the iron, leaves an aperture before the iron, called the *mouth* of the plane; this is very narrow where it opens in the lower side, or face, but grows wider as it rises up through the stock: the wedge is also cut forked, to allow more room for the shavings which the plane-iron cuts, to pass up before it through the mouth. When a plane of this kind is applied with its face upon the surface of a piece of wood, and pressed down upon it whilst it is moved forwards, the edge of the iron penetrates the wood to the depth which it projects through the face, and removes a shaving of that thickness, the whole breadth of the edge of the iron; the shaving turning up before the iron, passing through the mouth, and escaping. The inclination of the iron makes it cut easily; and if the iron is *set fine*, that is, if the edge projects but very little beyond the face, it will remove very thin shavings, and produce a flat and smooth surface: on the other hand, if it is *set rank*, that is, with a considerable projection, it will cut away very fast, producing a flat, though rough, surface, and quickly reducing the wood to its intended thickness: if the wood has an irregular surface, it soon reduces it to a plane, because the face, being flat, will not suffer the edge of the iron to descend into the hollow places, but removes all the eminences it passes over till they are reduced to one level.

This is a general description of several kinds of planes, which are all known by different names, from their various dimensions and purposes.

Joiners use the *jack plane*, the *long plane*, *trying plane*, *shooting plane*, or *jointer*, and the *smoothing plane;* all which they denominate *bench planes*, because the wood they are used upon is generally laid on the work-bench. They have also the *straight block*, for straightening short edges; *rebating planes*, for forming rebates; others for the same use, are called the *moving fillister*, *sash fillister*, and *side-rebating plane.* The *plough* is a narrow plane, provided with an apparatus to guide it, in moving straight forward, to plow a groove or trench at any required distance from the edge of a board, or other piece of wood, and to any depth or width. The *dado grooving plane* is also for forming grooves.

There are several other tools, which, having an iron fitted into a stock, are called *planes*, because they cut in the same manner, though, in strictness, they are not planes, for they do not make plane surfaces; these are *moulding planes*, with faces and cutting edges curved, to produce all the varieties of ornamental mouldings, and which are known by the names of *snipe's-bills*, *side snipe's-bills*, *beads*, *hollows*, *and rounds*, *ovolos*, and *ogees.* The varieties and different sizes of these form a vast number, with which every complete joiner is furnished. It is impossible to describe the terms applied to these tools without figures, as they are arbitrary, though generally known among workmen. The faces of all these planes are straight in the direction of their length, but a section across the face is the impression or reverse of the moulding they are intended to make, and the edge of the iron is curved to correspond with this curve when in its place, though in reality it is a very different figure, because it is inclined to the face of the plane at an angle of about forty-five degrees. Another distinction between these and the bench planes is that their mouths do not open so as to discharge the shaving through the stock at the top thereof, but the wedge completely fills the hole, and the shaving passes out sideways through a hole for that purpose: in some, these apertures are on the right, and in others on the left side; in the first case, the shaving is said, by the workmen, to be thrown on the bench, that is, upon the right side of the plane; but when the orifice of discharge is on the left, and consequently the shaven thrown upon the left, then the plane is said to throw the shaving off the bench. The *compass plane* is used by coach-makers, cabinet-makers, &c.; it is made with a convex face, formed to an arc of a circle in the direction of its length, and it therefore forms the concave surface of a cylinder. The *fork-staff plane* is straight in the direction of its length, but its face is made concave in its breadth, to the arc of a small cylinder; the edge of the iron is of course curved in the same manner, and it planes cylindrical surfaces. Coopers also employ long and heavy planes to form the edges of the staves of barrels, these are mounted in an inclined position on legs like a stool, with their faces upwards, and the stave is drawn backwards and forwards upon them.

Planes are so necessary for all kinds of work, that any who intend to work in wood, should understand the structure, and the manner of using them. The *jack plane* is used for taking off the rough and prominent parts from the surface of the wood, and reducing it nearly to the intended thickness, in coarse shavings, or slices. The stock of this plane is about seventeen inches in length, three inches high, and three and a half inches broad; all the sides are straight, and at right angles to each other: the mouth is cut through the solid of the stock to receive the iron, and hold it at such an elevation, as to make an angle of forty-five degrees with the face of the plane; the iron is a thin metal plate, one side consisting of iron, the other of steel; the lower end of the iron is ground to an acute angle off the iron side, forming a sloping part called *the basil of the iron*, so as to bring the steel side to a sharp edge: the wedge which fixes the iron in its place is let into two grooves of the same form, on the sides of the opening or mouth: two sides of the wedge are parallel, and it is forked, or cut away in the middle, leaving the sides like two prongs, to fill the lower part of these grooves; this allows the shaving to pass up, without obstruction, before the wedge: for the mouth or opening through the stock must be uninterrupted from the face to the top, and must be no wider on the face of the plane, than is sufficient for the thickest shaving to pass with ease; and as the shaving is discharged at the upper side of the plane, the opening through it must expand or increase from the face to the top, so as to prevent the shavings from sticking therein. A handle, called the *tote*, is fixed to the upper side of the stock, immediately behind the iron; it is formed to the shape of the hand, and the direction of the motion, so as to produce the most power in pushing the plane forward.

A workman in using the jack-plane, lays the piece of wood on the bench parallel to its sides, with the farther end lodged against the bench-hook; then laying the fore part of the plane upon the hind end of the wood, with the right hand he takes the handle, and pressing with his left upon the fore-end, thrusts the plane forward in the direction of the fibre of the wood and length of the plane, until he has extended the stroke the whole length of his arm, the shaving being discharged at the orifice; he then draws back the plane, and repeats the operation in the next adjacent rough part, proceeding in this manner until he has removed the rough parts throughout the whole breadth. He then steps forward the distance of the length he has planed, and operates upon another length in the same manner, proceeding this way by steps until the whole length is gone over and rough-planed. To do this is very easy; but a workman will not make good progress, nor do clean work, unless he has first adjusted his tool properly for the work. The methods for doing this are nearly the same for all planes. The first care is to obtain a sharp cutting-edge to the iron; if it requires grinding on the grindstone, the carpenter places his two thumbs under the iron, and the fingers of both hands above, laying the basil side to the grindstone, and holding it to the angle he intends it shall make with the steel side of it, keeping it steady while the stone revolves; and pressing the iron to the stone with his fingers; in order to prevent the stone from wearing the edge of the iron into irregularities, he moves it alternately from edge to edge of the stone, with so much pressure on the different parts, as will reduce it to the required bevel, and make the edge straight.

The basil being brought to a proper angle, and the edge to a regular and slight curvature, the roughness occasioned by the gritty particles of the stone is taken away by rubbing its edge on a smooth flat stone, or turkey-stone, sprinkled with olive-oil on its surface. As the basil is generally ground, to give a more acute angle than the edge of the iron would stand, for the quicker dispatch of wetting it, the face of the iron is inclined nearer to the perpendicular, while it is rubbed backwards and forwards with the same inclinatio[n] throughout. Every time the iron becomes dull or blunt by use, the sharpening is produced by grinding on the rubber stone, or flat grindstone, or on a turkey-stone; but, in repeating this, after the edge gets thick, it requires so much tim[e] to bring it up to an edge, that recourse must be had to th[e] grindstone. The iron being thus sharpened, must be fixed i[n] the plane by its wedge: the projection of the cutting-edg[e] must be just so much beyond the face of the plane, as tha[t] the workman may be able to work it freely in the act o[f] planing, and must be regulated by the stuff to be wrough[t] whether it be hard or soft, cross-grained or curling; so tha[t] a man may be able to perform the most work, or reduce th[e] substance most in a given time. If the stuff is good an[d] clean-grained, it is evident that a considerable projection ma[y] be allowed, as a thicker shaving may be taken. The extrem[e] ends of the edge of the iron must never enter the wood, a[s] this not only retards the progress of working, but chokes an[d] prevents the regular discharge of the shavings at the orifi[ce] of the plane. The projection of the cutting-edge is calle[d] *iron*, and the plane is said to have more or less iron, as th[e] projection is greater or less; when there is too much iro[n] the workman knocks with a hammer on the fore end of th[e] top of the stock, and the blows will loosen the wedge, an[d] raise the iron in a certain degree, after which the head of th[e] wedge must be knocked down to fix it again. When the wor[k]man has occasion to take out the iron to sharpen it, he strik[es] the fore end of the top of the stock smartly with the hamm[er] which loosens both the wedge and the iron.

All the other bench-planes are adjusted in the same mann[er] and indeed do not differ, except in dimensions, as we sh[all] explain, from the jack-plane. Of late years a great impro[ve]ment has been introduced in the irons of planes, to ca them to cut smooth; these are called *double-ironed;* they were at first only used in the finest shooting planes, but the advantages have been found so great, particularly in planing bad wood, that they have become general for all sorts of planes. The double iron consists of a second iron, with a reversed basil, screwed against the front side of the iron, so that its edge lies against the iron at a very small distance from, and parallel to, the cutting-edge; and applying closely to the steel side of the iron; it forms an inclined plane, which turns the shaving over immediately after it is separated or cut by the edge, and thus it prevents the iron from splitting the shaving deeper down than it will afterwards cut, and therefore leaving a rough or torn surface. This second iron is called *the cover of the iron;* and the basil of its edge, instead of being ground flat, as that of the iron, is rounding; the screw, which binds the cover upon the iron, passes through a slit in the cover, and thus admits of its edge being adjusted at any required distance from the cutting-edges of the iron, and this distance depends altogether on the nature of the wood the plane is to be worked upon. If the stuff is clean-grained, the edge of the cover may be set at a considerable distance, because the difficulty of pushing the plane forwards becomes greater, as the edge of the cover is nearer the edge of the iron, and the contrary when more remote: this is occasioned by the edge of the cover turning the shaving over, immediately upon its being cut up. The *trying-plane* is usually twenty-two inches long, three inches and three-quarters broad on the face, and three inches and one-eighth in height; it does not differ from the jack-plane, except in having a double handle, adapted for greater force; in use, it succeeds the operation of the jack-plane, to straighten the wood, and remove the ridges left by the former; it is set with less iron, and cuts a finer shaving: the mouth is also much narrower. When it is used upon a long piece of work, the workman takes every shaving the whole length, by stepping forwards, instead of stopping at arm's length, as with the jack-plane. The shaving of this plane, though finer, is so much broader than that of the jack, that it requires as much force to push it forwards.

The *long plane* is set very fine, for finishing work which is to be very straight; it is twenty-six inches long, three and a half broad, and three inches and one-eighth in height.

The *shooting plane*, or *jointer*, is the longest, and most correct plane used; it is employed after all the others, chiefly in shooting the straight-edges of boards which are to be jointed together; it is generally made two feet and a half long, three inches and three quarters broad, and three and a half high; it is used like the others, but with great care to move it steadily from one end of the work to the other, without pressing it down, as that might spring the plane, or the work, and cause the iron to cut when the work was something hollow, whereas the object is to make a perfectly straight edge. The face of this plane must be kept quite true, and therefore it is a great object to make it of a fine piece of clean-grained, hard beech, well seasoned, that it may not warp, or vary, by the weather.

The *smoothing plane* is very short, without any handle, and its sides are curved, so that it very much resembles a coffin; it is seven inches and a half long, three broad at the mouth, and two inches and three quarters in height; it is used for finishing work when put together, and to give the greatest degree of smoothness to the wood, for which purpose it is set with as fine an edge as possible.

Rebating planes are used for cutting out rebates: these are a kind of semi-grooves upon the edge of a board, or other piece of wood, formed by cutting down or reducing a small part of the breadth of the board to half, more or less, of the general thickness: by this means, if a rebate be cut on the upper side of one board, and the lower side of another, the two may be made to overlap each other, without making them any thicker at the joint. Rebates are also used for ornamenting mouldings, and many other purposes in joiners' work. The planes for cutting them are of different kinds, some having the cutting-edge at the side of the iron and of the stock, others at the bottom edge of the iron and the face of the stock, and others cutting in both these directions; the former, being used to smooth the side of the rebate, are therefore called *side-rebating planes;* whilst the others are used for smoothing the bottom. There is also a third sort, called *fillisters*, used for sinking, or cutting away the edge of a piece of wood to form the rebate, leaving it for the others to smooth the surfaces when cut. The rebate planes are about nine inches and a half long, and of various widths upon the face, from half an inch to an inch and three quarters, in all cases they have the mouth and the edge of the iron coming out at one edge of the face, and the side of the iron also exposed at one of the upright sides of the stock, whether it is formed with a cutting-edge there or not; this exposed side is either on the right or left, and they are named accordingly. In all cases, they throw the shaving out on the side, instead of the top of the stock. The cutting-edges and mouths are generally situated obliquely across the face, instead of being at right angles to the length of the plane, as in others.

The *moving fillister* is a rebating plane, which has a ruler of wood, called the *fence*, fixed upon its face by screws, in the direction of its length, and exactly parallel to the edge of the face; it therefore covers part of the length of the cutting-edge, and can be fixed at any required distance from the edge, to leave more or less of the cutting-edge exposed, and this quantity will be the breadth of the rebate it will cut; because when it is used, the edge of the fence is applied against the edge of the piece to be rebated, and thus gauges the breadth its iron shall cut away. The cutting-edge of this plane is not situated at right angles to the length of the stock, but has an obliquity of about forty-five degrees, the exposed side of the iron being more forwards than the other. By this obliquity, when the plane is worked it has a tendency or drift to run farther into the breadth of the wood, but as the fence, silding against the edge, prevents this, the drift always keeps the fence in contact with the edge, without the attention of the workmen; it also causes the iron to cut the bottom of the rebate smoother, particularly in a transverse direction to the fibres, or where the stuff is cross-grained, than could otherwise be done, when the steel face of the iron is perpendicular to the vertical sides of the plane. The principal use is, however, to contribute with the form of the cavity to throw the shaving into a cylindrical form, and thereby make it issue from one side of the plane. The iron is what is called *shouldered*, that is, the lower part, or shoulder, where the edge is, has double the width of the upper part, which is received into the mortise, and jambed fast by the wedge. It is the edge of this wide part only which is exposed at the side of the stock. Besides this principal iron, there is another small iron, called the *tooth*, which precedes the other, to scratch or cut a deep crack at the width of the rebate, thus making the shavings, which the iron cuts up from the bottom, separate sideways from the rest of the wood. This tooth is inserted in a vertical mortise through the stock, between the fore end of the stock and the iron. The lower end of this little iron is ground with a basil on the inside, so as to bring the bottom of the narrow side of the iron to a very convex edge; it is fastened by a wedge passing down before it in the mortise in the stock. The use of this tooth is principally for cutting the wood transversely when wrought across the fibres, and, by this means, it not only cuts the vertical side of the rebate quite smooth, but prevents the iron from ragging or tearing the stuff. The iron between the fence and the edge of the face of the plane, must project the whole breadth of the uncovered part of the face, otherwise the wood of the plane will bear it up, and prevent the plane sinking as it cuts away the rebate, and the edge of the tooth, or little iron, should stand out a little farther on the side of the plane than the iron. The depth of the rebate, which this plane will cut, is regulated by a stop fixed on the outside of the plane, at the intended height, above the level of the face: then, when the plane has penetrated or sunk the intended depth of the rebate, the stop comes to bear upon the solid of the wood beyond the rebate, and bears it off from cutting any longer. The stop is a piece of brass, which moves in a vertical groove made in the side of the stock, between the iron and the fore end of the plane; in this it is moved up and down by a screw, which is inserted in a vertical perforation from the top of the plane to the groove, and passing through a part projecting from the stop into the groove: the upper part of the screw is formed to a thumb-nut, to turn it round by, and it is so confined by proper collars, that it can neither move up nor down; but being turned, the inclination of the threads will rise or fall according to the direction in which the thumb-screw is turned, and cause the stop to move up and down in the groove on the side of the plane, thus regulating it at pleasure to the depth to which the rebate is required to be sunk.

In grinding and fixing the iron of this plane, it is necessary that the cutting-edge of the iron should stand equally prominent in all parts out of the face, otherwise the plane cannot make shavings of an equal thickness; and, consequently, instead of keeping the vertical position, will, as it proceeds, become deeper on the side on which the shavings are thickest, and then the part cut away will not be regular, for the bottom of the rebate will not be parallel to the upper surface of the wood, and the side which ought to have been vertical, will be a kind of a ragged curved surface, formed by as many gradations or steps in the depth, as the number of shavings.

The *sash fillister* differs, in several particulars, from the moving fillister: the breadth of the iron is something more than the whole breadth of the sole, so that the extremities of the cutting-edge are, in a small degree, without the vertical sides of the stock: the fence is adapted to be moved to a considerable distance, not being fixed as in the moving fillister, by screws upon the face, but sustained by two bars fixed fast to it, which pass through the two vertical sides of the stock, at right-angles to the sides, fitting tight in the two holes through which they pass: these bars are made rounding upon the upper side, and flat on the lower side: at the point, where they are united to the fence, they have thicker parts, or shoulders, projecting downwards, because it is necessary to have the fence fixed on a lower level than the face of the plane; the ends of the bars are ferruled, to prevent their splitting when the ends are struck with the mallet, in order to move them in the holes through the stock, and this brings the fence either nearer, or more remote from the stock, as may be wanted; and to fix it fast, when so adjusted, two small tapering pieces of wood, called *keys*, are inserted into two small wedge-like mortises, cut at the sides of the mortises, in which the bars pass through the stem; these wedges being drawn in, they will stick fast, and press against the bars, keeping them fast at all points, and thereby regulate the distance of the fence from the vertical side of the stock. This plane is generally employed to rebate narrow pieces of wood, such as sash frames; and the fence is applied against the opposite edge of the wood to that on which the rebate is to be formed.

The *plough* is a plane with a very narrow face, made of iron, fixed beneath a wooden stock, and projecting down from the wood of the stock, the edge of the iron being the full width, or rather more, than the face; it is guided by a fence with bars, like the fillister above described, to make, or plough out a groove of the width of the iron, and at any required distance from the edge of the wood; it has also a similar stop to regulate the depth it cuts to. Joiners, cabinet-makers, &c., in plaining thin, or valuable woods for veneering, &c., sometimes use fluted irons, having teeth in their edge; and a plane, thus mounted, is called a *toothing plane;* these irons apply to the stocks of different planes. *See* Tools.

Plane, in geometry, a surface which will everywhere coincide with a straight line.

Wolfius defines a plane, "a surface, from every point of whose perimeter, a right line may be drawn to every other point in the same."

As the right line is the shortest extent from one point to another, so is a plane the shortest extension between one line and another.

Planes are frequently used in astronomy, &c., for imaginary surfaces, supposed to cut, and pass through, solid bodies; and on this foundation is constructed the whole doctrine of conic sections.

When a plane cuts a cone parallel to one of its sides, it makes a parabola; when it cuts the cone parallel to its base, it makes a circle. *See* Circle and Parabola.

The sphere is wholly explained by planes, imagined to cut the celestial luminaries, and to fill the areas or circumferences of the orbits; and they are differently inclined to each other; and by us, the inhabitants of the earth, the plane of whose orbit is the plane of the ecliptic, their inclination is estimated with regard to this plane.

Plane, *Geometrical*, in perspective, a plane parallel to the horizon, whereon the object to be delineated is supposed to be placed. This plane is usually at right angles with the perspective plane. *See* Perspective.

Plane, *Horizontal*, a plane passing through the spectator's eye, parallel to the horizon, cutting the perspective plane in a straight line, called *the horizontal line.*

This, according to Brook Taylor's definitions of perspective, may be called *the vanishing plane of the horizon.* *See* Perspective.

Plane, *Inclined*, one that makes an oblique angle with a horizontal plane.

Plane, *Objective*, any plane face, or side, of an original object to be represented in perspective.

Plane, *Perspective*, a plane pellucid surface, ordinarily perpendicular to the horizon, and placed between the spectator's eye and the object he views; through which the optic rays, emitted from the several points of the object, are supposed to pass to the eye, and, in their passage, to leave marks that represent them on the said plane.

Plane, *Vertical*, a plane passing through the spectator's eye, perpendicular to the geometrical plane, and at right angles to the perspective plane. *See* Perspective.

Plane Table, a rectangular board, with a plane face, for finding the position and distance of a point, or of any number of points, situated in the same plane. By this mean the plan of horizontal objects, whether straight or crooked can very easily be ascertained by only one distance being given

PLANIMETRY, (from Latin, *planus*, plain, and Greek, *μετρεω*, to measure,) that part of geometry which considers lines and plane figures; without reference to heights or depths.

Planimetry is particularly restrained to the mensuration of planes or surfaces, in opposition to *stereometry*, or the mensuration of solids.

Planimetry, or the art of measuring the surfaces and planes of bodies, is performed with the squares of long measures, as square inches, square feet, square yards, square perches, &c.; that is, by squares whose sides are an inch, a foot, a yard, a perch, &c.; so that the area or contents of any surface is said to be found, when we know how many such square inches, feet, yards, &c., it contains.

PLANING MACHINE, a machine used to diminish the great manual labour of planing the surfaces of planks and boards of wood: in strictness, those alone should be termed planing machines, which reduce the surface of the wood to a true and smooth plane, by means of planes, or instruments of a similar nature, though actuated by the power of machinery instead of the strength of a man's arm; but custom has denominated those machines which cut flat surfaces in a different manner from planes, by the same name.

These machines are of modern invention; the first, we believe, was projected by General Bentham, who obtained a patent for it in 1791. It consisted of a plane, to be put in motion by means of a crank turned by a mill, to give it a reciprocating motion; or, on a smaller scale, it might be worked by hand in the usual manner, but the plane was so formed as to require none of the skill and attention necessary in the ordinary method of operating. The plane is made the full width of the boards intended to be planed, and on each side of it fillets, or cheeks, are fixed, which project beneath the face of the plane just as much as the thickness the board is to be reduced to: these cheeks, therefore, guide the plane sideways in passing along the board, and gauge it in thickness; because, when the board is reduced to the quantity that the cheeks are beneath the surface of the plane, the cheeks rest upon the bench, or surface, on which the board lies, and bear off the plane, so that it can cut no longer. The plane is kept down by its own weight, which is increased, when necessary, by loading it with weights, and these are contrived to be capable of shifting their position from one end of the plane to the other during the time it is making the stroke; because, at first, the pressure is required at the fore end to enter the cut, but, at the conclusion, it must be greatest at the hinder end, to prevent the fore end tripping down the instant it leaves the board. By another contrivance, the plane is caused to rise up sufficiently to clear the cutting edge from the wood when the plane is on its return. It is by a piece, which acts as a handle to the plane, and to which the power is applied, that it is fixed in the manner of a lever upon an axis extending across the width of the plane, and carrying at each side thereof a short lever, provided with rollers in their extremities; the handle projects upwards from the plane, which being forced forwards by it, assumes an inclined position, as do also the short levers, and their rollers then rise above the cheeks of the plane; but when the plane is drawn back, its handle is first drawn back into an erect position, and the levers moving with it, their rollers project beneath the cheeks of the plane, and raise it off the bench, the plane being in its return borne by them.

The bench for supporting the board during the operation, was also of a peculiar construction, in order to confine the work steady upon it. In cases when the boards to be planed are winding or irregular on the lower side, so that they cannot lie flat upon the bench, it is provided with two sides, which can be brought to close upon the edges of the board, and hold it steady between them, being furnished with one or more rows of flat teeth, to penetrate the wood and retain it; these sides are contrived to rise or fall upon the bench, to accommodate the different thicknesses of the boards. When a very thin board is to be planed, it might be liable to spring up to the iron, so as to be reduced even after the plane came to rest with its cheeks upon the bench; to avoid this, the edges of the board are to be held by the sides to the bench before-mentioned, but as it would still be liable to spring up in the middle part, heavy rollers, or rollers loaded with weights, are fitted in apertures made in the plane as near as possible to the cutting-edge, and these will keep the board down close upon the bench. For planing pieces of greater thickness at one end than the other, the cheeks of the plane are to be borne upon rulers of wood laid on the bench on each side, the wood being as much thicker at one end as the board is intended to be thinner at that end; therefore, when the plane has reduced the wood, the cheeks come to bear upon these rulers, and cause it to move not parallel to the bench, but inclined, according as they are thicker at one end than the other; in like manner, by using them of different thicknesses at the different sides, the boards may be made feather-edged.

Mr. Bramah invented a planing machine, which he used very advantageously for planing all kinds of timber flat, at a very trifling expense. In 1802, he took out a patent for the invention, which he describes, in his specification, to consist in the following particulars. "The cutting tools employed to reduce the wood, instead of being worked by hand, are to be fixed on frames, some of which are moved in a rotatory direction round an upright shaft, and others have a shaft lying in a horizontal position, like a common lathe. In other instances, the tools are fixed on frames, which slide in stationed grooves to be driven also by machinery. The principal points on which the merits of the invention rest are, 1. The materials to be wrought are made to slide in contact with the tool, instead of the tool being carried by the hand over the work in the usual way. 2. The tool is made to travel across the work in a square or oblique direction, except in cases where it may be necessary to fix the tool in an immovable station, and cause the work to fall in contact with it by a motion. 3. Instead of common tools, bent knives, spoke-shaves, or deep cutting gouges, are used for cutting off the roughest parts, and planes of various shapes and constructions, as the work may require, are applied to follow the former in succession, under the same operation, and which latter I call *finishers*. 4. These are fixed on frames which move in cases, like those on which the saws are fixed in a sawing-mill; and in other instances, these frames are fixed on a rotatory upright shaft turning on a step, and carrying the frame round in a direction similar to the upper mill-stone for grinding corn; and sometimes the frames turn on a horizontal shaft, resembling the mandrel of a common turning lathe. The different planes, tools, &c., are fixed in the frames, so as to fall successively in contact with the wood or other materials to be cut, so that the cutter or tool calculated to take the rough and prominent part, operates first, and those that follow must be so regulated as to reduce the material down to the line intended for the surface. These cutter frames must also have the property of being regulated by a screw or otherwise, so as to approach nearer the work, or recede, at pleasure, in order that a deeper or shallower cut may be taken at discretion, or that the machine may repeat its action, without raising or depressing the material on which they act. 5. When an upright shaft is used the pivot is to turn in oil, and it may be raised or depressed at pleasure, by means of a greater or less quantity of the said fluid being confined between the end of the shaft and the bottom of the step. 6. The materials to be cut must be firmly fixed on a frame, similar to those in sawing-mills, on which the timber is carried to the saws. These frames must be moved in a steady progressive manner as the cutter frame turns round, either by the same power which moves the latter, or otherwise, as may be found to answer best in practice. 7. The motion of the cutter frames must be under the control of a regulator, so that the velocity of the tool, in passing over the work, may be made quicker or slower, as such work may respectively require, to cause the cutter to act properly to the best advantage." For this purpose, Mr. Bramah proposes to use what he calls *an universal regulator of velocity*, and which he describes as follows: "I take any number of cog-wheels, of different diameters, with teeth that will exactly fit each other through the whole; suppose ten, or any other number, but, for an example, say ten, the smallest of which shall not exceed one inch in diameter, and the largest suppose ten inches in diameter, and all the rest to mount by regular gradations in their diameters, from one to ten. I fix these ten wheels, fast and immovable, on an axis perfectly true, so as to form a cone of wheels; I then take ten other wheels, exactly the same in all respects as the former, and fix them on another axis, also perfectly true, and the wheels in perfect gradation also; but these latter wheels I do not fix fast on their axes, like the former, but leave them all loose, so as to turn on the said axes, contrary to the former, which are all fixed. All these latter wheels I have the power of locking, by a pin or otherwise, so that I can, at discretion, lock or unite any single wheel at pleasure to the axis. I then place the two axes parallel to each other, with the wheels which form the two cones, as above described, in reverse position, so that the large wheel at one end of the cone may lock its teeth into the smallest one in the cone opposite, and likewise *vice versa.* Then suppose the axis, on which the wheels are permanently fixed, to be turned about, all the wheels on the other axis will be carried round with velocities correspondent to their diameters and those of the former, but their axis will not move. Then lock the largest wheel on the loose axis, and, by turning about the fastened axis, as before, it must take ten revolutions, while the opposite wheel performs but one; then by unlocking the largest wheel, and locking the smallest one at the contrary end of the cone in its stead, and turning as before, the fastened axis will then turn the opposite ten times, while itself only revolves once. Thus the axes or shafts of these cones, or conical combinations of wheels, may turn each other reciprocally, as one to ten, and ten to one, which collectively produces a change in velocity, under a uniform action of the *primum mobile*, as ten to a hundred; for when the small wheel on the loose axis is locked, and the fast one makes ten revolutions, the former will make one hundred; and by adding to the number of those wheels and extending the cones, which may be done *ad infinitum*, velocities may be likewise infinitely varied by this simple contrivance: A may turn B with a speed equal to thousands or millions of times its own motion; and by changing a pin and locking a different wheel, as above described, B will turn A in the same proportion, and their power will be transferred to each other, in proportion as their velocities, reciprocally. Here is a universal regulator at once for both power and velocity. In some instances I produce a like effect, by the same necessary number of wheels made to correspond in conical order, but, instead of being all constantly mounted on the axes or shafts, as above described, they will reciprocally be changed from one axis to the other, in single pairs, to match according to the speed or power wanted, just as in the former instance. This method will have, in all respects, the same effect, but not so convenient as when the wheels are all fixed."

In 1803, Mr. Bevans obtained a patent for a machine for planing, (or *sticking*, as the joiners term it,) all kinds of mouldings or rebates, and ploughing grooves, as well as forming flat surfaces of small breadth, which it does with very little labour: in this machine, the operations are performed by the planes commonly used for similar purposes, with only such alterations as are necessary to adapt them to the machinery by which they are put in motion with mechanical power instead of human labour; they are to be used either singly, or combined together in any number, according to the width of the boards to be worked at once, and the nature of the work to be done, so as to plane up, at one operation, such moulding as joiners work up, by using several planes successively for the different parts; this is effected by a kind of frame, or box, which admits of fixing any number of planes in it, side by side, and at any distance asunder, to form the compound moulding required. The work is fixed fast on a bench, and the box of planes is made to pass over it, in the direction of its length, by a connecting rod communicating at one end with the box or frame containing the planes, and, at the other end, with machinery capable of affording a reciprocating motion.

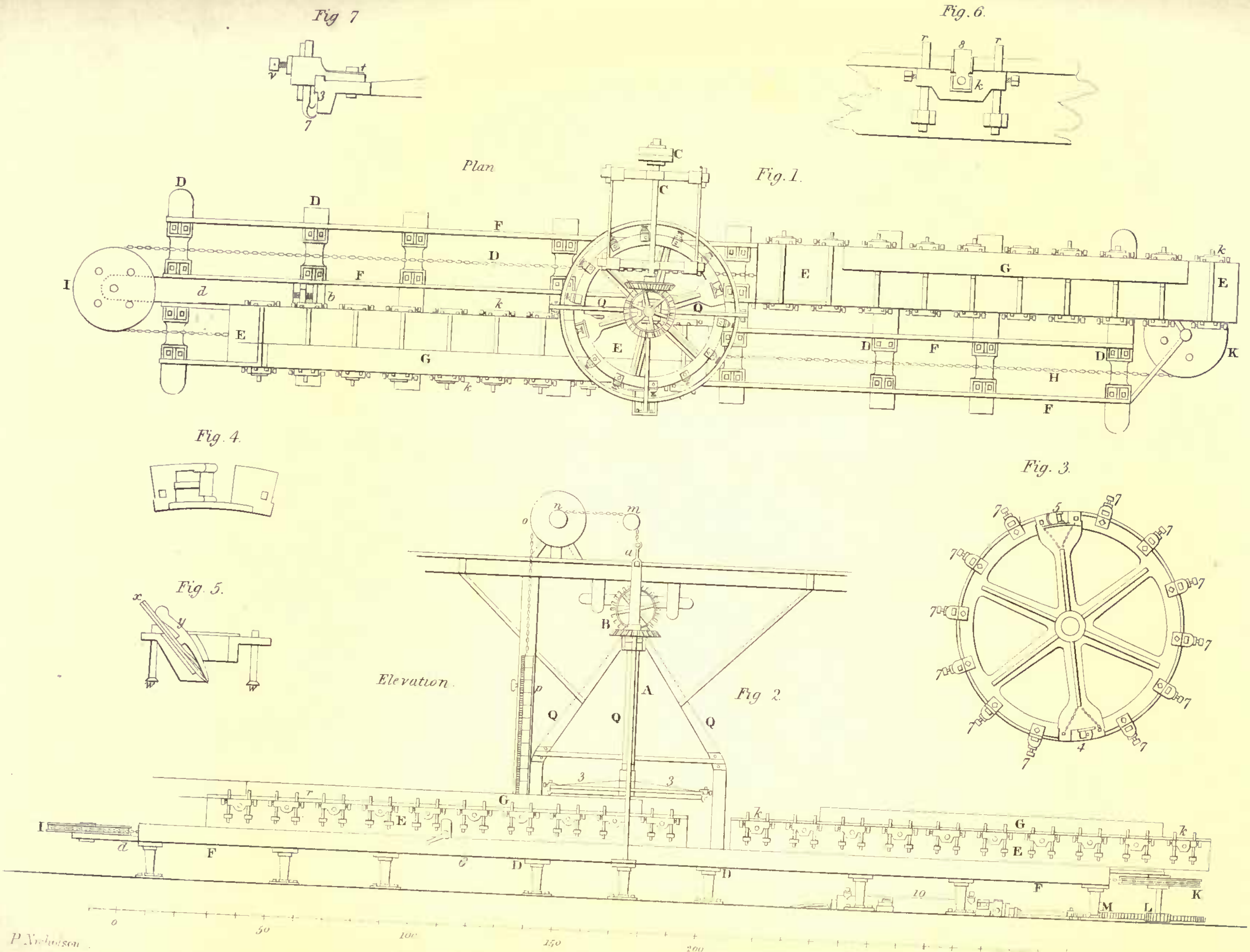
This machinery consists of a crank, whose radius must be nearly half the length of the required stroke, and must be regulated accordingly: this regulation is effected by the arm of the crank passing through a mortise in a strong box, fixed on an axis, and sliding in the said box to any required length, where it must be fixed by strong screws, the axis being turned by manual exertion, by horses, steam, water or any other power, and having its motion regulated by a fly-wheel.

The planes are loaded, to keep them in contact with their work, by a long beam of wood, set up on end upon the sides of the box, and connected therewith by being divided into two cheeks, which, at the lower sides, are formed to an arc of a circle, and united to the box by chains, in the same manner as the beams of steam-engines are connected with their piston-rods. The upper part of the beam is made to pass always through one point, by sliding between friction-wheels, or otherwise, in a tube hung on two pivots, perpendicularly over the centre of the work, and at such heights as may be most convenient for the length of the stroke required: the connecting-rod, from the crank before mentioned, is jointed to the upright beam, near its lower end, and by this means the motion is given to the box of planes, the chains and arches at the bottom allowing it, in all positions, to preserve the plane horizontal. To guide the box of planes in a rectilinear motion, and also to bear them off when the plank has been reduced to the depth required, fences are used, which are irons sliding perpendicularly in tubes or sockets, in the box or frame, and clipping a tongue or ruler, fixed in the direction of the required stroke, in the frame supporting the bench.

PLANISPHERE, (from Latin, *planus*, and Greek, σφαιρα,) a projection of the sphere, and the several circles thereof, on a plane; as upon paper, or the like. In this sense, maps of the heavens and the earth, in which are exhibited the meridians, and other circles of the sphere, are called planispheres. *See* PROJECTION.

In all planispheres, the eye is supposed to be a point viewing all the circles of the sphere, and referring them t

BRAMAH'S PLANING MACHINE.



Cross Section.

Fig. 9

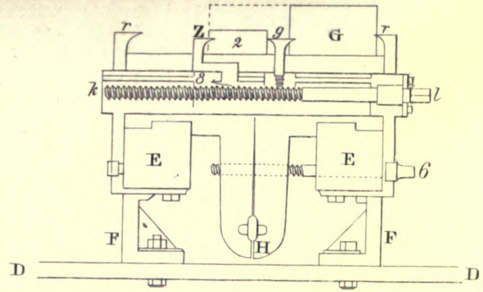
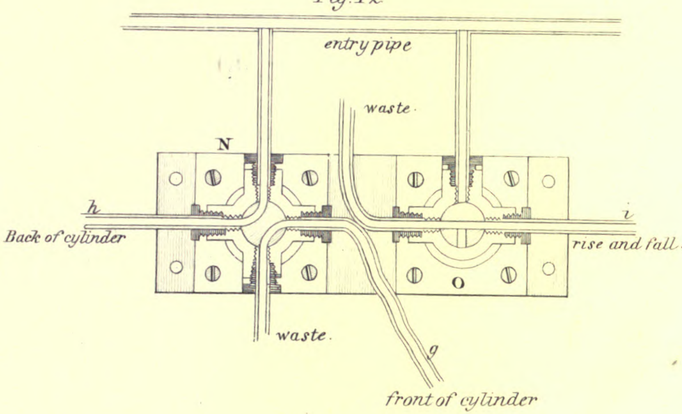
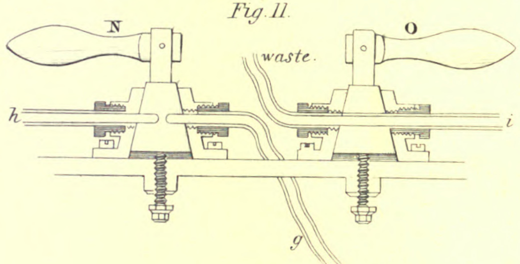


Fig. 12



Cocks

Fig. 11



Cylinder.

Fig. 10

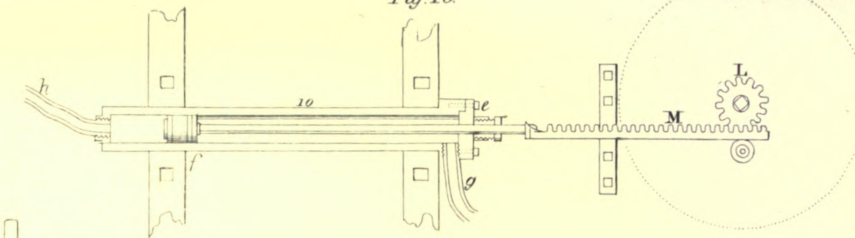
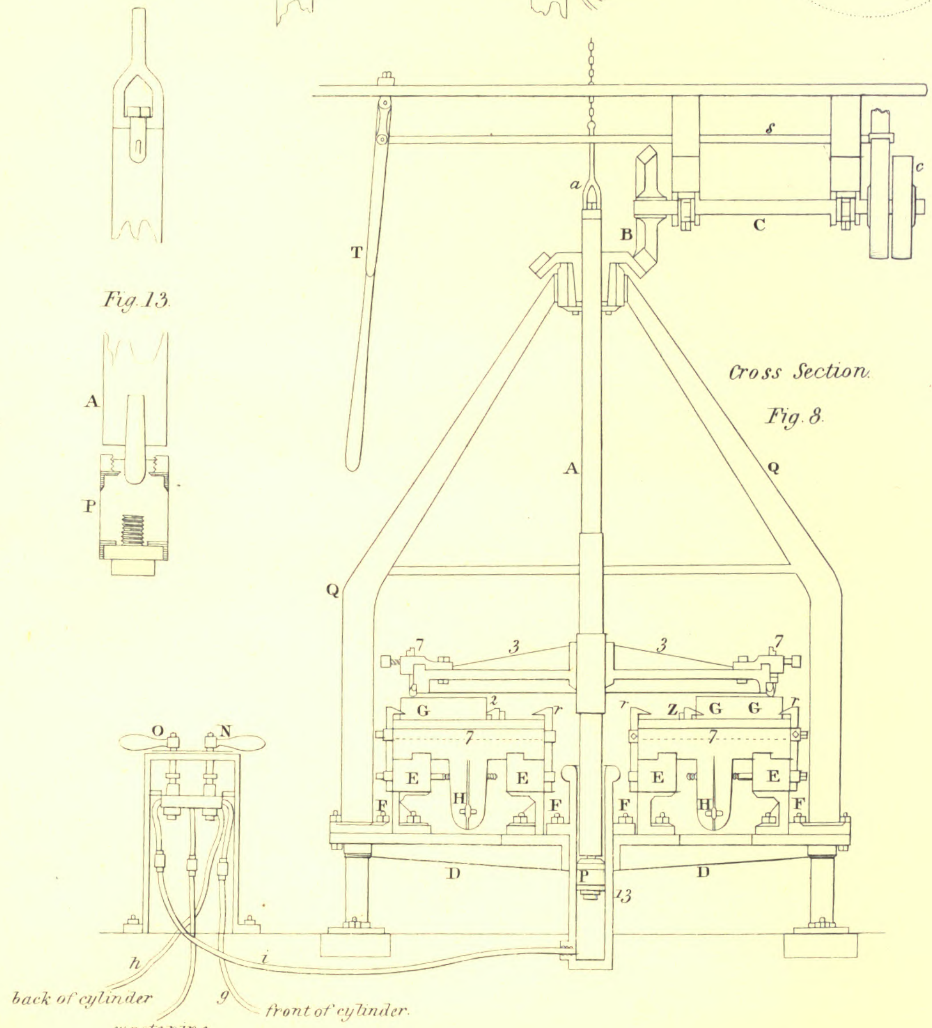


Fig. 13

Cross Section.

Fig. 8.



a plane on which the sphere is, as it were, flattened. This plane is called the *plane of the projection.*

A perspective plane is only a plane of projection placed between the eye and the object, so as to contain all the points which the several rays, drawn from the object to the eye, impress thereon. But in planispheres or astrolabes, the plane of the projection is placed beyond the object, which is the sphere. The plane of the projection is always one of the circles of the sphere.

Among the infinite number of planispheres which the different planes of projection, and the different positions of the eye, would furnish, there are two or three that have been preferred to the rest. Such are that of Ptolemy, where the plane of projection is parallel to the equator; that of Gemma Frisius, where the plane of projection is the colure, or solstitial meridian, and the eye the pole of the meridian; that of John de Royas, a Spaniard, whose plane of projection is a meridian, and the eye placed in the axis of that meridian, at an infinite distance. This last is called the *analemma.* The common defect of all these projections is, that they distort and alter the figure of the constellations, so that it is not easy to compare them with the heavens; and that the degrees in some places are so small, that they afford no room for operation.

All these faults M. de la Hire provided against in a new projection, or planisphere; where it is proposed the eye shall be so placed, as that the divisions of the circles projected shall be sensibly equal in every part of the instrument. The plane of his projection is that of a meridian.

PLANK, (from the French, *planche*) a general name for all timber, excepting fir, which is from one inch and a half to four inches thick: if of less dimensions it is called a *board.*

Plank-Hook, a pole with an iron hook at its end, with which navigators shift their runs, or wheeling-planks, as occasion requires.

Plank-Sheers, or, Plan-Sheers, the pieces of plank wrought horizontally over the heads of the timbers of the forecastle, quarter-deck, and round-house, for the purpose of covering the top of the side; hence, sometimes called *covering-boards.*

PLANTING, in architecture, denotes the laying the first courses of stone on the foundation, according to the measures, with all the exactness possible.

PLASTER, (from πλαζω) in building, a composition of lime, sometimes with hair, sometimes with sand, &c. to parget or cover the nudities of a building.

Plaster of Paris, a fossile stone, serving many purposes in building; and used likewise in sculpture, to mould and make statues, basso-relievos, and other decorations in architecture.

It is dug out of quarries, in several parts of the neighbourhood of Paris; whence its name. The finest is that of Montmartre. *See* Gypsum.

Plaster of Paris, amongst our workmen, is of two kinds, viz., *crude,* or in the stone, and *burnt,* or beaten.

The *crude* is the native plaster, as it comes out of the quarry; in which state it is used as shards in the foundations of buildings.

The *burnt* plaster is a preparation of the former, by calcining it like lime in a kiln or furnace, and then beating it into powder, and diluting and working it. In this state it is used as mortar, or cement, in building.

This, when well sifted, and reduced into an impalpable powder, is used also to make figures, and other works of sculpture; and is, besides, of some use in taking out spots of grease, &c. in stuffs and silks.

The method of representing a face truly in plaster of Paris is this: the person, whose figure is designed to be taken, is laid on his back, with any convenient thing to keep off the hair. Into each nostril is conveyed a conical piece of stiff paper, open at both ends, to allow respiration. These tubes, being anointed with oil, are supportod by the hand of an assistant; then the face is lightly oiled over, and the eyes being kept shut, alabaster fresh calcined, and tempered to a thinnish consistence with water, is, by spoonfuls, nimbly thrown all over the face, till it lies near the thickness of an inch. This matter grows sensibly hot, and, in about a quarter of an hour, hardens into a kind of stony concretion; which, being gently taken off, represents, on its concave surface, the minutest parts of the original face. In this a head of good clay may be moulded, and therein the eyes are to be opened, and other necessary amendments made. This second face being anointed with oil, a second mould of calcined alabaster is made, consisting of two parts joined lengthwise along the ridge of the nose; and herein may be cast, with the same matter, a face extremely like the original.

If finely powdered alabaster, or plaster of Paris, be put into a bason over a fire, it will, when hot, assume the appearance of a fluid, by rolling in waves, yielding to the touch, steaming, &c., all which properties it again loses on the departure of the heat; and being thrown upon paper, will not at all wet it, but immediately discover itself to be as motionless as before it was set over the fire; whereby it appears, that a heap of such little bodies as are neither spherical, nor otherwise regularly shaped, nor small enough to be below the discernment of the eye, may, without fusion, be made fluid, barely by a sufficiently strong and various agitation of the particles which compose it; and, moreover, lose its fluidity immediately upon the cessation thereof.

Two or three spoonfuls of burnt alabaster mixed up thin with water, in a short time coagulate, at the bottom of a vessel full of water, into a hard lump, notwithstanding the water that surrounded it. Artificers observe, that the coagulating property of burnt alabaster will be very much impaired, or lost, if the powder be kept too long, especially if in the open air, before it is made use of; and when it hath been once tempered with water, and suffered to grow hard, they cannot, by any powdering of it again, make it serviceable for their purpose as before.

This matter, when wrought into vessels, &c., is still of so loose and spongy a texture, that the air has easy passage through it. Mr. Boyle gives an account, among his experiments with the air-pump, of his preparing a tube of this plaster, closed at one end and open at the other, and, on applying the open end to the cement, as is usually done with the receivers, it was found utterly impossible to exhaust all the air out of it; for fresh air, from without, pressed in as fast as the other, or internal air, was exhausted, though the sides of the tube were of considerable thickness. A tube of iron was then put on the machine; so that being filled with water, the tube of plaster of Paris was covered with it; and, on using the pump, it was immediately seen, that the water passed through into it as easily as the air had done, when that was the ambient fluid. After this, trying it with Venice turpentine instead of water, the thing succeeded very well; and the tube might be perfectly exhausted, and would remain in that state several hours. After this, on pouring some hot oil upon the turpentine, the case was much altered; for, the turpentine melting, it became a thinner fluid, and, in this state, capable of passing like water into the pores of the plaster. On taking away the tube after this, it was remarked that the turpentine, which had pervaded and filled its pores, rendered it transparent, in the manner that water gives transparency to that singular stone called *oculus mundi.* In this manner the weight of air, under proper management, will be capable of making several sorts of glues penetrate plaster of Paris; and not only this, but baked earth, wood, and all other bodies porous enough to admit water on this occasion.

Plaster of Paris, diluted with water into the consistence of a soft or thin paste, quickly sets or grows firm, and, at the instant of its setting, has its bulk increased; for Mr. Boyle has found, that a glass vessel, filled with the fluid mixture, and closely stopped, bursts while the mixture sets, and sometimes a quantity of water issues through the cracks.

This expansion of the plaster, in passing from a soft to a firm state, is one of its valuable properties, rendering it an excellent matter for filling cavities in sundry works, where other earthy mixtures would shrink and leave vacuities, or entirely separate from the adjoining parts.

It is probable, also, that this expansion of the plaster might be made to contribute to the elegance of the impressions it receives from medals, &c., by properly confining the soft matter, that its expansion may force it into the minutest traces of the figure; the expansion of the matter doing the same office as the pressure by which the wax is forced into the cavities of a seal.

Plaster of Paris promotes the fusion of forged iron.

This substance is commonly used for taking casts and impressions from figures, busts, medals, &c., as it is adapted to the double use of making both casts and moulds for forming them.

There is also a plaster of a coarser sort than the plaster of Paris, which is sometimes used in this country for floors in gentlemen's houses, and for corn-granaries: it is made of a blueish stone, taken out of quarries, which are generally at the side of a hill, much like the stone of which Dutch terras is made; the stone is burnt like lime, becomes white by burning, and, when mixed with water, does not ferment like lime: when cold, it is beat into a fine powder; and, when used, the quantity of about a bushel is put into a tub, and water applied to it till it becomes liquid: in this state it is well stirred with a stick, and used immediately; for, in less than a quarter of an hour, it becomes hard and good for nothing, as it will not bear being mixed a second time, like lime.

Plaster Floors, such floors as are constituted of plaster, prepared from such lime as possesses a strong binding property. They are highly useful in cottages and farm-houses, as affording much security against fire. In constructing them, the joists are laid in the usual manner, and on them is nailed a sort of strong reed, found in Huntingdonshire, upon which the plaster is applied; but in order to save it, there is frequently a thin coat of common lime laid on first, to fill up the crevices and inequalities. On this the plaster is then spread out, to the thickness of about two inches, being laid on with as much expedition as possible. The plaster is sold at the kilns in the midland districts, at 6*d.* the bushel; and the expense of laying it on, if burnt and prepared, is 5*d.* the square yard; but if to be burnt and prepared by the workmen, about as much more. These floors are said to be excellent and cheap. Where reeds cannot be procured, laths may be made use of, but they come much higher. Floors of this sort are much in use in Nottinghamshire, as well as in Rutlandshire, where the upper floors of the farm-houses are made of it.

These kinds of floors should be more attended to in constructing small houses, both of the cottage and other kinds, as being cheap, readily laid, and at the same time secure.

PLASTERER, a workman to whom the decorative part of architecture owes a considerable portion of its effect, and whose art is required in every department of building. In ordinary edifices, he lays the ceilings, and covers the walls with a smooth coat, to render them sightly, and prevent the obtrusion of air through any crevices left by the bricklayer and carpenter, or occasioned by settling. In buildings of greater importance, in addition to this service, he also furnishes mouldings, ornamental as well as plain, and covers the exterior walls with stucco, imitative of stone.

The tools of a plasterer consist of *a spade*, or shovel, of the usual description; *a rake*, with two or three prongs, bent downwards from the line of the handle, for mixing the hair and mortar together; *trowels* of two kinds, and various sizes; *stopping* and *picking-out tools*; rules called *straight-edges*; and wood *models*.

Plasterer's *trowels* are more neatly made than the tools of the same name used by other artificers; they are of two sorts, viz., the *laying and smoothing tool*, which consists of a flat piece of hardened iron, about ten inches in length, and two inches and a half wide, very thin, and ground to a semicircular shape at one end, but left square at the other: on the back of the plate, near the square end, is riveted a small iron rod, with two legs, one of which is fixed to the plate; and, to the other, a round wooden handle is adapted; with this tool, all the first coats of plastering are laid on, as are also the last, or the *setting*, as it is technically denominated. The other kind of trowels, which are made of three or four sizes, are for *gauging* the fine stuff and plaster used in forming cornices, mouldings, &c. The longest size of these is about seven inches in length on the plate, which is of polished steel, and two inches and three-quarters broad at the heel, diverging gradually to a point; to the heel, or broad end, a handle is adapted, commonly of mahagony, with a deep brass ferule. The smaller trowels are fitted up in a similar manner, only they gradually vary in size downwards to the length of two or three inches.

The *stopping and picking-out tools* are of polished steel, of various sizes, though most generally about seven or eight inches in length, and half an inch in breadth, flattened at both ends, and ground away to somewhat of a round. These tools are used in modelling and finishing mitres and returns to cornices, as likewise in filling up and perfecting the ornaments at their joinings.

The *straight-edges* are used for keeping the work in an even or perpendicular line; and the *models* or *moulds* are for running plain mouldings, cornices, &c. Of these last the plasterer requires a great number, as very little of his *finishing* can be completed without them. With a good mould, an adept in his profession may execute most exquisite mouldings, possessing a sharpness and breadth unequalled by any other method now practised.

Good workmen keep their tools very clean; after being used, they are wiped free from the plaster that cleaves to them, before they are put away, and they are daily polished by the hawk-boys.

Plasterers have technical divisions of their work, by which its quality is designated, and from which its value is ascertained; as, *lathing; laying; pricking-up; lathing, laying and set: lathing, floating, and set; screed; set or putty rendering and set*, or *rendering, floated, and set; trowelled stucco*, &c., each of which will be found fully described in the next article. *See* Plastering.

Plasterers' work is measured and valued by persons known in the trade as *measurers*, though popularly denominated *surveyors*. All common plastering is measured by the square yard of nine feet; this includes the partitions, walls, and ceilings of rooms, inside and exterior stuccoing, &c. Cornices are measured by the foot superficial, their numbers being girt to obtain their width; while their length is taken at that of the cornice. Running measures consist of beads, quirks, arrises, and small mouldings. Ornamental cornices are frequently valued by the foot run.

As the labour on plasterer's work is frequently a greater consideration than the materials used, it is necessary for the master to be attentive to the noting down the time occupied by his men in executing their several pieces of plastering; otherwise he will be unable to put an adequate value on his work.

PLASTERING, the art of covering the walls and ceilings of a house, or other edifice, with a composition, of which the ground-work is lime and hair-mortar, finished with a coating of finer materials. It is of various kinds; as white lime and hair mortar on bare walls; the same on laths, as in partitioning and plain ceiling; renewing the insides of walls, or double-partition walls; rough-casting on heart-laths; plastering on brick-work, with finishing-mortar, in imitation of stone-work, and the like upon heart-laths; modelling and casting ornamental and plain mouldings; and making and polishing the scagliola for columns of wood or brick and their antæ.

In all the operations of plastering, lime forms an extensive article, as it pervades the whole; and for its nature, properties, and preparation, the reader is referred to the word Lime; suffice it here to remark, that most of the lime used in London is prepared from chalk, and is brought thither from Purfleet, in Kent; but for stuccoing, and other work requiring strength and permanency, that which is made at Dorking, in Surrey, has a decided pre-eminence.

Next to lime, the plasterer depends much on what is called *plaster of Paris* (see that article); for this alone enables him to give the required form and finish to all the superior parts of his business. With this he makes his ornaments and cornices; and he also mixes it with the lime for filling up the concluding coat to the walls and ceilings of rooms. The name of this composition is derived from the circumstance of its abounding in the hills of Montmartre, in the environs of the French capital; but what is chiefly used in London is prepared from a sulphate of lime dug in Derbyshire.

Cements used by plasterers for inside work are of two or three kinds; the first is called *lime and hair*, or *coarse stuff*, and is prepared as common mortar, only with the addition of hair from the tan-yards being mixed with it. The mortar is first mixed with the requisite quantity of sand, and then the hair is worked in by the labourer with the rake.

Next to this is *fine stuff*, consisting of pure lime slaked with a small quantity of water, and then, without any extraneous addition, supersaturated with water, and put into a tub in a half-fluid state, where it remains till the water is evaporated. In particular cases, a small portion of hair is sometimes worked into this fine stuff, before it is laid on.

For inside walls, this fine stuff is mixed with very fine washed sand, in the proportion of one part sand to three parts of *fine stuff*, and then it obtains the name of *troweled*, or *bastard stucco*, with which all walls intended to be painted are finished. *Gauge-stuff* consists of three-fifths of fine-stuff and one-fifth of plaster of Paris, mixed together with water, in small quantities at a time, to render it more ready to set, or fix itself. This cement is mostly used in forming cornices and mouldings run with a wooden model. When great expedition is requisite, plasterers gauge all their mortars with plaster of Paris, which enables them to proceed with their work, because it sets as soon as laid on.

Next to the materials, the technical divisions of the plasterers' work claim attention, and are as follow:—

1. *Lathing:* this operation consists in nailing laths on the ceiling or partition. If the laths be of oak, they will require wrought-iron nails; but if of deal, cast-iron nails may be used. Those mostly used in London are of fir, imported from the Baltic and America, in pieces called *staves*. Laths are made in three-foot and four-foot lengths; and, with respect to their thickness and strength, are either single, lath-and-half, or double. The single are the thinnest and cheapest; those called *lath-and-half* are supposed to be one-third thicker than the single; and the double laths are twice their thickness. In lathing ceilings, the plasterer should use both the lengths alluded to; and, in nailing them up, he should so dispose them that the joints may be as much broken as possible, that they may have the stronger key, or tie, and thereby strengthen the plastering with which they are to be covered. The thinnest laths are used in partitions, and the strongest for ceilings. *See* Lath.

Having nailed the laths in their appropriate order, the next business is to cover them with the plaster, in doing which, the most simple and common operation is that of,

2. *Laying:* this consists in spreading a single coat of lime and hair all over a ceiling, or partition; carefully observing to keep it even and smooth in every direction. This is the cheapest kind of plastering.

3. *Pricking-up* is performed in the same manner as the foregoing, but it is only a preliminary to a more perfect kind of work. After the plaster is laid on, it is crossed all over with the end of a lath, to give it a key, or tie, for the coat that is to be laid upon it.

4. *Lathing, laying, and set*, is when the work, after being lathed, is covered with one coat of lime and hair, and, when that is sufficiently dry, a thin and smooth coat is spread over it, consisting of lime only, or, as the workmen call it, *putty* or *set*. This coat is spread with the smoothing-trowel, which the workman uses with his right hand, while in his left hand he is furnished with a large flat brush of hog's bristles. As he lays on the putty, or set, with the trowel, he draws the brush, dipped in water, backwards and forwards over it, and thus produces a surface tolerably even for cheap work.

5. *Lathing, floating, and set*, differs from the foregoing, in having the first coat pricked up to receive the set, which is here called the *floating*. In performing this last operation, the plasterer is provided with a substantial straight-edge, frequently from ten to twelve feet in length, which must be handled by two workmen. All the parts to be floated are then tried by a plumb-line, to ascertain whether they are perfectly flat and level; and wherever any deficiency appears, the hollow is filled up with a trowel-full, or more, of lime and hair only; this is termed *filling-out;* and when these preliminaries are settled, the *screeds* are begun to be formed.

6. A *screed* signifies a style of lime and hair, about seven or eight inches in width, gauged quite true by drawing the straight-edge over it till it is so. These screeds are made at the distance of about three or four feet from each other, in a vertical direction all round the partitions and walls of a room. When they are all formed, the intervals are filled up with lime and hair, called by the workman *stuff*, till they are flush with the face of the screeds. The straight-edge is then worked horizontally over the screeds, by which all the superfluous stuff, projecting beyond them in the intervals, is removed, and a plain surface is produced. This operation is termed *floating*, and may be applied to ceilings as well as partitions or upright walls, by first forming the screeds, in the direction of the breadth of the apartment, and filling up the intervals as above described. As great care is requisite

in this kind of work, to render the plaster sound and even, none but skilful workmen should be employed upon it.

7. The *set* to floated work is performed in a mode similar to that already prescribed for *laying;* only, as it is employed for best rooms, it is done with more care. There is also added to it about one-sixth of plaster of Paris, to make it set more expeditiously, and give it a closer and more compact appearance, as well as to render it more firm, and better calculated to receive the white-wash, or colour, when dry. For floated stucco work, the pricking-up coat cannot be too dry; but, if the floating that is to receive the setting coat be too dry before the set is laid on, there will be danger of its peeling off, or of its assuming the appearance of little cracks, or shells, which would disfigure the work. Particular attention is therefore to be paid to have the under-coats in a due state of dryness when the exterior surface is laid on. And here it may also be remarked, that cracks and other unpleasant appearances in ceilings are more frequently the effect of weakness in the laths, covered with too much plaster; or, on the contrary, of too little plaster upon strong laths, than of any sagging, or other inadequacy in the timbers of the building. If the laths be properly attended to, and the plastering laid on by a judicious careful workman, no cracks are likely to appear.

8. *Rendering, and set*, or *rendering floated, and set*, combines both the foregoing processes, only it requires no lathing. *Rendering* is to be understood of a wall, whether of brick or stone, being covered with a coat of lime and hair; and by *set* is denoted a superficial coat, upon the rendering of fine stuff or putty. These operations are similar to those described for setting of ceilings and partitions; and the *floated and set* is laid on the rendering in the same manner as on partitions, &c., as above explained for the best kind of work.

9. *Troweled stucco*, which is a very neat kind of work, used in dining-rooms, halls, &c., when the walls are proposed to be painted, must be worked upon a floated ground, and the floating should be as dry as possible before the stucco is applied. In this process, the plasterer is provided with a wooden tool, called *a float*, consisting of a piece of half-inch deal, about nine inches long and three wide, planed smooth, with its lower edges a little rounded off, and having a handle on the upper surface. The stucco is prepared as described above, and afterwards well beaten and tempered, with clean water, for use. The ground intended to be stuccoed is first prepared with the large trowel, and made as smooth and level as possible; and when the stucco has been spread upon it, to the extent of four or five feet square, the workman, with the float in his right hand, and a brush in his left, begins to rub it smooth with the former, having first sprinkled it with water from the latter: this he does in small portions at a time, and proceeds, alternately sprinkling and rubbing the face of the stucco, till the whole is reduced to a fine even surface. He then prepares another square of the ground, and proceeds as before, till the whole is completed. The water has the effect of hardening the face of the stucco, and, when the floating is well performed, it will feel as smooth as glass.

Rough-casting, or *rough-walling*, is an exterior finishing, much cheaper than stucco, and therefore more frequently employed on cottages, farm-houses, &c., than on buildings of a higher class. The wall intended to be rough-cast is first pricked-up with a coat of lime and hair; and when this is tolerably dry, a second coat is laid on, of the same materials as the first, but as smooth as it can possibly be spread. As fast as the workman finishes this surface, he is followed by another, with a pail-full of rough-cast, with which he bespatters the new plastering, and the whole dries together. The rough-cast is composed of fine gravel, clean washed from all earthy particles, and mixed with pure lime and water, till the whole is of a semi-fluid consistency. This is thrown from the pail, upon the wall, with a wooden float, about five or six inches long, and as many wide, made of half-inch deal, and fitted with a round deal handle. While, with this tool, the plasterer throws on the rough-cast with his right hand, he holds in his left a common whitewasher's brush, dipped in the rough-cast also, with which he brushes and colours the mortar, and the rough-cast he has already spread, to give them, when finished, a regular uniform colour and appearance.

Cornices.—These are either plain or ornamented; and sometimes they embrace a portion of both classes. The first thing here to be attended to, is to examine the drawings, and measure the projections of the members: if they project more than seven or eight inches, bracketing must be resorted to. This consists in fixing up pieces of wood, at the distance of about eleven or twelve inches from each other, all round the place proposed for the cornice, nailing laths to them, and covering the whole with a coat of plaster, allowing in the brackets for the stuff necessary to form the cornice: in general, about one inch and a quarter is sufficient. A beech mould is next to be made of the profile of the intended cornice, by the carpenter, of about a quarter of an inch in thickness, with the quirks, or small sinkings, of brass. All the sharp edges are to be carefully removed by the plasterer, who must also open, with his knife, all the points that he finds incompetent to receive the plaster freely. These preliminaries being adjusted, two workmen, provided with a tub of putty, and a quantity of plaster of Paris, proceed to run the cornice. Before they begin, however, to use the mould, they gauge a screed upon the wall and ceiling, of putty and plaster, covering so much of each as will correspond with the top and bottom of the intended cornice. On this screed, one or two slight deal straight-edges are nailed, adapted to as many notches, or chases, made in the mould, for it to work upon. The putty is then to be mixed with about one-third of plaster of Paris, and brought to a semi-fluid state by the addition of clean water. One of the workmen, with two or three trowelfuls of this composition upon his *hawk*, which he holds in his left hand, begins to plaster over the surface intended for the cornice, with his trowel, while his partner applies the mould, to ascertain the parts where more or less may be wanted. When a sufficient quantity of plaster has been laid on, the workman with the mould, holding it steadily and firmly against both the ceiling and the wall, moves it backwards and forwards, which removes the superfluous stuff, and leaves an exact impression of the mould upon the plaster. This is not indeed effected at once, but while he works the mould to and fro, the other workman takes notice of any deficiencies, and fills them up, by adding fresh supplies of plaster. In this manner, a cornice of from ten to twelve feet in length, may be formed in a very short time; indeed, expedition is essentially requisite, as the plaster of Paris occasions a very great tendency in the putty to set; and to prevent this taking place too rapidly, it is necessary to sprinkle the composition frequently with water from a brush; as they generally endeavour to finish all the lengths, or pieces, between any two breaks, or projections, at one time, to secure the truth and correctness of the cornice. In cornices of very large proportions, and in cases where the orders of architecture are to be applied, three or four moulds are requisite, which are applied in the same manner, till all the parts are formed. Internal and external mitres, and small returns, or breaks, are afterwards modelled and filled up by hand; an operation upon which a dexterous plasterer much piques himself.

When cornices are to be charged with ornaments, the plasterer leaves certain indentions, or sinkings, in the mould, in which the casts are laid. These ornaments were formerly made by hand, by artists called *ornament-plasterers;* but now they are cast in plaster of Paris, which has almost superseded that branch of art; at least, the few professors of it who remain, are limited in their labours to the modelling and forming of moulds to cast from. Ornaments, to be cast in plaster of Paris, are previously modelled in clay from the design. When the clay model is finished, and has acquired some degree of firmness from the action of the atmosphere, a wooden frame is adapted to it, and after it has been retouched, and finished, the frame is filled up with melted wax, which, when cool, on the mould being turned upside-down, drops off, and presents an exact cameo, or counterpart, of the model, in which the most enriched and curiously-wrought mouldings may be cast by the common plasterer. These wax models are contrived to cast about a foot in length of the ornament at once; such lengths being most easily got out from the cameo. The casts are made of the finest and purest plaster of Paris, saturated with water; the wax mould being oiled previously to its being poured in. When first taken from the mould, the casts, or intaglios, are not very firm; but after they have been suffered to dry a little, either in the open air or in an oven, they become hard, and are scraped and cleaned up for the workmen.

Friezes and basso-relievos are executed in a similar manner, only the wax mould is so contrived that the cast may have a back ground of plaster, at least half an inch thick: this is cast to the ornament, or figure, so that it strengthens and secures their proportions, at the same time that it promotes their general effect.

Nor is the process different for capitals to columns, except that they require a number of moulds to complete them. To make a good mould, however, requires the utmost skill of the modeller. The Corinthian capital requires a shaft, or bell, to be first made, on which are afterwards to be fixed the foliage and volutes; all which, as well as the other details, require distinct cameos.

In forming cornices that are to be charged with ornaments, the plasterer takes care to have proper projections in the running mould, so as to leave a groove or indention in the cornice, into which the cast ornament is laid, and secured in its place, by spreading a small quantity of liquid plaster of Paris on its back. Friezes, likewise, are prepared for in the cornice in a similar manner, by leaving a projection in the running mould, at the part where they are intended to be inserted, and they are fixed in their places by liquid plaster. Detached ornaments, designed for a ceiling, or other part, where no running mould has been employed, are cast in pieces, corresponding with the design, and fixed upon the ceiling, &c. with white-lead, or the composition known under the name of *iron cement.*

Good plastering is known by its exquisite appearance, both as to regularity and correctness, and its solid effect having no cracks, nor indications of them, visible.

The making and working of stucco has, for a considerable time past, occupied the attention of chemists, physicians, architects, and plasterers; but the only beneficial result has been a more extensive knowledge of the materials used in it: indeed, our climate, from its great moisture, prevents its being brought to superlative perfection, though, among the various compositions that have been proposed and tried, some are comparatively excellent. The common stucco now in use for external work, is known, among plasterers, by the name of *Bailey's compo;* it consists of Thames sand cleanly washed, and ground Dorking lime, mixed dry, in the proportion of three of the latter to one of the former, which when well incorporated together, should be secured from the air in good tight casks, till the moment it is wanted for use. Walls intended to be covered with this composition, must be first prepared, by raking the mortar from the joints, and picking the bricks, or stones, till the whole wall is properly indented. The part must then be clean brushed of all dust and other extraneous matter, and well soaked with clean water. The stucco is then to be supersaturated with water, till it bears the appearance and consistence of ordinary whitewash: in which state it is to be rubbed over the wall with a flat brush of hogs' bristles, and then left to become tolerably dry and hard, which is ascertained by its becoming more white and transparent than when at first laid on. This process is called *roughing in.* Screeds are next to be formed upon the wall, with fresh stucco from the cask, tempered with water to a proper consistency, and spread on the upper part of the wall about eight or nine inches wide, and against the two ends, beginning at the top, and proceeding downwards to the bottom. In this operation, two workmen are required; one to supply the stucco, the other to use and try the plumb-rule and straight-edge. When these are truly formed, other screeds must be made, vertically, about four or five feet apart, unless apertures in the wall should prevent it, in which case they must be formed as near together as possible. When the screeding is all done, more *compo* must be prepared, and in larger quantities than was done for the former process; and, when ready, both the workmen begin to spread it with their trowels over the wall in the space left between each pair of screeds that are nearest together. When this is done the straight-edge is to be applied across both, and dragged from the top to the bottom, so as to remove whatever superfluous stucco may project above the screeds. Should any hollow places appear, fresh stucco must be applied, and the straight-edge again drawn over the spot, till the *compo* is brought even to the face of the screeds, and the whole is level with the edge of the rule. The workmen then fill up another interval; and thus they proceed, till the whole of the wall is covered. The wall is then to be finished, by floating, or hardening the surface, by rubbing it with the common wood float, and sprinkling it with water, an operation that is performed, as above directed, for troweled stucco; always remembering to begin the floating on the part first filled up.

This kind of compo, or stucco, is frequently used by plasterers for cornices and mouldings, in the same manner that has already been described in common plastering. But here, the workman finds requisite to add a small portion of plaster of Paris, to make it fix better while running or working the mould. Such addition, however, is not calculated to give strength to the stucco; and is only made through the necessity of having a quick set.

Some years ago, the patent stucco of Dr. B. Higgins, was in great repute, and employed by the founders of the Adelphi, in the Strand, with considerable success. It consisted of 14lb. or 15lb. of good stone lime, 14lb. of bone-ashes, finely powdered, and 98lb. of clean sand, coarse or fine, according to the intended nature of the building: these were mixed up into mortar as quickly as possible with lime-water, and used as soon as made.

The various suggestions and modes of forming the same materials into stucco, amount to about forty in number, only varying the proportions; but few of them have been found to remain tolerably entire in this climate for thirty years together. In 1796, Mr. Parker obtained a patent for a cement that is impervious to water, and may be successfully employed in ice-houses, cisterns, tanks, &c. (*See* CEMENT, and MORTAR.) In his specification, Mr. Parker observes, "nodules of clay, or argillaceous stone, generally contain water in their centre, surrounded by calcareous crystals, and having veins of calcareous matter. They are formed in clay, and are of a brown colour, like the clay." These nodules, he directs, should be burned, after being broke into small pieces, in a kiln, with a heat nearly sufficient to vitrify them; after which they are to be reduced to powder. Two measures of water added to five of this powder, produces *tarras;* lime and other matters may be added or withheld at pleasure: and the proportion of water may be varied. The term of the patent being now expired, there are many other manufactures of this cement, which are found to be of equal goodness as to quality, and some of them of rather a better colour than the original; a recommendation, or rather improvement, of considerable importance, since the fresco-painting, or whitewash, laid upon Mr. Parker's composition, when applied to the fronts of houses, is soon taken off by the rains, and leaves the walls of a dingy and unpleasant appearance.

An allusion has been made above, to the fresco-painting, or staining, laid upon walls plastered with this cement; this is done to give them an appearance of stone-buildings, and is performed by diluting sulphuric acid (oil of vitriol) with water, and adding the fluid ochres, &c., to give the required tint. When the stucco is washed over with this kind of paint, the affinity existing in the iron of the cement ceases, the acid and colour suspended in and upon the stucco is fixed, and the surface assumes, when dexterously managed, the appearance of an ashlar bond of masonry.

Columns, &c. done in Scagliola, is a distinct branch of plastering, discovered or invented in Italy, where it has been much used, and thence introduced into France, where, having fascinated all the cognoscenti, it obtained the title of *scagliola.* The late Henry Holland, who first brought it to England, engaged the artists from Paris to execute it; some of whom, finding a demand here for their labour, remained in the country, and instructed our own workmen in the art. Columns and pilasters are executed in this branch of plastering, in the following manner. A wooden cradle, composed of thin strips of deal, or other wood, is made to represent the column designed, but about $2\frac{1}{2}$ inches less in diameter than the shaft is intended to be when finished. This cradle is lathed round, as for common plastering, and then covered with a pricking-up coat of lime and hair: when this is quite dry, the artists in scagliola commence their operations, and, by an imitation of the most rare and precious marbles, produce a most astonishing and delusive effect; for, nothing short of actual fracture can discover the counterfeit: and any stone, partaking of the quality of marble, may be exactly imitated by it; the imitation taking as high a polish, and feeling to the touch as cold and solid, as the most compact and solid marble. The workmen select the purest gypsum they can obtain, which, after breaking it into small pieces, they calcine. As soon as the largest fragments lose their brilliancy, the fire is withdrawn; the calcined powder is passed through a very fine sieve, and mixed up as it is to be used with a solution of Flanders glue, isinglass, &c. In this solution the colours required in the marble to be imitated are also diffused: but when the work is to be of various colours, each colour is separately prepared, and they are afterwards mingled and combined, nearly in the same manner that a painter mixes the primitive colours on his palette, to compose his different tints. When the powdered gypsum is prepared and mingled for the work, it is laid on the shaft of the column, &c. over the pricked-up coat of lime and hair, and then it is floated with moulds of wood, made to the requisite size, the artist using the colours necessary for the imitation during the floating, by which means they become mingled and incorporated with the surface. To give the work the requisite polish, or glossy lustre, so much admired in works of marble, the workman rubs it with a pumice-stone with one hand, while with the other he cleans it with a wet sponge. He then polishes it with tripoli and charcoal and fine soft linen; and after going over it with a piece of felt dipped in a mixture of oil and tripoli, he finishes the process by the application of pure oil.

This imitation is the most complete that could be conceived; and, when the bases and capitals are made of real marble, as is the common practice, the deception is beyond discovery. When not exposed to the weather, it is also little inferior to real marble in point of durability, retains its lustre full as long, and is not one-eighth of the expense of the cheapest imported.

There is another species of plastering, though done by a distinct set of persons, known to the public by the name of *composition ornament,* used not only for the decorative parts of architecture, but also for the frames of pictures, looking-glasses, &c. This composition, which is very strong when quite dry, and of a brownish colour, consists of the proportion of two pounds of powdered whiting, one pound of glue in solution, and half a pound of linseed-oil, mixed together in a copper, heated, and stirred with a spatula till the whole is incorporated. After being suffered to stand to settle and cool, it is laid upon a stone, covered with powdered whiting, and beaten till it assumes a tough and firm consistence; after which it is put by for use, and covered with wet cloths to keep it fresh. The ornaments to be cast in this composition are modelled in clay, as for common plastering, and afterwards a cameo, or mould, is carved in a block of box-wood. This carving requires to be done with the utmost neatness and truth, otherwise the symmetry of the ornament to be cast from it will be spoiled. When the composition is to be used, it is cut with a knife into pieces adapted to the size of the mould, and forced with the hand closely into every part. It is then placed in a press worked by an iron screw, by which it is farther compressed into every crevice: after being removed from the press, the mould is turned upside-down, with a smart tap on a board, which dislodges the composition, and the mould leaves it with its face upwards. One foot in length is as much as is usually cast at one time, and when the ornament first drops from the mould, all the superfluous composition is pared away with a knife, and thrown into the copper towards a fresh supply for the next cast. The ornaments, when formed, are glued upon wooden, or other grounds, or they are affixed by means of white-lead, &c., after which they are painted or gilt, according to the purpose for which they are intended. This composition is at least 80 per cent. cheaper than carving, and in most cases is equally well calculated to answer all the purposes of that art.

It were much to be wished, that the art of plastering could be again brought to its ancient perfection. In our best buildings, the plastered walls and ceilings crack and fly, and, in a little time, grow damp, or moulder to decay.

The Romans had an art of rendering their work of this kind much more firm and durable; and there is no reason to despair of reviving this art by proper trials.

The ancient plastering of these people, preserved to this time, where it has not met with violent blows, or injuries from accidents, is still found as firm and solid, as free from cracks or crevices, and as smooth and polished on the surface, as if made of marble. The bottoms and sides of the

Roman aqueducts were lined with this plastering, and endured many ages without hurt, unless by accidents: witness that whereof some yards are still to be found on the top of the Pont de Gard, near Nismes, for the support of which that celebrated bridge was built to carry water to the said town. The roofs of houses, and the floors of rooms, at Venice, are covered with a sort of plaster, of later date, and yet strong enough to endure the sun and weather for several ages, without cracking or spoiling, and without much injury from being trod upon.

The secret of preparing this Venetian plaster is not among us; but it would be worth while to try whether such a substance might not be made by boiling the powder of gypsum dry over the fire (for it will boil in the manner of water); and when this boiling or recalcining is over, mixing with it resin, or pitch, or both together, with common sulphur, and the powder of sea-shells. If these were all mixed together, the water added to it hot, and the matter all kept upon the fire till the instant of its being used, so that it might be laid on hot, it is possible this secret might be hit upon.

Wax and oil of turpentine may be also tried as additions; these being the common ingredients in such cements that we have accounts of as the firmest. Strong ale-wort is, by some, directed to be used instead of water, to make mortar of limestone of a more than ordinary strength. It is possible that the addition of this tenacious liquor to the powdered ingredients of this proposed plaster, might greatly add to their solidity and firmness. *See* Cement, Mortar, and Stucco.

PLATBAND, any flat square moulding, whose height much exceeds its projecture. Such are the faces, or fasciæ, of an architrave, and the platbands of the modillions of a cornice.

The platband is signified, in Vitruvius and others, by the words *fascia*, *tænia*, and *corsa*.

Platband of a Door or Window, is used for the lintel, where that is made square, or not much arched. These platbands are usually crossed with bars of iron, when they have a great bearing; but it is much better to ease them by arches of discharge built over them.

Platbands of Flutings, are the lists, or fillets, between the flutings of columns.

PLATE, a term applied generally to those horizontal timbers bedded in brick, or other walls, for the purpose of sustaining other timbers, &c.: thus we have *wall-plate*, *gutter-plate*, &c.

PLATE-GLASS, *see* Glass.

PLATES, *Ground*, *see* Ground-sill.

PLATFOND, the same as soffit. *See* Soffit.

PLATFORM, a row of beams, which support the timber-work of a roof, and lie at the top of the wall where the entablature ought to be raised.

Platform is also used for a kind of terrace, or broad, smooth, open walk, at the top of a building, whence a fair prospect of the adjacent country may be taken. Hence an edifice is said to be covered with a platform, when it is flat at top, and has no ridge. Most of the Oriental buildings are thus covered, as were all those of the ancients. Cæsar was the first among the Romans who procured leave to build his house with a ridge or pinnacle.

PLINTH (from πλινθος, *a brick*), a flat square member, in form of a brick: sometimes, also, called *the slipper*.

It is used as the foot, or foundation of columns; being that flat square table, under the mouldings of the base and pedestal, at the bottom of the whole order; seeming, if we follow the notion of Vitruvius, to have been originally intended to keep the bottom of the primitive wooden pillars from rotting.

The plinth is also called the *orle* or *orlo*. And Vitruvius calls the Tuscan abacus, *plinth*, from its resembling a square brick.

Plinth of a Statue, &c., a base or stand, flat, round, or square, serving to support a statue, &c.

Plinth of a Wall, a term for two or three rows of bricks advancing out from the wall; or, in general, for any flat high moulding, serving in a front wall to mark the floors, or to sustain the eaves of a wall, and the larmier of a chimney.

PLOTTING, among surveyors, the art of describing, or laying down on paper, &c., the several angles and lines of a tract of ground surveyed by a theodolite, or like instrument, and a chain.

In surveying with the plain-table, the plotting is needless; the several angles and distances being laid down on the spot, as fast as they are taken. But in working with the theodolite, semicircle, or circumferentor, the angles are taken in degrees, and the distances in chains and links; so that there remains a subsequent operation, to reduce those numbers into lines, and thence to form a draught, plan, or map. This operation is called *plotting*.

Plotting is performed by means of two instruments, the protractor and plotting-scale. By the first, the several angles observed in the field with a theodolite, or the like, and entered down in degrees in the field-book, are protracted on paper in their just quantity. By the latter, the several distances measured with the chain, and entered down, in like manner, in the field-book, are laid down in their just proportion.

Plotting-scale, a mathematical instrument, used in plotting grounds, usually of box-wood, sometimes of brass, ivory, or silver, either a foot or half a foot long, and about an inch and a half broad.

On one side of the instrument are seven several scales or lines, divided into equal parts. The first division of the first scale is subdivided into ten equal parts, to which is prefixed the number 10, signifying that ten of those subdivisions make an inch; or that the division of that scale are decimals of inches.

The first division of the second scale is likewise subdivided into 10, to which is prefixed the number 16, denoting that sixteen of those subdivisions make an inch. The first division of the third scale is subdivided, in like manner, into 10, to which is prefixed the number 20. To that of the fourth scale is prefixed the number 24; to that of the fifth, 30; that of the sixth, 40; and that of the seventh, 48; denoting the number of subdivisions equal to an inch, in each respectively. The two last scales are broken off before the end, to give room for two lines of chords, marked by the letters c c.

On the other side of the instrument is a diagonal scale, the first of whose divisions, which is an inch long, if the scale be a foot, and half an inch, if half a foot, is subdivided diagonally into 100 equal parts; and at the other end of the scale is another diagonal subdivision, of half the length of the former, into the same number of parts, viz., 100.

Next the scales is a line divided into hundredth-parts of a foot, numbered 10, 20, 30, &c., and a line of inches subdivided into tenths, marked 1, 2, 3, &c.

PLUG AND FEATHER, or Key and Feather, a method of dividing hard stones, described at length in the article Eddystone Lighthouse.

PLUGS, pieces of timber driven perpendicularly into a wall, with the projecting part sawn away, so as to be flush with the face.

PLUMBER, (from the French *plombier*, derived from the

Latin *plumbum*, lead), an artist who works in lead, and to whom is confided the pump-work, as well as the making and forming of cisterns and reservoirs, large or small, water-closets, &c., for the purposes of domestic economy. The plumber does not use a great variety of working tools, because the ductility of the metal upon which he operates does not require them. They consist of an iron *hammer*, rather heavier than a carpenter's, and with a short thick handle; two or three wooden *mallets*, of different sizes; and a *dressing and flatting tool.* This last is of beech, about 18 inches long and $2\frac{1}{2}$ inches square, planed smooth and flat on the under surface, rounded on the upper, and one of its ends tapered off round, as a handle. With this tool the plumber stretches out and flattens the sheet-lead, or dresses it to the shape required, using first the flat side, and then the round one, as occasion may suit. The plumber has also occasion for a *jack* and a *trying* plane, similar to those of the carpenter (see PLANE), with which he reduces the edges of sheet-lead to a straight line, when the purposes to which it is to be applied require it. He should also be provided with a *chalk-line*, wound upon a roller, for marking out the lead into such breadths as he may want. His cutting-tools consist of a variety of *chisels* and *gouges*, as well as *knives;* the latter of which are used for cutting the sheet-lead into slips and pieces, after it has been marked out by the chalk-line. *Files* of different sizes are requisite for the plumber, in various operations. In soldering, *ladles* of three or four sizes, for melting the solder; and iron instruments, called *grozing-irons*, are used by the plumber. These grozing-irons are of several sizes, and commonly about 12 inches in length, tapering at both ends, the handle-end being turned quite round, to allow of its being firmly held while in use. The other end is a bulb, of a spindle-shape, or sometimes spherical, of a size proportioned to the soldering intended to be executed. They are heated to redness, when wanted for use.

A plumber's *measuring rule* is two feet in length, divided into three equal parts of eight inches each. Two of its legs are of box-wood, and duodecimally divided; the third leg consists of a piece of slow-tempered steel, attached to one of the box-legs, by a pivot, on which it turns, and falls, when not in use, into a groove cut in such leg for its reception. This steel leg will pass into places that the others could not enter, and is also useful for occasionally removing the oxide, or any other extraneous matter, from the surface of his heated metal.

Scales and weights are also necessary to the master plumber, as he cannot charge for anything till it has been weighed. He must also be supplied with *centre-bits* of all sizes, and a *stock*, to work them in, for the purpose of making perforations in lead or wood, through which he may want to insert pipes, &c. He also has occasional recourse to compasses, to strike circular pieces of lead, to line or cover figures of that shape. Plumbers charge their sheet-lead by the hundred-weight.

PLUMBERY, or PLUMBING, (from the Latin *plumbum*, lead), the art of casting and working in lead, and using it in building. As this metal is very easily fusible, it is cast into figures of any kind, with great facility, by running it in proper moulds of clay, plaster, &c., but the chief articles in plumbery are sheets and pipes of lead; which form the basis of the plumber's work.

Lead is obtained from the mines, and, from its being generally combined with sulphur, it has been denominated a *sulphuret.* After the ore has been taken from its bed, it is smelted, first being picked, in order to separate the unctuous and rich, or genuine ore, from the stony matrix and other impurities; the picked ore is then pounded under stampers, actuated by machinery, and afterwards washed to carry off the remainder of the matrix, that could not be separated in picking. It is next put into a reverberatory furnace to be *roasted*, as the workmen call it, during which operation it is repeatedly stirred to facilitate the evaporation of the sulphur. When the surface begins to assume the appearance of a paste, it is covered with charcoal, and well shaken together: the fire is then increased, and the purified lead flows down on all sides into the basin of the furnace, whence it runs off into moulds prepared for its reception. The moulds are capable of receiving 154lb. of lead each; and their contents, when cool, are called *pigs* in the commercial world.

The natural colour of lead is a bluish white; when newly melted, or cut, it is very bright; but is soon tarnished on exposure to the atmosphere; assuming first a dirty gray colour, which afterwards becomes white. It is capable of being hammered into very thin plates, and may be drawn into wire; but its tenacity is very inferior to that of other metals; for a leaden wire the hundred-and-twentieth part of an inch in diameter is only capable of supporting 18.4lb. without breaking. Lead melts at the temperature of 612° of Fahrenheit's thermometer; and, if a stronger heat be applied, it boils and evaporates. If cooled slowly, it crystallizes. The change of its external colour is owing to its gradual combination with oxygen, which converts its exterior surface into an oxide: this outward crust, however, preserves the rest of the metal for a long time, as the air can penetrate it but very slowly. Lead is not acted upon immediately by water, though that element greatly facilitates the action of the air upon it; for it is known, that when lead is exposed to the atmosphere, and kept constantly wet, the process of oxidation takes place much more rapidly than it does under other circumstances: hence the white crust, that is to be observed upon the sides of leaden vessels containing water, just at the place where the surface of the water terminates. For other particulars relative to this metal, *see* LEAD.

Plumbers purchase lead in *pigs*, and reduce it themselves into sheets, or pipes, as they have occasion. Of sheet-lead, they have two kinds, cast and milled; the former is used for covering flat roofs of buildings, laying of terraces, forming gutters, lining reservoirs, &c.; the latter, which is very thin, for covering the hips and ridges of roofs: this last they do not manufacture themselves, but purchase it ready prepared of the lead merchants, as it comes from the ore and roasting furnaces.

In casting sheet lead, a copper is provided, well fixed in masonry at the upper end of the workshop, near the mould, or casting-table, which consists of strong deal boards, well jointed together, and bound with bars of iron at the ends. The sides of this table, of which the shape is a parallelogram, varying in size from 4 to 6 feet in width, and from 16 to 18 feet and upwards in length, are guarded by a frame or edging of wood, 3 inches thick, and 4 or 5 inches higher than the interior surface, called the *shafts*; the table is fixed upon firm legs, strongly framed together, about 6 or 7 inches lower than the top of the copper; at the upper end of the mould, nearest the copper, a box, called *the pan*, is adapted in its length to the breadth of the table, having at its bottom a long horizontal slit, from which the heated metal is to issue, after it has been poured in from the copper. This box moves upon rollers along the surface of the rim of the table, and is put in motion by means of ropes and pulleys fixed to beams above. While the metal is melting, the surface of the mould, or table, is prepared by covering it with a stratum of dry and clean sand, regularly smoothed over with a kind of rake, called *a strike*, which consists of a board, about 5 inches broad, and rather longer than the inside of the mould, so that its ends, which are notched about two inches deep, may ride upon the shafts; this, being passed down the whole length of the table, reduces the sand to a uniform surface. When this is done, the pan is brought to the head of the table, close to the copper, its side having been previously guarded by a coat of moistened sand, to prevent its firing from the heat of the metal, which is now emptied in with ladles from the copper. These pans, or boxes, it must be observed, are made, as to their contents, equal to the quantity of melted lead requiredto cast a whole sheet at one time; and the slit in the bottom is so adjusted as to let out, during its progress along the table, just as much as will completely cover it, of the thickness and weight per foot required. Everything being thus prepared, the slit is opened, and the box is moved along the table, dispersing its contents from the top to the bottom, and leaving in its progress a sheet of lead of the desired thickness. When cool, the sheet is rolled up and removed from the table, and other sheets are cast, till all the metal in the copper is exhausted. The sheets so formed are rolled up, and weighed, it being by weight that the public is charged for sheet lead.

In some places, instead of having a square box, upon wheels, with a slit in the bottom, the pan consists of a kind of trough, being composed of two planks nailed together at right angles in their length, with two triangular pieces fitted in between them at their ends. The length of this pan, as well as that of the box, is equal to the whole breadth of the mould: it stands with its bottom, which is a sharp edge, on a bench at the head of the table, leaning with one side against it: and on the opposite side is a handle to lift it up by, in order to pour out the liquid metal. On the side of the pan next the mould, are two iron hooks to hold it to the table, and prevent it from slipping, while the metal is pouring out of it into the mould. The mould, as well as the pan, is spread over, about two inches thick, with sand sifted and moistened, which is rendered perfectly level by moving over it the strike, and smoothing it down with a plane of polished brass, about a quarter of an inch thick, and nine inches square, turned up on all the four edges, and with a handle fitted to the upper, or concave side. Before they begin to cast, the strike is made ready, by tacking two pieces of old hat on the notches, or by covering them with leather cases, so as to raise the under side of the strike about the eighth of an inch, or more, above the sand, according to the proposed thickness of the sheet: the face, or under surface of the strike is then smeared with tallow, and laid across the breadth of the mould, with its ends resting on the shafts. The melted lead is then put into the pan with ladles, and, when a sufficient quantity has been put in, the scum is swept off with a piece of board to the edge of the pan, and is suffered to settle on the coat of sand, to prevent its falling into the mould when the metal is poured out. It generally happens, that the lead, when first taken from the copper, is too hot for casting; it is therefore suffered to cool in the pan, till it begins to stand with a shell or wall on the sand with which the pan is lined. Two men then take the pan by the handle, or one man takes it by means of a bar and chain fixed to a beam in the ceiling, and, turning it down, the metal runs into the mould: another man stands ready with the strike, and as soon as all the metal is poured in, he sweeps it forward, and draws the residue into a trough at the bottom prepared to receive the refuse. The sheet is then rolled up, as before. In this mode of operation, the table inclines in its length about an inch, or an inch and a half, in the length of 16 or 17 feet, or more, according to the required thickness of the sheets; the thinner the sheet the greater the declivity, and *vice versa;* the lower end of the mould is also left open, to admit of the superfluous metal being thrown off.

When it is intended to cast a cistern, the size of the four sides is measured out; and the dimensions of the front having been taken, long slips of wood, on which the mouldings are carved, are pressed upon the sand, and leave their impression; and figures of birds, beasts, &c. are likewise stamped in the internal area, by means of leaden moulds: whatever of the sand has been disturbed in doing this, is then made smooth, and the process of casting goes on as for plain sheets; only, instead of rolling up the lead when cast, it is bent into four sides, so that the two ends may be joined at the back, where they are soldered together; and afterwards the bottom is soldered up.

The lead that lines the Chinese tea-boxes, is reduced to a degree of thinness, to which European plumbers cannot, it is said, approach. The following account of the process by which these plates are formed, was communicated to a writer in the *Gentleman's Magazine*, by an intelligent mate of an East-Indiaman: The caster sits by a pot, containing the melted metal, and has two large stones, the lower one fixed, and the upper moveable, having their surfaces of contact ground to each other, directly before him. He raises the upper stone by pressing his foot upon its side, and with an iron ladle pours into the opening a proper quantity of the fluid metal. He then lets fall the upper stone, and thus forms the lead into an extremely thin irregular plate, which is afterwards cut into a proper shape.

Cast sheet lead, used for architectural purposes, is technically divided into lead of 5lb. 5½lb. 6lb. 6½lb. 7lb. 7½lb. 8lb. and 8½lb. by which is understood that every superficial foot is to contain those respective weights, according to the price agreed upon.

The milled lead used by plumbers is very thin, seldom containing more than 4lb. to the foot. It is by no means adapted to gutters or terraces, nor indeed to any part of a building that is much exposed either to great wear, or to the effects of the sun's rays: in the former case it soon wears away; in the latter it expands and cracks. It is laminated in sheets of about the same size as those of cast lead, by means of a roller, or flatting-mill.

To cast pipes without soldering, a kind of mill, furnished with arms, or levers, to turn it by, is used. The moulds, which are of brass, consist of two pieces, which open and shut by hooks and hinges; their inward calibre, or diameter, being according to the size of the intended pipe, and usually about two feet and a half in length. In the middle is a core, or round piece of brass, or iron, rather longer than the mould, and of the thickness of the proposed inward diameter of the pipe. This core passes through two copper rundles, one at each end of the mould, which they serve to close; and to this is joined a small copper tube, about two inches long, of the intended thickness of the leaden pipe. These small tubes retain the core in the centre of the cavity of the mould. The core being in the mould, with the rundles at its two ends, and the lead melted in the furnace, the metal is taken up in a ladle and poured into the mould through a small aperture, in the shape of a funnel, at one end. When the mould is full, a hook is passed into the end of the core, which, by turning the mill, is drawn out; the mould is then opened, and the pipe itself is taken away. If it be desired to have the pipe lengthened, one end of it is put in the lower part of the mould, with the extremity of the core passed into it: the mould is then shut, and the upper rundle and tube applied as before; the pipe serving for rundle and tube at the other end. Fresh metal is then poured in, which unites itself with the former length of pipe; and the operation being repeated, a pipe of any required length may be obtained.

Pipes are made of sheet-lead, by beating it round wooden cylinders of the length and thickness required; and then soldering up the edges.

Both these methods are now superseded, by the use of a machine, worked by steam, which produces a much neater article, of almost any length, and at considerably less expense.

Solder is used by plumbers to secure the joints of lead-work, where other means would be improper, or impossible. It is a rule, that solder should be easier of fusion than the metal intended to be soldered; and that it should be as nearly as possible of the same colour. The plumber, therefore, uses what is technically called *soft solder*, which is a compound of equal parts of tin and lead, fused together, and run into moulds, not much unlike, in shape, to a gridiron: in which state it is sold to the manufacturer by the pound. In the operation of soldering, the surfaces, or edges, intended to be united are scraped very clean, and brought close up to each other, in which state they are secured by an assistant, while the plumber lays a little resin, or borax, upon the joint, to prevent an oxidation of the metal. The heated solder is then brought in a ladle and poured on the joint, after which it is smoothed and finished, by rubbing it about with a red-hot grozing iron; and, when completed, it is made smooth by filing.

For the method of laying embossed figures upon a leaden ground, see the article Lead.

In covering terraces, or flats, with sheet-lead, a bottom, as level as possible, should be first laid of plaster, or of boards; if the latter, they should be of sufficient substance to prevent their warping, or flying upwards; for if this be not attended to, the lead will soon become unsightly, and be liable to crack. As the sheets of lead never exceed in their breadth above six feet, it becomes necessary, in covering large surfaces, to have joints, which are managed several ways; but, in all, the main object is to have them water-tight. The preferable mode is by forming *laps* or *roll-joints*, which is done by having a *roll*, or strip of wood, about two inches square, but rounded on its upper side, nailed under the joint of the sheets, where the edges lap over each other; one of these edges is to be dressed up over the roll on the inside, and the other is to be dressed over them both on the outside, by which means the water is prevented from penetrating. No other fastening is required than what is acquired from the hammering of the sheets together down upon the flat; nor should any other be resorted to, where sheet-lead is exposed to the vicissitudes of the weather, because they occasion it to expand and shrink, which, if prevented by too much fastening, would cause it to crack, and be quickly good for nothing but the melting-pot. Circumstances sometimes occur, that preclude the use of rolls, and then the method by *seams* is resorted to: this consists in simply bending the approximate edges of the lead, up and again over each other, and then dressing them down close to the flat, throughout their length. But this is not equal to the roll, either for neatness or security. Soldering is also sometimes had recourse to, for securing the joints; but this is not to be recommended, as lead so fixed will be sure to leak after an exposure to the sunshine of a single summer. Leaden flats and gutters should be always laid with a current, to keep them dry. A fall from back to front, or in the direction of the length of the sheet, is the general rule. A quarter of an inch to the foot run is a sufficient inclination: but the fall, or *current*, as it is called, is generally agreed upon between the carpenter and plumber, while the former is preparing the ground, or platform, on which the lead is to be laid.

In making gutters, &c., pieces of milled lead, called *flashings*, about eight or nine inches wide, are fixed in the walls all round the edges of the sheet-lead, with which the flat is covered, and are suffered to hang down over them, so as to prevent the passage of rain through the interstice between the raised edge and the wall. If the walls have been previously built, the mortar is raked out of the joint of the bricks next above the edge of the sheet, and the flashings are not only inserted into the crack at the upper sides, but their lower edges are likewise dressed over those of the lead in the flat or gutter. And when neither of these modes can be resorted to, the flashings are fastened by wall-hooks, and their lower edges are dressed down, as before.

Drips in flats, or gutters, are formed by raising one part above another, and dressing the lead as already described, for covering the rolls. They are resorted to when the gutter, or flat, exceeds the length of the sheet; or sometimes for convenience. They are also an useful expedient to avoid soldering the joints.

Reservoirs are generally made of wood, or masonry, for their exterior, and lined with cast sheet-lead, soldered at the joints. As these conveniences are rarely in places subject to material change of temperature, the soldering may be resorted to, without fear of its occasioning damage to the work, by promoting a disposition in the lead to crack.

The plumber's employment in pumps is confined generally to two or three kinds, required for domestic purposes, of which the suction and lifting pumps are the chief; these, as well as water-closets, are manufactured by a particular set of workmen, and sold to the plumber, who furnishes the lead pipes, and fixes them in their places.

Plumber's work is commonly estimated by the pound or hundred-weight; but the weight may be discovered by the measure of it, in the manner below stated. Sheet-lead used in roofing, guttering, &c., is commonly between seven and twelve pounds weight to the square foot; but the following table shows the particular weight of a square foot for each of the several thicknesses.

Thickness.	Pounds to a Square Foot.	Thickness.	Pounds to a Square Foot.
.10	5.899	.15	8.848
.11	6.489	.16	9.438
$\frac{1}{9}$	6.554	$\frac{1}{6}$	9.831
.12	7.078	.17	10.028
$\frac{1}{8}$	7.373	.18	10.618
.13	7.668	.19	11.207
.14	8.258	$\frac{1}{5}$	11.797
$\frac{1}{7}$	8.427	.21	12.387

In this table the thickness is set down in tenths and hundredths, &c. of an inch; and the annexed corresponding numbers are the weights in avoirdupois pounds, and thousandth-parts of pound. So the weight of a square foot of $\frac{1}{10}$ of an inch thick, or $\frac{10}{100}$, is 5 pounds, and 899 thousandth-parts of a pound; and the weight of a square foot to $\frac{1}{9}$ of an inch thickness, is 6 pounds and $\frac{554}{1000}$ of a pound. Leaden pipe of an inch bore is commonly 13 or 14 pounds to the yard in length.

The plate exhibits the various forms of joining the lead at the concourse of an external angle made by a flat at the top, and one of the sloping sides of the roof; also, the method of joining the sheets between opposite extremities to which the joints or seams run parallel.

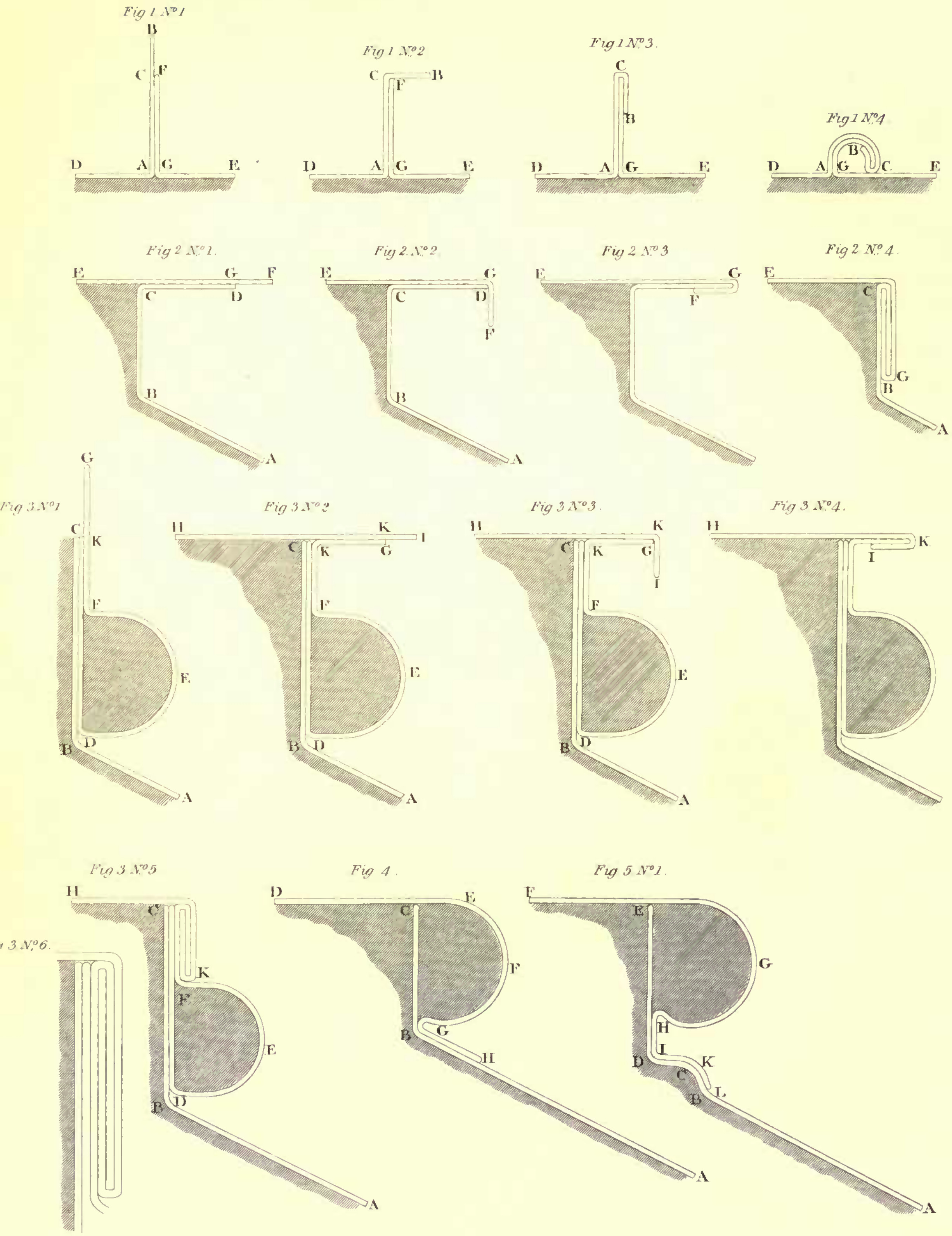


Fig 1 N°1
Fig 1 N°2
Fig 1 N°3
Fig 1 N°4
Fig 2 N°1
Fig 2 N°2
Fig 2 N°3
Fig 2 N°4
Fig 3 N°1
Fig 3 N°2
Fig 3 N°3
Fig 3 N°4
Fig 3 N°5
3 N°6
Fig 4
Fig 5 N°1

Figure 1. No. 1.—The first part of the operation of joining two sheets both in the same flat or plane. D A and E G are supposed to be portions of the flat joining together at A G, where each is bent to a right angle, D A B and E G F; the part, A B, which rises upwards, exceeds the part G F, in contact by C D, which is about one-third.

No. 2 explains the second step of this operation, exhibiting the part, G F, bent over the end D, perpendicular to the horizon.

No. 3 is the third step, and shows the part, D F, No. 2, bent so as to be parallel to the horizon, and consequently coincident with the surface, C D, of the upper part; and, so far as this operation has gone, it is the same as the first.

No. 4 exhibits the entire finish or last step of the operation.

The other method is by a roll of wood fixed over the upright part, which descends downwards to cover the slates, and is exhibited in *Figure* 3, Nos. 1, 2, 3, 4, 5, 6, which are sufficiently plain to inspection, from what has been explained of *Figures* 1 and 2.

PLUMMET, Plumb-Rule, or Plumb-Line, an instrument used by masons, carpenters, &c. to draw perpendiculars, in order to judge whether walls, &c. be upright, planes horizontal, and the like.

Its name is derived from a piece of lead, *plumbum*, fastened to the end of a thread or chord, which usually constitutes this instrument.

Sometimes the string descends along a ruler of wood or metal raised perpendicularly on another; in which case it becomes a level.

At sea, a plummet is used by the pilot to sound the depth of the water.

PLUTEUS, the wall which sometimes closes the intervals between the columns of a building. The term is also applied to the podium intervening between two orders of columns placed one above another.

PLYERS, in fortification a kind of balance used in raising or letting down a draw-bridge. They consist of two timber levers, about twice the length of the bridge they lift, joined together by other timbers framed in the form of a St. Andrew's cross, which serve as a counterpoise. They are supported by two upright jambs, on which they swing; and the bridge is raised or let down by means of chains joining the ends of the plyers and bridge.

PLYMOUTH MARBLE, a sort of marble dug in great plenty about Plymouth, and in some parts of Devonshire, where it lies in very thick strata, from whence it is carried to London in large quantities; and, when wrought, looks little less beautiful than some of the Italian marble.

It is very hard and firm, and of a beautiful texture; its ground is of blueish-white, and its variegations are principally a pale red, and in smaller quantities brown and yellow: these lie in very orderly beds, and there is often a very agreeable glow of a faint red diffused through the whole substance. It is remarkably even in its whole structure, and is therefore capable of a more than ordinarily elegant polish.

PODIUM (Latin), a continued pedestal, or plinth, serving to support a colonnade: it consists of a plinth, base, die, and corona. It is sometimes made to break forward under each column, such projection being distinguished by the name of *stylobate.* Also, in the theatre of the ancients, the wall that separated the orchestra from the scene.

POINT (from *punctum*, formed from *pungere, to prick*), a term in various arts.

Point, *Accidental*, a term used by the old writers on perspective, instead of *the vanishing point*, adopted by Brook Taylor. Accidental points were the vanishing points in the horizontal line, and were thus found:—The representation of two original points being obtained, a line was drawn through them both, and produced to meet the vanishing line of the horizon, and the intersecting point was called *the accidental point*, which served to draw all other lines, whose originals were parallel to the first. The method given by Dr. Brook Taylor is, however, much more direct; as the vanishing point is found by a geometrical process, viz., by drawing a straight line through the eye, parallel to an original line, which serves likewise for the vanishing point of all its parallels.

Point, in geometry, according to Euclid, is a quantity which has no parts, or which is indivisible. Wolfius defines it, that which terminates itself on every side; or which has no terms or boundaries distinct from itself. This is what we otherwise call *the mathematical point*, and is only conceived by the imagination; yet it is in this that all magnitude begins and ends, the flux or motion of the point generating a line, that of a line a surface, &c. Hence, some define a point to be the inceptive of magnitude. Hobbes defines a point to be a body whose magnitude is not considered; but his false notions of a point, line, and surface, have led him into many errors. Monsieur de Crouzas also has supposed a line to be composed of points in his *Geometry*, and in his comment on the *Analyse des Infiniment Petits.* One line can cut another only in a point. Any three points being given out of a right line, a circle, or part of a circle, may be drawn, that shall pass through them all.

Point, in perspective, a term used for various parts, or places, with regard to the perspective plane.

Point, in physics, the smallest or least sensible object of sight, marked with a pen, point of a compass, or the like.

This is what we popularly call *a physical point*, which, in reality, has parts, though those parts are not here regarded. Of such points does all physical magnitude consist.

This physical point coincides with what Mr. Locke calls *the point sensible*, and which he defines to be the least particle of matter, or space, we can discern. He adds, that, to the sharpest eye, this is seldom less than thirty seconds of a circle, of which the eye is the centre.

Point, *Conjugate*, is used for that point into which the conjugate oval, belonging to some kinds of curves, vanishes.

Point, *Objective*, a point on a geometrical plane, whose representation is required on the perspective plane.

Point of Contrary Flexures, in the higher geometry, the point of a curve wherein it is inflected to a part contrary to that to which it originally tended.

Point of Distance, in perspective ,the distance of the picture, transferred upon the vanishing line from the centre, or from the point where the principal ray meets it; and thus it is generally understood to be on the vanishing line of the horizon.

Point of Reflection, in geometry, is commonly used instead of *point of retrogradation*, or *retrogression.*

Point of Sight, the place of the eye whence the picture is viewed, according to the definition of Dr. Brook Taylor; but, according to the old writers on perspective, the point of sight is what Brook Taylor denominates *the centre of the picture.*

Point of View (the same as *the point of sight*) is the situation of the eye of the spectator when viewing an object to be represented in a picture.

Point, *Visual*, see Visual.

POINTED ARCH, an arch pointed at the top, resembling the point of a lance. *See* Architecture.

POINTED ARCHITECTURE, that style of architecture which originated in the substitution of the pointed for the semicircular arch, and which began to be employed in the early part of the twelfth century. The pointed arch is formed by the intersection of two segments, which in the earlier examples are very flat, and form very acute arches; but in the later periods are of quicker curvature, and the arches in consequence proportionately depressed. The pointed arch, however, although the main feature in the style, does not form its only peculiarity; but in principle as well as in matters of detail, the style is peculiar and distinct from every other. This subject has been fully discussed under the article Gothic Architecture, a name which the style has assumed in common with the above and many others. It is our intention in this place to consider only the origin of the style and the manner of its development. On this subject we are left almost entirely to our own resources, no manuscripts being known to exist which give us any information respecting it, nor are we acquainted with even the names which the Gothic architects employed to designate the different divisions of their style. As regards the architects themselves, too, and the precise date of the buildings erected by them, we are left much in the dark; and whatever conclusions may have been arrived at, have been founded on little better than conjecture. Many archæologists, architects, and others interested in the question, have treated upon the subject, and have eliminated a great deal of useful information by their researches, although not one of them can be said to have come to a conclusive or satisfactory result regarding the question immediately before them. Many theories have been broached by different writers, some of which are plausible, and others little better than ridiculous; none are so perfect as to obtain universal assent, nor is it to be expected under the circumstances that they should be so. It is perhaps owing to the uncertainty necessarily attending the research, that the subject has been so fashionable amongst antiquaries; but however unsatisfactory their inquiries may have been as regards the matter in dispute, we must not forget that it is in all probability to such inquiries we owe our present knowledge on the subject, and the present appreciation of the style. Our very want of information as to its origin has probably been rather an advantage than otherwise, for we have been compelled thereby to search into the matter, and seek knowledge from every quarter; whereas had the question been easy of decision, all the information which we have obtained in this manner might have been lost to us.

Of the many theories which have been started, we shall here take notice of some of the more prominent, commencing with such as require but little comment, and proceeding in those which seem entitled to some further consideration. Bishop Warburton, one of the writers on the subject, discovers the prototype of a Gothic cathedral in a grove of trees, such an imitation having been employed, as he supposes, from the circumstance of the Celts being accustomed to worship in such places, and from their early associations having introduced the same forms in their constructed temples. The trunks of the trees are supposed to be represented by the pillars, and the overhanging branches by the ribs of the vaulting. The same opinion is said to have been entertained by Raphael d'Urbino; but we venture to say that the resemblance between a Gothic aisle and an avenue of trees is not at first sight very striking, and that the idea is rather in accordance with the imagination of the poet than the researches of the antiquary. It makes somewhat against this theory, that all evidence goes against the introduction of the Pointed style by the Goths, and also that the closest resemblance is to be found in the later, and not in the earlier examples. It is not improbable that Warburton himself felt dissatisfied with this notion, for it is not known to exist in more than one edition of his commentary on Pope's works, though later editions were published during his lifetime.

Similar to the preceding is the opinion entertained by Sir James Hall, who, with equal felicity of imagination, refers us to interlaced wicker-work as the undoubted prototype of the Pointed style in all its parts—its groined roofs, clustered pillars, and traceried windows; and thus Gothic churches become representations of the primitive churches in this island. Sir James has taken upon himself no inconsiderable amount of labour in his endeavour to prove his theory the correct one, and has profusely illustrated his book to show how precise is the imitation; but his illustrations, as well as his argument, go to prove the converse of his proposition, not that Gothic architecture took its origin from interlaced twigs and branches, but only that wicker-work may be made to assume the forms frequent in that style. The same argument respecting the similarity being most conspicuous in the later examples, exists also in this instance.

Mr. Murphy, well known by his publications on the architecture of Spain, refers us to the pyramids of Egypt as the grand type of the style; and in his splendid work on the church of Batalha, after having stated the tendency of every ornament to the general pyramidal form, says—"It appears evident from this instance, that the pyramidal form actually exists throughout the several component parts, and the general disposition of the edifice approaches as near to it at least as the ordonnance of an historical painting which is said to be pyramidally grouped. Hence we may comprehend the reason why the arch was made pointed, as no other forms could have been introduced with equal propriety in a pyramidal figure, to answer the different purposes of uniformity, fitness, and strength; it is in vain, therefore, that we seek its origin in the branches of trees, or in the intersection of Saxon or Grecian circles, or in the perspective of arches, or in any other accidental or fortuitous circumstances. The idea of the pointed arch seems clearly to have been suggested by the pyramid, and its origin must consequently not be attributed to accident but to ordination." That there may be some truth in this theory as regards the pyramidal grouping of these buildings we are not prepared to deny; but neither are we prepared to assert that the principles of Pointed architecture were therefore derived from the pyramids of Egypt. A contemporary has given the following somewhat amusing critique or illustration of the arguments brought forward by Mr. Murphy. "The pyramids of the Egyptians are tombs; the dead are buried in churches, and on their towers pyramidal forms are placed; consequently the pyramids of the towers indicate that there are graves in the churches; and as the pyramidal form constitutes the essence of the Pointed-arch style, and the pyramids of the towers are imitations of the Egyptian pyramids, the pointed arch is derived from the latter."

Some authors are anxious to discover the prototype in a framed timber building, but in what the resemblance exists it is somewhat difficult to determine. The late Mr. Barry attributes the Gothic style to the corruption of Greek and Roman art; Mr. Dallaway, to the desire of novelty and the caprice of the Italians. Lord Orford perceives the prototype in shrines for reliques, and observes, "it was a most natural transition for piety to render a whole church as it were one shrine:" he adds, "the Gothic style seems to bespeak an amplification of the minute, not a diminution of the great." Of the first two, Mr. Barry and Mr. Dallaway, we are inclined to think that both are, to a certain extent, correct, that Pointed architecture was a gradual development of the principle of the arch, and that taking it as a whole it does owe its origin to the Romanesque or Debased Roman, in a similar manner as the Roman was, in a degree, an imitation of the Grecian orders. That it owes its existence also—at least partially—to a desire for novelty, we are not in a position to contradict; but that it originated in Italy, we consider a matter of very great improbability. Dr. Whittaker, with whom Mr. Whewell somewhat agrees, is of opinion that pointed arches were known to, and practised by, the Romans during the empire, and originated in the intersection of cross-vaulting, examples of which are to be seen in the palace of Diocletian, at Spalatro. This suggestion is very worthy of consideration, and is, at least, a method by which the pointed arch was constructed, and that, too, accidentally, as it were, and in regular course. Vaulting, we know, was employed by the Romans, and, as a matter of necessity, cross-vaulting succeeded; and in some cases, by such a system, the pointed arch was described in the process. It is not unlikely that this circumstance should have been noted, and turned to practical advantage.

In connection with this should be considered an hypothesis, which has been held by Dr. Milner, Mr. Bentham, and several others, and which has met with a considerable share of public favour. Their supposition is that the pointed arch has been suggested by the intersection of semicircular arches. That interlaced arches were largely employed in Norman architecture as a means of decoration, there can be no question, and that, too, previous to the introduction of the pointed arch. That pointed arches were thus formed by the intersection is equally certain; nor is it at all improbable that the idea may have suggested itself thereby. Still this solution of the question is not unattended with difficulty or objection. In the first place, Dr. Milner is evidently incorrect in attributing its invention to Henry of Winchester, for it is known that the abbey of Clugny, in France, where he himself had been monk, was constructed with pointed arches; and therefore it is more reasonable to suppose that he had copied the idea from that building, rather than have invented it from his observation of the form in the intersection of semicircular arches. But laying aside this objection, which applies only to a peculiar and individual instance, and considering the theory simply on its own merits, we cannot consider it perfectly satisfactory; for it is somewhat improbable that the leading feature of the style should have had its origin in an accidental and unessential matter of detail; that a grand principle of construction should have been eliminated from a mere method of decoration.

Some authors have asserted that the style was invented by the Goths; whether the term Gothic formed the principal ground for such an assertion, it is not easy to determine; but it is very certain that no reason can be assigned for it which would have much greater weight than even this; for as regards this people, we have no reason to suppose that they possessed any style of architecture of their own, but rather the reverse; and although their king, Theodoric, did erect some buildings, they were constructed in the same style as the structures already existing in the country. It is true that Gibbon, in his Fall of the Roman Empire, states that the representation of Theodoric's palace at Verona, still extant on a coin, supplies the oldest and most authentic model of Gothic architecture; but in the work to which he refers for an engraving of this coin, we find none, indeed, of a coin, but one of a seal; the building represented on which is in a totally dissimilar style. One conclusive argument, however, against this theory, consists in the fact, that no building of this style has ever been known to exist which can claim so great an antiquity as that desired to be established by this statement; and, moreover, that the Gothic style was not introduced into Italy till a comparatively late period, when the Goths had been long since forgotten, and, indeed, never obtained a permanent footing in that country.

Other writers, with greater show of reason, have derived our knowledge of this style from the Saracens, supposing it to have been brought over by the Crusaders; nor is such an opinion taken up without good grounds, as it meets some grand difficulties which others are subject to, and yet is in many points unsatisfactory. As regards its chronology, this theory is fortunate; for it certainly was about the time of the Crusades that the style became prevalent; while yet, on the other hand, there is good evidence to suppose that one or two buildings of the kind existed in Europe before any of the Crusades had taken place. Another circumstance in its favour is, that it is the only supposition which will account satisfactorily for the simultaneous adoption of the style throughout Europe; a circumstance which, in all the other ideas which have been broached, forms an insurmountable objection to their acceptance. Whether the pointed arch was common in Saracenic buildings of the time, has been a matter of endless discussion; nor does it seem to have ever been satisfactorily proved or disproved, owing to a want of accurate information, and uncertainty as to the date of existing examples. There seems reason to believe that the pointed arch did exist, but was not so prevalent as some would have us suppose, or at least not in that form in which we find it in Europe; but whether pointed arches were to be found or not, is not a matter of such consequence as some would make it; nor does it of necessity prove anything; for we know that this form is to be found occasionally in ancient buildings of other countries, from which no one has attempted to deduce its introduction into Europe. But even supposing the styles to assimilate as regards the pointed arch, they agree in no other principle; in the buildings of the Saracens, we find neither cross-vaulted roofs nor arcades forming nave and aisles, nor clustered columns, nor crocketed pinnacles, nor towers, nor spires: their mosques are mostly square on plan, and are conspicuous chiefly for their bulbous domes, the nearest approach to the Gothic spire being found in the minarets. The idea of Gothic window-tracery is said to have been derived from the perforated fret-work of Arabian architecture; but if so, it must be recollected that such tracery is only to be found in the later examples when the style was fully developed; and, moreover, that we have a more satisfactory mode of accounting for its introduction. The above theory is supported by Warburton, Warton, Whittington, Lord Aberdeen, and Sir Christopher Wren; the last author, however, seems to prefer the supposition of the introduction of the arch into Europe by the Moors of Spain, but for this opinion there does not appear to be anything like the amount of evidence which may be produced in favour of the former. Other writers prefer to give the honour to the Visi-Goths of Spain, rather than to their Arabian invaders, but apparently with little better reason.

We have now taken a cursory glance at most of the leading theories respecting the introduction of the pointed style into Europe; but, as we have seen, not one of them is free from objections of considerable importance. One main objection, which affects nearly all of them, is this, that instead of the resemblance to the supposed prototype being, as it ought to be, the closest and most exact in the first stages of the style said to be derived from it, the resemblance is there least of all discernible. There is another objection, which touches every one of them—they all seem to rest satisfied when they have found, or thought they have found, the origin of the pointed arch, forgetting that this does not comprise the entire question at issue; their only inquiry appears to have been as to who were the inventors of the pointed arch, and not of pointed architecture. Now, there is a vast difference between the two questions, for the former embraces but a fractional part of the latter: a pointed arch is but a component part, and does not of itself constitute absolute Gothic architecture, although it is one and a very important characteristic of it. At the same time there are other peculiarities little less important; such are its principle of verticality; its lofty towers and spires; its cross-vaulting; its light and clustered pillars, with their slender shafts; its tracery, mullions, &c.; these are all necessary to make up a complete whole, and each and all ought to be considered in determining the origin of the style.

With such conflicting opinions as to the origin of the style, it is not to be expected that there should be any agreement as to what European country was the first to adopt it. The honour has been claimed for England, France, and Germany: the claim has been made for England by Sir Henry Englefield and Horace Walpole; but although the buildings of the style are to be found in this country in great number and variety, and are, on the whole, of greater purity, and in our opinion, of superior excellence, to those on the continent, still more satisfactory evidence has been elicited in favour of the latter. The late Mr. Hope, in his historical Essay on Architecture, has produced much able argument in favour of Germany; whilst Wetter, a writer of that country, contends that priority of date, as regards the adoption and development of the style, properly belongs to France. The claim has been made for Italy, but there seems to be little evidence to favour such an opinion; and Mr. Gally Knight, in his elaborate work on the ecclesiastical architecture of that country, gives good reason for disregarding it.

Notwithstanding the variety and antagonism of the opinions which have been started upon the subject, it is possible that more than one of them may be partially correct, because a variety of circumstances may have contributed more or less towards the same end; but we must confess that the change of style has not as yet been sufficiently accounted for. Whether the question will ever be determined beyond dispute, may fairly be questioned; nor do we know that any substantial advantage would be gained thereby. It is true, we are every day advancing to a more perfect knowledge of the style, and, in the course of our inquiries, some unexpected light may be thrown upon the subject; but be this as it may, it is certain that it will be much more advantageous to continue our practical study of the style, than to turn aside for the mere purpose of speculating on its origin.

POINTS, *Proportion of Mathematical.* It is a current maxim, that all infinities, whether infinitely great or infinitely small, are equal; yet is the maxim false in both cases. Dr. Halley shows several infinite quantities, which are in a finite proportion to each other; and some infinitely greater than others.

The like, the honourable Mr. Roberts shows of infinitely small quantities, viz., mathematical points. He demonstrates, for instance, that the points of contact between circles and their tangents, are in a subduplicate proportion to the diameters of the circles; that the point of contact between a sphere and a plane is infinitely greater than that between a circle and a tangent; and that the point of contact in spheres of different magnitudes are to each other as the diameters of the spheres.

POLISHING, the art of giving a gloss or lustre to a thing; particularly a precious stone, marble, glass, a mirror, or the like.

For grinding and polishing steel, the grindstones used are made to revolve, either vertically or horizontally, with a velocity so great as to describe sometimes as much as sixty feet in a second. The steel is also, in some cases, drawn backwards and forwards horizontally on a circular surface; and in order that the action may be equally distributed throughout the surface, it is allowed to revolve on an axis by means of the friction; its motion being confined to one direction by the action of a catch. Various substances, chiefly of mineral origin, are also used, on account of their hardness, as intermediate materials, for grinding and polishing others. These are diamond-dust, corundum, emery, tripoli, putty, glass, sand, flint, red oxyde of iron, or crocus martis, and prepared chalk. These are sometimes applied in loose powder, and sometimes fixed on wood, leather, or paper. Cuttle-fish bone and seal-skin are furnished by the animal kingdom; and Dutch rushes by the vegetable; these are employed chiefly in polishing wood or ivory. Marble is made smooth by rubbing one piece on another, with the interposition of sand; the polishing-blocks are sometimes caused to revolve by machinery in a trough, in which the marble is placed under water, and are drawn at the same time gradually to and from the centre; or the slab itself, with the frame on which in rests, is drawn slowly backwards and forwards, while the blocks are working in it. Granite is polished with iron rubbers, by means of sand, emery, and putty; but it is necessary to take care, during the operation, that the water, which trickles down from the rubbers, and carries with it some of the iron, may not collect below the columns, and stain them; an inconvenience which may be wholly avoided by employing rubbers of glass.

POLLARD, in planting, a term applied to a tree that has been frequently polled or lopped, and its top taken off, or headed down to the stem, for the purpose of fire-wood, or small poles for hurdle-wood, and other similar uses, as well as for hop-poles, &c. It is a term most commonly in use in the southern and eastern districts of the kingdom. But though much wood of this small sort may be provided in this way, the practice has been highly reprobated, not only as being destructive of good timber, but as a barbarous system which disfigures, and renders the appearance of the country disagreeable.

POLYCLETUS, a celebrated sculptor of antiquity, a native of Sicyon, who flourished about the year 430 B.C. He was supposed to have carried the art to the highest degree of perfection, at least as far as the excellence of single figures could go. One of his figures, representing a life-guard of the king of Persia, was performed in such exact proportions that it was called *the rule*, and artists came to study it as a model. He made the statue of a boy, which was estimated at a hundred talents (nearly 20,000*l.* sterling). The emperor Titus had two naked boys playing at a game, by his hand, which was considered as a perfect performance. It was peculiar to him, that he formed almost all his figures supported on one thigh, which made them appear deficient in variety.

POLYCHROMY (Greek πογυς and χρῶμα, colour), the art of painting in positive colours, either on flat surfaces or sculptured figures. It was much used by the Egyptians in their edifices, and they were probably the first to introduce such ornament. The Greeks adopted the same method of decoration, and improved upon it; as also did the Romans. There are still existing many specimens of the application of this art in the ruins of Herculaneum and Pompeii, the colours still retaining their brilliancy. The Arabs excelled in this art, as is evidenced by their edifices, which owe much of their peculiar beauties to the aid of colour. The interiors of their edifices are completely covered with polychromatic decoration, such parts of the walls as were not covered with actual painting being lined with coloured and glazed tiles. Polychrome was also in general use amongst our mediæval architects, and the grand effect of their buildings was considerably heightened by such ornamentation. We regret that even in the present day any prejudices should be found to prevail against its introduction into our ecclesiastical buildings; we have, however, more than one of our recent churches in which such assistance has not been despised; and we feel sure that the contrast between such and the cold bare walls of the majority, will at length prevail against every prejudice. We are glad to be able to allude, also, to the restoration of this art to its proper position, in the instance of a public building such as the British Museum, and we trust that its success there will lead to its general adoption.

POLYFOIL, an ornament prevalent in Gothic architecture, formed of a moulding, disposed in a number of segments of circles, producing projecting points at their intersections, termed cusps: thus we have *trefoil*, consisting of three cusps; *quatrefoil*, of four; and *polyfoil*, of any number above four.

POLYGON (from πολυγωνος, formed from πολυς, *many*, and γωνια, *angle*) a multilateral figure, or one whose perimeter consists of more than four sides and angles.

If the sides and angles be equal, the figure is called a *regular polygon*. For *similar polygons* see SIMILAR.

Polygons are distinguished according to the number of their sides. Those of five sides are called *pentagons;* those of six, *hexagons;* those of seven, *heptagons*; those of eight, *octagons*, &c.

POLYGONS, *General properties of.* Euclid demonstrates the following:—1. That every polygon may be divided into as many triangles as it hath sides. 2. The angles of any polygon, taken together, make twice as many right angles, abating four, as the figure hath sides. Thus, if the polygon hath five sides, the double of that is ten; whence, subtracting four, there remains six right angles. 3. Every polygon, circumscribed about a circle, is equal to a right-angled triangle, one of whose legs is the radius of the circle, and the other the perimeter, or sum of all the sides of the polygon. Hence every regular polygon is equal to a right-angled-triangle, one of whose legs is the perimeter of the polygon; and the other a perpendicular, drawn from the centre to one of the sides of the polygon.

Hence, also, every polygon circumscribed about a circle is larger than it; and every polygon inscribed is less than the circle. The same likewise appears hence, that the thing containing is ever greater than the thing contained. Hence, again, the perimeter of every polygon circumscribed about a circle, is greater than the circumference of that circle; and the perimeter of every polygon inscribed, less; whence it follows, that a circle is equal to a right-angled triangle, whose base is the circumference of the circle, and its height the radius; since this triangle is less than any polygon circumscribed, and greater than any inscribed.

Nothing therefore is wanting to the quadrature of the circle, but to find a right line equal to the circumference of a circle.

The subjoined table gives the areas of polygons and their perpendiculars from the centre to one of the sides, the side being supposed equal to unity.

Number of sides.	Area.	Perpendiculars.
3	.433013	.2886751
4	1.000000	.5000000
5	1.720477	.6881910
6	2.598076	.8660254
7	3.633912	1.0382617
8	4.828427	1.2071068
9	6.181824	1.3737387
10	7.694209	1.5388418
11	9.365640	1.7028437
12	11.196152	1.8660254

To apply this rule generally, multiply the square of the side of the given polygon by the number found in the table of areas for a polygon, having the same number of sides as that whose area is required.

POLYGRAM, (Greek, πολυς, and γραμμα,) in geometry, a figure consisting of many lines.

POLYHEDRON, or POLYEDRON (from πολυεδρον, formed from πολυς, *many*, and ἑδρα, *side*,) a body comprehended under many rectilinear sides, or planes.

If the sides of the polyhedron be regular polygons, all similar and equal, the polyhedron becomes a regular body, and may be inscribed in a sphere; that is, a sphere may be drawn round it, so that its surface shall touch all the solid angles of the body.

POLYHEDROUS FIGURE, a solid contained under, or consisting of, many sides. *See* POLYHEDRON.

POLYSTYLE, (Greek, πολυς, *many*, and στυλον, *a column*,) a term applied to buildings which are surrounded by a multitude of columns.

POMEL, a boss or knob terminating a conical or dome-shaped roof.

POMPEII, an ancient city of Naples, overwhelmed in the first century by the same disastrous catastrophe which destroyed *Herculaneum.* It is said to owe its name to the triumphant pomp in which Hercules led his captives along the coast after his conquest of Spain; it was probably situate on an arm of the sea, and served as a port for the inland towns; which inlet of the sea has been filled up by successive eruptions, besides that which destroyed the town. It is about fourteen miles from Naples, on the road to Nocera. From Naples to Torre del Greco, the highway is almost a street, so close are the villas, villages, and towns to each other. As the road runs along the coast, and at the foot of Vesuvius, every break gives on one side a view of the bay, on the other of the mountain. Torre del Greco still presents, in its shattered houses, half-buried churches, and streets almost choked up with lava, a melancholy instance of the ravages of the eruption. The depth of the destructive torrent is, in some places, twenty-five feet, so that the entrance into several houses is in the second story, and into one church through the great window over the western door. Some edifices were entirely destroyed: others were surrounded, incrusted, and filled with lava, and may perhaps give a very accurate idea of the state of Herculaneum at the time of its destruction. The town of Torre del Greco was supposed, by Cluverius, to occupy the site of Herculaneum, because the distances nearly corresponded; and inscriptions have been found that seem to corroborate this conjecture. In fact, making allowances for the extent of the ancient town, there is little more than three-fourths of a mile difference, so that its name and jurisdiction extended probably much farther. In the vicinity of this place are the ruins of ancient barracks, which were the quarters of a legion of Roman soldiers, and behind the barracks are two theatres, one small, and supposed to have been covered, the other large; both these edifices were lined with marble, beautifully paved, and in every respect highly-finished. These theatres are exactly of the same form as the Teatro Olimpico of Palladio at Verona; having, like it, a narrow proscenium, and three entrances, one large and the other two less, to the stage, from the scenery behind. These theatres, when discovered, were nearly entire, but though they have been stripped of all their decorations, they still retain all their great characteristic features. Behind the little theatre is a temple of Isis, occupying an angle formed by two streets. Some have supposed that oracles were issued from this temple, and have declaimed against the priestcraft that was practised here; but it does not appear that oracles were ever given at Pompeii, as this was a privilege reserved to the ancient and more renowned temples; besides, oracles had everywhere ceased before this edifice, or temple, if it may be so called, was erected; and, moreover, the entrances into it are too public, and the whole contrivance too gross to dupe the dullest peasant, much less the polished inhabitants of Pompeii. In this building there are niches, where various statues of Venus, Priapus, &c., were found, which, with the furniture, marble, and pictures, were transported to Portici. Behind this temple, on one side, is a court surrounded with a portico, supported by sixteen Doric pillars, and, from a sort of pulpit on one side, it may be inferred, that it was intended for some public assembly. Another court follows with a similar portico, and communicates with the grand portico of the theatre supported by more than sixty stone pillars of the Doric order, but, in proportion, bordering upon Tuscan. Near this portico lie several fragments of columns of a much larger size, and of bolder proportion; which, perhaps, belonged to the temple of Neptune, and may have been thrown down and laid in their present situation by the earthquake, which nearly destroyed this city a few years previous to the eruption that buried it finally. The most perfect and most curious object that has yet been discovered is a villa at a little distance from the town. It consists of three courts; in the first and largest is a pond, and in the centre an ædicula, or little temple: there are numerous apartments of every description, paved in mosaic, coloured and adorned with various paintings on the walls, all in a very beautiful style. The baths in this villa seem to have been objects of particular attention.

Cicero's Pompeianum stood in the neighbourhood of this town, and possibly on this very spot. It was a favourite retreat, much frequented by Cicero and his friends. The houses at Pompeii are on a small scale, generally of one, sometimes of two stories; the principal apartments are always behind, enclosing a court, with a portico round it, and a marble cistern in the middle; two had glass windows, in the others shutters only were used; the pavements are all mosaic, and the walls are stained with mild colours; the decorations are bassorelievos in stucco, and paintings in medallions. Marble seems to have been common. An extent of about 500 feet of the town wall has been completely cleared. It is from eighteen to twenty feet high, twelve thick, and fortified at short distances with square towers. In the main street, passing in front of the temple of Isis, has been discovered the portico of the theatre. Near the same spot, ten feet below the level of the street, was found a human skeleton, and immediately beneath it a large collection of gold and silver medals in the finest preservation, chiefly of the reign of Domitian. Under a superb portico, in the quarter of the tombs, a number of skeletons have been discovered, and among them those of a female and several children. Three finger-rings and several ear-rings were found among the bones. Among the vases discovered, there were two which were full of water, with a small quantity of ashes at the bottom. In one the water was limpid and odourless; in the other it was of a brownish tinge, and had the taste of lye.

POMPEION, a stately edifice at Athens, in which were kept the sacred utensils made use of at festivals, and where all things necessary for the solemn processions were prepared. It stood at the entrance of the old city, which looked towards Phalerum, and was adorned with many statues of the Athenian heroes. This word was likewise used for any utensils employed on these occasions.

POMPEY'S PILLAR. *See* PILLAR.

POPPY HEAD, a carved ornament used as a terminating ornament at the top of the standards of ancient church-benches. The designs of such ornaments are not confined to one particular form, as the name might appear to signify, but were most frequently in the form of a finial composed of foliage of various kinds, grotesque figures, crests, and various other devices.

PORCH, (from the Latin, *porticus*) a kind of vestibule, supported by columns, much used at the entrance of the ancient temples, halls, churches, and many other buildings. *See* ATRIUM.

In the ancient architecture, a porch was a vestibule, or a disposition of insulated columns, usually crowned with a pediment, forming a covert place before the principal door of a temple, or court of justice.

When it had four columns in front, it was called a *tetrastyle;* when six, *hexastyle;* when eight, *octostyle;* when ten, *decastyle*, &c. Vitruvius calls it *pronas;* Pollux *προδομος*, *prodomos:* when finer than ordinary, the ancients call it, also, *propyleum.*

Porches are almost universal in churches, and are usually on the south side, and in the second bay from the west, but the position is frequently determined by the circumstances of the locality.

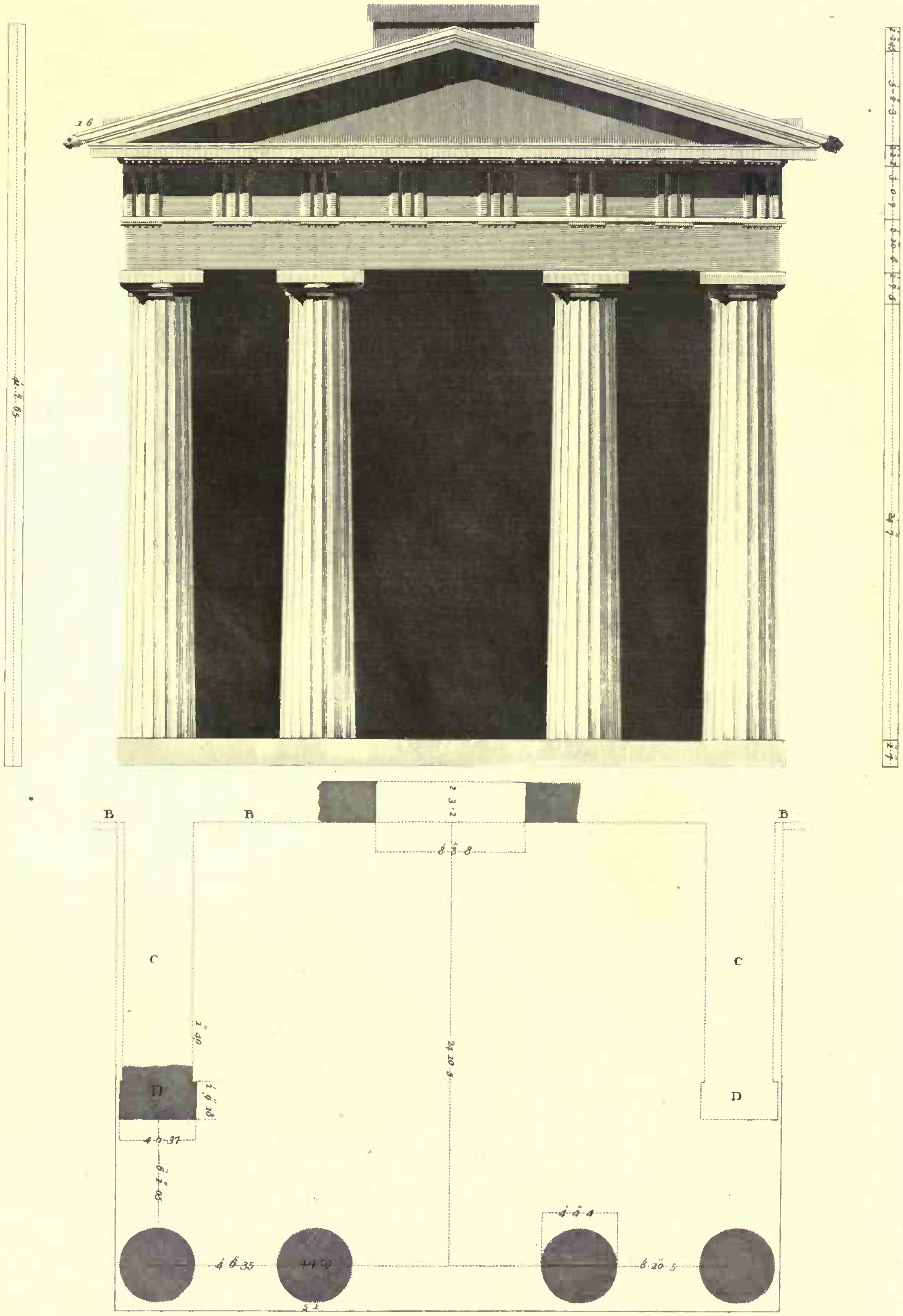
Norman porches are frequently of large dimension, and highly enriched with the ornament peculiar to that period; many such have been preserved in buildings which in other respects have been entirely rebuilt in a later style. Many fine porches of this kind are to be found at Malmesbury, Sherbourne, and Southwell, the last having a room over it; there is also a very fine one at the Temple Church, London. Early English specimens occur at Wells, Salisbury, Lincoln, and Westminster; and the examples in this as well as in the Norman style, are almost invariably of stone. Decorated and Perpendicular porches are frequently of wood, sometimes entirely closed at the sides, but more often of open work, and with ornamental barge boards at the end of the roof; many very beautiful specimens are to be found of both styles.

A few Galilee porches exist in some of our cathedrals. *See* GALILEE, and CATHEDRAL, also CHURCH.

PORPHYRY, (from *πορφυρος*, *purple*) a denomination that distinguishes a large class of primitive rocks, composed of one substance, in the form of grains, or crystals, imbedded in another, consisting most commonly of a compact paste, as its basis. The base is clay-stone, horn-stone, compact felspar, pitch-stone, pearl-stone, or obsidian; the implanted grains, or crystals, are of quartz, or felspar. Of porphyry there appear to be two formations; the most ancient consists principally of horn-stone and felspar porphyry, and the most recent are of clay, pitch-stone, pearl-stone, and obsidian porphyry. The porphyritic formation is not very distinctly separated from the other rock formations which accompany it, nor is its rank among the primitive mountains, with regard to antiquity, very clearly ascertained. The mountains of porphyry are not stratified, and never enclose beds of other substances. Its texture is commonly compact, but it occasionally occurs in schist-stone. It is not very rich in mineral veins; the clay porphyry is the most rich. The mines of Schweitz, in Hungary, which are of this description, are found in this species of rock.

Some writers have reckoned five species of rocks belonging to the proper porphyritic formation, which are as follows: viz., 1, *Horn-stone porphyry*, the base of which, being horn-stone, is generally red or green, with a conchoidal, or splintery fracture; and enclosing crystals of quartz and felspar. This is also distinguished, says Kirwan, by its hardness, slight transparency, and want of lustre; it is fusible without difficulty. Sometimes the felspar is decayed, and sometimes

PORTICO.



PORTICO.

The Ionic Temple on the Ilissus.

Drawn . by. P. Nicholson . Eng.d by. R . Thew.

also the horn-stone, whilst the quartz and hornblende remain entire: the whole thus acquires the appearance of indurated volcanic ashes, though the quartz might prove the contrary: if the felspar alone be decayed, the horn-stone will appear porous, and may be taken for lava. Its transitions are into granite and sand-stone. 2. *Felspar porphyry*, the base of which is commonly red compact felspar, enclosing crystals of felspar and quartz. 3. *Sienitic porphyry*, which differs from the preceding in containing crystals of hornblende in addition to the other ingredients. 4. *Pitch-stone porphyry*, the base of which is pitch-stone, either red, green, brown, gray, black, or yellow, of various shades, having generally many colours at once in the same specimen. According to Kirwan, this porphyry has the following characters: lustre, greasy, 2.1: transparency, 2.1: fracture, imperfectly conchoidal: hardness, 8, 9, 10: the felspar often blue: the fracture of some is slaty, and colour yellowish-gray: lustre, scarcely 1; transparency, 1; hardness, scarcely 9; specific gravity, 2.452. 5. *Clay porphyry*, the base of which is indurated clay, passing into horn-stone; generally of a reddish colour, and containing crystals of quartz and felspar. The colour of this porphyry, belonging to Kirwan's argillaceous porphyries, is generally some shade of gray, or greenish-gray, or brown, or blackish or reddish-brown, or isabella-yellow. Lustre and transparency, 0; fracture, earthy; hardness, from 5 to 7; sometimes adhering to the tongue.

PORTABLE BRIDGE. *See* Bridge.

PORTAIL, the face or frontispiece of a church, viewed on the side in which is the great door. Also, the great door, or gate itself, of a palace, castle, &c.

PORTAL, (perhaps a diminutive of the French, *porte*, door, gate,) a term used for a little square corner of a room, cut off from the rest of the room by the wainscot; frequent in ancient buildings, but now disused.

Portal is sometimes also used for a little gate, *portella*; where there are two gates of a different size: also, a kind of arch of joiner's work before a door.

PORT-CRAYON, (French) a pencil-case, an instrument serving to enclose a pencil, and occasionally also used as a handle for holding it. It is usually four or five inches long, and contrived so that the pencil may be slid up and down by means of a spring and button. Its outside is filed into eight sides or faces, on which are sometimes drawn the sector lines: its inside is round; sometimes it is made round or cylindrical, both without and within, and has its length divided into inches and parts of inches.

PORTCULLIS, (from the French *portecoulisse*) called also *herse* and *sarrasin*, an assemblage of several great pieces of wood, laid or joined, across one another, like a harrow, and each pointed at the bottom with iron.

These were formerly hung over the gateways of fortified places, to be let down in case of a surprise, when the enemy should come so quick as not to allow time to shut the gates. But now the orgues are more generally used, as being formed to answer the purpose better.

PORTICI, a small town of Italy, about six miles from Naples, on the sea-shore, at the foot of Vesuvius. Its principal ornament is a royal palace. Under this town and palace lies buried, at the depth of 70 feet under accumulated beds of lava, the city of Herculaneum, the first victim of the fires of Vesuvius. The Prince d'Elbœuf, after the first discovery was made by accident, purchased the spot, and continuing the excavations that had been begun, discovered various statues, pillars, and even a whole temple of the finest marble, adorned with statues. Upon the interposition of the Neapolitan government, the work was stopped for twenty years; however, the excavations were occasionally continued, and a basilica, two temples, and a theatre, were successively discovered, and stripped of their numerous pillars and statues. Streets were observed, that were paved and flagged on the sides, and private houses, and even monuments, explored. A prodigious number of statues of bronze, of different sizes, pillars of marble and alabaster, and paintings and mosaics, many of them entire and in high preservation, others fractured and damaged, have been drawn from the edifices of this subterraneous city, and give a high idea of its opulence; to these we may add many species of ornaments used in dress, of weapons and armour, of kitchen utensils and domestic furniture, of agricultural and chirurgical instruments. The theatre is at present the only part open to inspection. Of all the articles drawn from Herculaneum, the most curious and valuable are the MSS. Of these many dissolved into dust as soon as they were exposed to the air: while others, though scorched, or rather burnt, resist the action of that element. The number of the latter, it is conjectured, may be about 1800.

PORTICO, (from the Latin *porticus*, a gate) a kind of gallery on the ground; or a piazza encompassed with arches supported by columns. The roof is usually vaulted, sometimes flat. The ancients called it *lacunar*. *See* Lacunaris.

The most celebrated porticos of antiquity were those of Solomon's temple, which formed the atrium, or court, and encompassed the sanctuary: that of Athens, built for the people to divert themselves in, and where the philosophers held their disputes and conversations; which occasioned the disciples of Zeno to be called *stoics*, from the Greek *ϛοα, porticus*; and that of Pompey at Rome, consisting of several rows of columns.

Plate I.—Plan and elevation of the Doric portico at Athens.

Plate II.—Portico of the Ionic temple, on the Ilissus, at Athens.

Porticos were numerous buildings in Rome for the convenience of the public in sultry or inclement weather; distinguished from those which formed the vestibules, or which decorated the entrance of temples. Some of the principal were the *porticus duplex*, so called from its double row of pillars, erected by Cneius Octavius, near the Circus Flaminius, after the defeat of Perses; it was of the Corinthian order, and ornamented with brazen capitals; the walls were decorated with paintings representing the achievements of the founder. The *portico of Pompey*, annexed to his theatre, was supported by 100 marble columns; opened on both sides into groves of plane-trees, was refreshed by fountains and streams, and, in summer time, was the favourite resort of the young, the gay, and the gallant. Augustus erected several porticos; and, prompted by his example, many of his most distinguished and opulent friends vied with each other in similar works of magnificence. Among the former were the porticos of Caius and Lucius, with a basilica annexed to it; that of Octavia, which rose near the theatre of Marcellus, and contributed not a little to its beauty as well as convenience; that of Livia, near the Roman Forum. This latter was ornamented with a collection of ancient pictures, and shaded by a vine of prodigious luxuriance. Ovid alludes to it in his usual lively manner. But this, and every edifice of the kind prior to this æra, was eclipsed by the splendour of the *Palatine* portico, dedicated to Apollo. It was supported by pillars of Numidian marble, enlivened with exquisite paintings and statues, and emblazoned with brass and gold. It enclosed the library and temple of Apollo, so often alluded to by the writers of the Augustan age, and was deservedly ranked among the wonders of the city. It is described by Propertius, lib. xi. 81. Another portico, erected by this emperor, was called *Ad Nationes*, from the statues with which it was furnished, representing various nations in their respective habits. It was, perhaps, still more remarkable for a statue of Hercules, lying neglected on the ground, though it had been brought from Carthage, and was that to which the Carthaginians were accustomed to offer human victims. The *Porticus Septorum* was finished, or repaired, by Agrippa, as Pliny says, and enclosed not the *Septa Tribata Comitii*, where the people assembled to vote, but *Diribitorium*, or place where the legions were mustered and paid. These edifices were all of marble, and the latter, in particular, unusually magnificent. Agrippa also built and gave his name to another portico, which, as some suppose, was connected with the present portico of the Pantheon, and carried around it. But as he had erected *Thermæ*, and other noble fabrics near that edifice, it is more probable that his portico enclosed the whole, and united them together in one grand circumference. That it was extensive, is evident from Horace, who represents it as a public walk, much frequented. The materials were, as in all Agrippa's works, rich marbles, and the ornaments, paintings and statues. The portico of *Hercules*, or of *Philippus*, was so called because it was rebuilt by the latter at the instigation of Augustus, and dedicated to Hercules, whose temple it enclosed, under the appellation of *Musagetos*, a leader of the Muses. It was erected solely for the ornament of the city, and of course was decorated with an unusual profusion of splendid objects; the paintings of Apelles, Zeuxis, and Antiphilus, forming part of its furniture. Several porticos took their names from the temples to which they were annexed, and seem to have formed either vast squares or courts before, or immense galleries round their respective temples, thus detaching them from ordinary buildings, and giving them a distinguished and solitary grandeur. The porticos of *Quirinus* and *Europa*, are mentioned by Martial as fashionable places of resort, and must consequently have been very spacious. That of *Isis* was remarkable, not only for paintings but mosaics.

The approach to the curiæ, the basilicæ, and the forums, were generally by porticos; several ranges of porticos led to the capitol, and lined the sides of the declivity; the Campus Martius was surrounded by an uninterrupted colonnade; almost every emperor distinguished himself by the erection of a new edifice of the kind; and Nero is said, by Suetonius, to have lined the streets of Rome (those probably which he himself had rebuilt) with a continued portico. Several porticos were erected by later emperors, of astonishing extent; such were that of Gallienus, extending nearly two miles along the Via Flaminia; and that of Gordian in the Campus Martius, which was a mile in length, and formed of one range of pilasters and four of columns, opening upon plantations of box, cedar, and myrtle.

PORTLAND STONE, (*Saxum Arenarium Portlandicum*, of Da Costa, and *Psadurium Hebes*, *Albidum*, *Laxius*, of Hill), an alkaline sand-stone, of a dull whitish colour, heavy, moderately hard, of a somewhat flat texture, and composed of a large roundish grit, cemented together by an earthy spar, and intermixed with numerous glittering spangles of pure spar; the grit splits in the cutting of the stone, so that it is capable of being brought to a surface very smooth and equal; it will not strike fire with steel, and burns to a slight ashen hue. The Portland stone belongs to the third variety of the compact limestone, under the calcareous genus, whose fracture is earthy, according to Kirwan's arrangement. Its specific gravity is 2.461. There are vast quarries of it in the island of Portland, in Dorsetshire, whence its name. It is brought from thence in large quantities to London, and is much used in building. This and all similar sorts of stone, composed of granules, and not of a laminated texture, will cut and rive in any direction, as well in a perpendicular, or in a diagonal, as horizontally and parallel to the site of the strata. For this reason they have obtained the name of *free-stone*. This stone is very soft when it comes out of the quarry, works very easily, but becomes in time very hard and durable.

POSITION, in architecture, the situation of a building with regard to the points of the horizon. Vitruvius directs the position of a building to be such, that the four corners may point directly to the four winds.

Position, in geometry, a term sometimes used in contradistinction to *magnitude*. Thus a line is said to be *given in position* (*positione data*) when its situation, bearing, or direction, with regard to some other line, is given: on the contrary, a line is *given in magnitude*, when its length is given, but not its situation.

Sir Isaac Newton shows how to find a point, from which three lines, perpendicularly let fall, to three other lines given in position, have any given ratio, &c.

POST, in building, a large piece of timber, placed upright in houses, &c. The corner posts are called the *principal*, or *fencing* posts; the posts framed between the principal posts for strengthening the roof of a house are called the *queen-posts*. An excellent method to preserve posts from rotting, is to burn the outside of the ends that are to be set in the ground to a coal.

Post, *Crown*, or King-Post. *See* Crown-Post.

Post and Paling, a kind of close wooden fence, constructed by means of posts set into the ground, and pales nailed to rails between them.

This sort of fence can seldom be had recourse to for common farm-purposes, except about the buildings or home-stalls. The only circumstances concerning it, which seem to require any notice in this place, are, that the posts, whether of rough or sawn timber, should be charred, or burnt, in a superficial manner, in the parts which are designed to be set in, or nearly on a level with the surface of the ground, in order to prevent their decay in these places. The posts should also be well and firmly put into the earth; and the sawn rails, whether for close or open paling, should be cut triangular-wise, by slitting square scantlings diagonally. The pales of open paling should be cut in the same manner; the broadest sides of the pales being firmly nailed against the broad flat sides of the rails, at such distances from each other, and of such height and strength, as the given purpose may stand in need of, or require.

Post and Railing, another sort of open wooden fence, often used for protecting young quick-hedges, consisting of posts and rails, &c.

These sorts of fences, or protections, should likewise have constantly the parts which are set into the ground, and the rails, prepared in the same manner as directed above.

POSTERN, a small doorway in the rear of a building, more particularly applied to those of castles, which were reserved for private communication with the exterior.

POSTICUM, the postern-gate, or back-door, of any fabric, for private entrance.

POSTIQUE (from the Italian *posticcio*, *added*;) an ornament of sculpture is said to be *postique*, when it is superadded after the work itself is done. A table of marble, or other matter, is also said to be *postique*, when it is incrustated in a decoration of architecture, &c.

POSTSCENIUM, or Parascenium, among the Romans, was a place behind the theatre, where the actors withdrew to dress, undress, &c.

POT-METAL, that kind of stained glass into which the colours are incorporated while in a state of fusion.

POWDERINGS, a term sometimes used for devices serving to fill up vacant spaces in carved works; as also in escutcheons, writings, &c.

POWER, in mechanics, a force, which, being applied to a machine, tends to produce motion; whether it actually produces it or not. In the former case, it is called a *moving* power; in the latter, a *sustaining* power. If the power be a man, or a brute, it is called an *animate* power; if the air, water, fire, gravity, or elasticity, an *inanimate* power. *See* FORCE.

POWER, is also used for any of the six simple machines, viz., the *lever*, *balance*, *screw*, *axis in peritrochio*, *wedge*, and *pulley;* which are particularly called the *mechanical powers.*

POZZOLANA. *See* PUZZOLANA.

PRACTICE. See CROSS MULTIPLICATION.

PRAXITELES, a celebrated sculptor of antiquity, born in Magna Græcia, who flourished about the year 364 B. C. He excelled particularly in the working of marble, and was the author of some of the most famous statues noticed by ancient writers; among these were two of Venus, one clothed and the other naked. The first was purchased by the Coans, who preferred it as the most decent. The Cnidians took the other, which was so exquisitely beautiful, that many persons took a voyage to the island for the sole purpose of seeing it. Praxiteles was deeply enamoured of the famous courtezan Phryne, of whom he made several statues, one of which was erected at Delphi. Many of his performances were in the Ceramicus at Athens; among the rest the statues of Harmodius and Aristogiton, which Xerxes carried away, and Alexander afterwards restored. Many were extant at a later period in Rome. His most noted works were in marble, but he cast many statues in metal, which, as well as those of marble, were greatly admired. He had a son, Cephissodorus, who inherited his skill and fame.

PREACHING CROSS, a cross erected in the highway for the purpose of preaching, as implied by the adjective.

PRECEPTORY, a subordinate or branch establishment of Knights' Templars, under the management of a *preceptor;* the same as the *commandery* of the Knights' Hospitallers.

PREPARATION, (from the Latin, *præparatio*), in mathematics, one of the parts or branches of a demonstration.

If it be a proposition in geometry that is to be demonstrated, the preparation consists in certain lines to be drawn in the figure: if a proposition in arithmetic, in some computation to be made, to obtain more easily the demonstration.

PRESBYTERY, that part of the church in the chancel set apart for the officiating priests.

PRESERVING OF TIMBER. *See* TIMBER.

PRICE BOOK, a book containing the prices of labour and materials, of the various articles employed in building. See *The Universal Price Book*, with regard to labour only, under the articles Carpentry and Joinery.

PRICK-POST, or QUEEN-POST. *See* Post.

PRIME FIGURE, in geometry, one that cannot be divided into any other figures more simple than itself.

Such is a triangle among planes; and the pyramids in solids. For all planes are made of the first, and all bodies, or solids, are compounded of the second.

PRIMING, among painters, the laying on of the first colour.

PRINCIPAL BRACE, a brace immediately under the principal rafters or parallel to them, in a state of compression, assisting with the principals to support the timbers of the roof.

PRINCIPAL POINT, a point in the perspective plane, upon which a line drawn from the eye, perpendicular to the plane, falls. This point is in the intersection of the horizontal and vertical plane; and is also called the *point of sight*, and *point of the eye. See* PERSPECTIVE.

PRINCIPAL RAFTERS, two inclined timbers in a roof, either meeting each other in the middle, or the ends of a beam in the middle of the roof, the lower ends resting on the ends of the tie-beam: their office is to support the roof.

PRINCIPAL RAY, that which passes perpendicularly from the spectator's eye to the perspective plane, or picture. Whence the point where this ray falls on the plane is, by some, called *the principal point*, which other writers call *the centre of the picture*, and *the point of concurrence.*

PRIORY denotes a society of religious, the superior of which was denominated a prior, or prioress; and of these there were two sorts; as where the prior was chief governor, as fully as any abbot in his abbey, and was chosen by the convent; such were the cathedral priors, and most of the Austin order, and where the priory was a cell subordinate to some great abbey, and the prior was placed and displaced at the will of the abbot.

PRISM, (from πρίσμα, something sawn, or cut off) in geometry, an oblong, or solid body, contained under more than four planes, and whose bases are equal, parallel, and alike situate.

PRISMOID, (formed of πρίσμα and εἶδος) a solid figure, having for its two ends any dissimilar parallel plane figures of the same number of sides, and all the upright sides of the solid trapezoids. If the ends of the prismoid be bounded by dissimilar curves, it is sometimes called a *cylindroid.*

To find the solidity of a prismoid, the general rule is: To the sum of the areas of the two ends, add four times the area of a section parallel to, and equally distant from both ends: multiply the last sum by the height, and one-sixth of the product will be the solidity. Or, if the basis be dissimilar rectangles, take two corresponding dimensions, and multiply each by the sum of double the other dimension of the same end, and the dimension of the other end corresponding to this last dimension: then multiply the sum of the products by the height, and one-sixth of the last product will be the solidity.

PRISON, an edifice erected for the confinement of debtors and criminals, until they be discharged or convicted. The principal properties in the construction of a prison, are those of strength and convenience. Strength is of the utmost consequence, in order to prevent the escape of the prisoners; and convenience, to promote their health; to have the apartments of their due size and arrangement, according to the different species of criminals, and to be handy in respect of the keeper.

Before the philanthropic labours of the celebrated Howard had made known to the world the dreadful condition of the public prisons of that day, such places were hardly fitted for the habitations even of the lowest animals, much less for the confinement of human beings. But his exertions having called public attention to the subject, a gradual amelioration has taken place, not only in the construction but in the whole system of prison discipline; until it may be doubted whether modern philanthropy is not running into the opposite extreme, and rendering abodes intended for the punishment of the vicious, superior to those attainable by the unfortunate and the poor.

It would be impossible to point out with any degree of minuteness the successive steps in prison improvement; nor is it, perhaps, strictly within the objects of this work to do so; it will be sufficient to describe one or two modern buildings adapted for the confinement of criminals, as specimens of the great advance made within the last few years.

Before doing so, however, it may not be uninteresting to give Mr. Howard's recommendations relative to the situation and arrangements of a prison, by way of showing the ideas entertained at that time on the subject.

"A county gaol," he says, "and indeed every prison, should be built on a spot that is airy, and, if possible, near a river, or brook. I have commonly found prisons situate near a river, the cleanest and most healthy. They generally have not (and, indeed, could not well have) subterraneous dungeons, which have been so fatal to thousands: and, by their nearness to running water, another evil, almost as noxious, is prevented, that is, the stench of sewers.

"I said, a gaol should be near a stream; but I must annex this caution, that it be not so near as that either the house or yard shall be within the reach of floods. This was so little thought of at Appleby, in Westmoreland, when their new gaol was first building, that I saw the walls marked from nine inches to three feet high by floods.

"If it be not practicable to build near a stream, then an eminence should be chosen: for as the wall round a prison should be so high as greatly to obstruct a free circulation of air, this inconvenience should be lessened by rising ground, and the prison should not be surrounded by other buildings, nor built in the middle of a town or city.

"That part of the building which is detached from the walls, and contains the men-felons' ward, may be square, or rectangular, raised on arcades, that it may be more airy, and leave under it a dry walk in wet weather. These wards over arcades are also best for safety; for I have found that escapes have been most commonly effected by undermining cells and dungeons. If felons should find any other means to break out of this raised ward, they will still be stopped by the wall of the court, which is the principal security; and the walls of the wards need not then be of that great thickness they are generally built, whereby the access of light and air is impeded.

"I wish to have so many small rooms, or cabins, that each criminal may sleep alone. These rooms to be ten feet high to the crown of the arch, and have double doors, one of them iron-latticed, for the circulation of air. If it be difficult to prevent their being together in the day-time, they should, by all means, be separated at night. Solitude and silence are favourable to reflection; and may, possibly, lead them to repentance. Privacy and hours of thoughtfulness are necessary for those who must soon leave the world; (yet how contrary to this is our practice! Keepers have assured me, that they have made £5 a day after the condemnation of their prisoners.)—In the Old Newgate there were fifteen cells for persons in this situation, which are still left standing, and are annexed to the new building.

"The separation I am pleading for, especially at night, would prevent escapes, or make them very difficult; for that is the time in which they are generally planned, and effected. This also would prevent their robbing one another in the night. Another reason for separation is, that it would free gaolers from a difficulty of which I have heard them complain: they hardly know where to keep criminals admitted to be evidence for the king: these would be murdered by their accomplices, if put among them; and in more than one prison, I have seen them, for that reason, put in the women's ward.

"Where there are opposite windows, they should have shutters; but these should be open all day. In the men-felons' ward, the windows should be six feet from the floor; there should be no glass; nor should the prisoners be allowed to stop them with straw, &c.

"The women-felons' ward should be quite distinct from that of the men; and the young criminals from old and hardened offenders. Each of these three classes should also have their day-room, or kitchen, with a fire-place; and their court and offices all separate.

"Every court should be paved with flags, or flat stones, for the more convenient washing it; and have a good pump, or water laid on—both, if possible; and the pump and pipes should be repaired as soon as they need it; otherwise the gaols will soon be offensive and unwholesome, as I have always found them to be in such cases. A small stream constantly running in the court is very desirable. In a room, or shed, near the pump, or pipe, there should be a commodious bath, with steps (as there is in some country hospitals) to wash prisoners that come in dirty, and to induce them afterwards to the frequent use of it. It should be filled every morning, and let off in the evening through the sewers into the drains. There should also be a copper in the shed, to heat a quantity of water sufficient to warm that in the bath, for those that are sickly. There should also be an oven: nothing so effectually destroys vermin in clothes and bedding, nor purifies them so thoroughly when tainted with infection, as being a few hours in an oven moderately heated.

"The infirmary, or sick wards, should be in the most airy part of the court, quite detached from the rest of the gaol, and raised on arcades. These rooms should never be without crib beds and bedding. In the middle of the floor of each room there should be a grate of twelve or fourteen inches square, for a current of air, covered with a shutter or hatch at night.

"The sewers, or vaults, of all prisons, should be in the courts, and not in the passages, and (like those in the colleges) close boarded between the seat up to the ceiling, the boards projecting ten inches before each seat.

"The infirmary and sheds will not render the court unsafe, provided the walls have parapets, or small *chevaux de frise.*

"Debtors and felons should have wards totally separate; the peace, the cleanliness, the health, and morals of debtors, cannot be secured otherwise.

"The ward for men-debtors should also be over arcades, and placed on one side of the gaoler's house. This house should be in or near the middle of the gaol, with windows to the felons' and the debtors' courts. This would be a check on the prisoners, to keep them in order; and would engage the gaoler to be attentive to cleanliness and constant washing, to prevent his own apartments from being offensive.

"A chapel is necessary in a gaol. I have chosen for it what seems to me a proper situation. It should have a gallery for debtors, or women; for the latter should be out of sight of all the other prisoners, and the rest may be separated below. Bibles and prayer-books should be chained at convenient distances on each side: those who tear, or otherwise damage them, should be punished."

The introduction of the separate system of confining prisoners, led to great alterations in the mode of constructing prisons; and the penitentiary at Millbank was built for the purpose of carrying this plan of prison-discipline into effect. It was completed in the year 1821, and is calculated for the reception of twelve hundred convicts. The outer walls inclosed not less than eighteen acres. The principal entrance on Millbank is a stone-fronted lodge, with a Gothic arch, and false portcullis over the gates. At the top, "Penitentiary" is written in large characters. The cells for solitary confinement are arranged within the quadrangular building, which stands a considerable distance from the outer wall. At each angle of the structure there is a tower or bastion to form water-closets, to communicate with the different ranges of cells. Each side has three tiers of windows (twenty-seven in a tier) strongly grated with iron. The bastions are also pierced for loop-holes, to give light and air. Projections, or out-works, are built for various departments, and the space between the building and the wall is laid out as gardens.

The model prison at Pentonville was planned with a view to embrace every improvement that modern science could suggest. It is placed in an elevated and airy situation, well adapted for such a building, and for securing the health of the prisoners. The following description will show the general principle adopted in its construction.

The boundary-wall is of a height above the ground sufficient to preclude all chance of escape by climbing, and the foundation of such a depth as to prevent undermining in the course of a single night. It presents an even, smooth surface on both sides. A clear space is preserved on the outside of the boundary, that no erection may be made against it, and that the exterior may be open to inspection; and in like manner the prison-wings are not connected with it, but a clear space preserved round the interior. There is only one gateway in this external boundary, which is placed immediately opposite the entrance-door, opening into an enclosed court-yard. The gate being retired a little, it is deemed will be of advantage in affording the means of defending it through loop-holes made in the side-walls, should attempts be made to force it during riots or popular excitement. Accommodation is afforded within the prison walls for officers, in detached houses. The prison is entered by a broad passage, leading through the entrance-building to the central hall, on the sides of which are convenient apartments for turnkey, male and female superintendents, and surgeon, and a mess-room for the officers, together with a room for the magistrates, and an office for the governor. These last rooms look into a central-hall, and command a view of the interior of the prison; there are likewise staircases leading to the basement, infirmary, and chapel. The basement of the entrance-building contains reception-cells, a cleansing-room for males, a fumigating oven for disinfecting prisoners, clothes; store-rooms for clothing; and prison stores, such as bedding, &c.; water-closet; and a room for the steward or prison-officer employed about the kitchen and store departments. A portion of the upper part of this entrance-building is appropriated as a chapel, and the remainder as an infirmary, or convalescent-rooms—the former entering into the central hall, and the latter entirely detached from the rest of the prison by a partition-wall, being a separate staircase from the passage below. The central hall, as before explained, opens from the floor to the roof, and is used as the principal station of the officers engaged in carrying on the discipline of the prison. A gallery—which is a continuation of that into which the prison-rooms or cells open—runs round the central hall, about ten feet above the floor, affording access to the chapel and all the wings, staircases being placed in convenient situations communicating with it. The windows of the hall overlook the airing-yards, and the greater part of the space within the boundary wall. The general kitchen of the prison, the bread-room, scullery, coal-cellar, and an apparatus for cooking, and for ventilating and warming the entrance-building, are situated in the basement under the central hall, and a small portion of the adjacent wings. The prison-wings, as before explained, radiate from the central hall, an open passage or corridor being designed to run longitudinally through the centre of each; and the prison-rooms, or cells, open into the corridor; these being ranged in three stories. The lower range is on the level of the floor of the corridor and hall; the upper ranges open upon a narrow gallery attached to the wall, which is continued round the central hall, as already explained. At the farther extremity of each prison-wing, a flight of steps, covered by a trap-door, lead to the punishment cells, which are placed in the basement. In the centre of each wing, a circular iron staircase is designed to communicate with the galleries, and continued into the store-rooms below. In addition to the stores and ventilating apparatus, placed in the basement, under the centre of each prison-wing is a large bath, the use of which is essentially conducive to the health of the prisoners. The general dimensions of the cells are about 13 feet long by 7 broad; 9 or 10 feet high to the under side of the arched ceiling. It is deemed desirable that the length should greatly exceed the breadth, as this affords a better opportunity of taking exercise, and facilitates the unobserved inspection of the interior. The partitions between the cells are not less than 18 inches in thickness, thereby precluding, as much as possible the transmission of sound between adjoining cells. The external walls are two bricks and a half thick, or two feet of stone; the internal walls next the corridor or passage, two bricks thick, or 18 inches of stone; the flues are 12 by 5 inches, and are worked in the corridor-wall and the external wall for ventilation. The windows of the cells are placed close under the arch, and have stone sills. The iron window-frame is a fixture let into a groove, with proper rebates for the glass, which is unpolished. The general dimensions of the windows are about 3 feet 6 inches long, and not exceeding 11 inches in breadth. For additional security, a strong wrought-iron bar is placed outside the window-frame, in the direction of its length, so as to divide the opening into two portions of about 5 inches each. The cells have single doors, the frame of which is of oak, 6 inches by 5; the doors, 2 inches thick, of deal, framed flush on both sides; the edges covered with felt, to prevent noise in the transmission of sound; a strong iron plating is on the side next the cell, riveted through, and the doors are hung with strong 4½-inch butt hinges, and fastened with a spring lock and latch; a bevelled aperture is cut for the inspection slide; and a trap-door, 6 by 9, is fixed in the door for passing provisions through, and which is hung on two centres, so as to form a shelf when let down; it is fitted with a strong bottom thumb-bolt, to secure it in its place. The outer door next the corridor is hung with 4½-inch butt hinges, working on centres, the object being that the door may be opened without noise, for inspection; the edge is covered with felt, and shuts into a rebate in the door frame, flush with the wall. For every cell there are suitable means provided for a constant supply of fresh water, and for necessary relief, without entailing unwholesome smells. The exercise of prisoners in the open air, without compromising individual separation, is thus obtained. The airing-yards radiate from a central point, round which is placed a dark passage, affording an inspection into each yard. The advantage of a dark passage is, that it facilitates close and unobserved inspection. The yards have open railings at both extremities, in order to allow a free circulation of air; and they are so constructed that no two prisoners can see each other. A small roof is attached to the division-walls, to afford shelter when necessary: and the position of the yards with reference to the doors in the centre of the prison-wings, gives a ready means of access from the cells.

The chapel is fitted up with separate stalls or sittings; the sides of each stall, and the doors, which form the continuation of those sides, and shut up the general passage to each row, radiate upon the pulpit, so that each prisoner can see, and be seen, by the chaplain. The back of each row of seats is made of such a height as to intercept the communication between the rows, when the prisoners are standing up, and yet not so high as to conceal them from the observation of the prison-officers when sitting down. A double passage is made down the centre of the chapel, opening into and communicating with the gallery surrounding the central hall, and thus affording two points of access to it. A staircase leads from the gallery to a door on a convenient level for entering, near the upper row of seats, from whence a succession of steps, arranged in pairs, communicate downwards with each row in front. The ceiling of the chapel is coved, and ventilators are introduced into it; the roof and the bearers supporting the seats being made of iron. For the ventilation of the cells, an apparatus is placed in the centre of the basement-story of each wing, the object of which is to secure a more complete ventilation than could be obtained, if the system had been extended from either extremity. The apparatus consists of a proportion of large tubes or pipes for hot water, and in connection with it there is a large cold-air flue communicating with a shaft out of doors, which serves for two wings. The fresh air introduced through the flue, is brought in contact with and passes through the tubes of the apparatus, and may therefore be warmed or left at its natural temperature, as may be desirable. The air thus brought from without, then passes to the right and left along the flue which runs horizontally under the floor of the corridor, from whence a communication is established by lateral small flues, separately with each cell, both on the lower and upper floors.

The means whereby foul air is extracted from the flues are these: a grating is placed close to the door of each cell, on the side next to the outer wall, and diagonally opposite to where the fresh air is introduced. This grate opens into a flue which passes down the outer wall, and communicates with a main foul-air flue placed under the floor of the basement. These main foul-air flues terminate in a chimney-shaft rising above the top of the building. With a view to obstruct the transmission of sound, and prevent that communication which might be attempted by means of the flues, the main foul-air flues are divided into three compartments, one for each range of cells. By means of the system of flues which has been described, a communication is established—first, from the outer-air, and then from the floor of each cell back again through the extracting or foul-air flues or chimney into the outer air. In order to regulate the quantity of air admitted into each cell, which, with apertures of equal size, would differ in proportion to the distance from the apparatus, a valve or damper may be placed in the extracting flues, close to the outer door of each cell in the corridor, so constructed as not to close it up entirely, but to leave sufficient range to operate upon the circulation; the damper being at the command of the superintending officer, he is enabled to regulate the quantity according to circumstances. By the application of this system of ventilation, it has been found that a circulation of air of from six to eight cubic feet per minute, may be kept up through all the cells, at all times of the year, and under all possible circumstances, when the doors and windows of each are perfectly closed.—*Fourth Report of the Inspectors of Prisons.*

In September, 1847, a number of gentlemen taking an active part in the management of prisons, assembled at Brussels under the title of a "Penitentiary Congress;" for the purpose of discussing various questions connected with prison discipline. In this "Congress," colonel Jebb commissioned by the secretary of state (for England), Mr. B. Rotch (the Middlesex magistrate), and Mr. Charles Pearson, took a distinguished part.

"Foremost amongst the subjects of debate was *the mode of constructing cellular prisons*; and, as this is a matter which greatly concerns architects and others of our readers, we deem it right to record the results.

"Colonel Jebb rightly remarked, that there was an intimate connection between the construction and the discipline of a prison. He was impressed with the necessity of having the various departments and the various offices of the establishment kept quite distinct one from the other, with a convenient mode of access to the centre and the cells. It was also essential that the families of the officers should not live in the prisons; that the latter should come to their employment at a certain hour during the day, and attend alternately at night. He saw by a paragraph in the programme, that it was proposed not to construct prisons with more than three stories, including the ground-floor. He thought, however, when the number of prisoners amounted to 700 or 800, it would be more convenient to have four stories, than very long wings. With respect to the attending of divine worship, a mode existed in Pentonville and other places, by which all the prisoners might proceed separately to the church or chapel, and hear and see the person officiating, without being seen by any one, except by him. The time occupied in proceeding to and departing from divine service, was seven minutes respectively. With respect to the size of the cells, he thought that, as a general rule, they should be about 13 feet long, 7 broad, and from 8 to 9 feet high. Of course it would be necessary sometimes to make larger cells for special purposes."

The following are some of the propositions, which were agreed to *nem. con.*

"The buildings and exercise-ground should be disposed so as to receive the rays of the sun, and be sheltered from rain and the north wind. 2nd. The destination of a prison must in some sort determine its internal arrangement. If it is to be a penal prison, none but convicts of one sex should be placed in each, and the number should never surpass the maximum of 500, although the congress were of opinion that a less number would be better. If it is to be a preventive establishment, different wings and sections should be parted off for the different categories of prisoners. The two sexes at any rate must be kept distinct. 3rd. The number of stories should not be more than three, including the ground-floor. The parts of the prison specially destined for persons undergoing their sentences, should be disposed in such a manner as, 1st, to allow of a complete separation by day as well as by night; 2nd, to give them the means of open-air exercise; 3rd, to enable them to be suitably employed, to receive instruction, and to assist at divine service and religious exercises, without infringing the rule of separation. 4th. To facilitate the mode of superintendence of the prisoners, and of frequent communication with them."

The following propositions were read and discussed:—

"*Central Observatory.*—The various parts of the building should be connected with a central point of inspection, from which the head of the establishment may inspect, without being under the necessity of moving all the essential branches of the service. Regard must be had to the internal distribution of the localities, to the arrangement of the galleries, and to the choice of the materials of construction, in order that no material obstacle may thwart that inspection.

"*Cells.*—In the disposition and arrangement of the cells, regard must be had to the following conditions:—1. The cells must be large enough to allow of the prisoners taking exercise, carrying on trades, and enjoying sufficient space and air for the preservation of their health: the space should vary from 28 to 35 cubic metres. 2. They should be lighted up, ventilated, and heated in a suitable manner. 3. Their construction should be such as to allow no communication between their inmates. 4. They should be furnished with bed and bedding, with a fixed wash-hand basin with a tap; with a water-closet, and with other necessary articles. The prisoners should also have the means of giving the alarm to the attendants, in case of illness or accident, or under any circumstances in which their presence might be necessary. The prisoners should be subjected to an easy, but unperceived inspection.

"*Special Cells.*—In penal prisons, it is necessary to have a certain number of special cells for the infirmary, for special punishments, for the different callings, and for prisoners on their first arrival. The cells for infirmaries, chiefly reserved for patients who cannot be suitably attended to in the ordinary cells, should be more spacious than the former, and should be disposed in such a manner as to allow of the access of the attendants. One cell of that kind for every forty or fifty prisoners would possibly be sufficient. Cells for punishment should be stronger than others, and should be built in such a manner as to be easily darkened, if necessary. One such cell would be sufficient for about 100 prisoners. The dimensions of the cells for the exercise of certain trades should correspond with the use to which they are put: they should be situated in preference on the lower stories, and their number must depend on the nature of the trades carried on in the prison. In prisons where prisoners are constantly arriving, a certain number of cells should be made, in which each prisoner may be placed temporarily, previous to being seen by the surgeon: and such cells might be of smaller dimensions than others.

"*Heating and Ventilation.*—Whatever the system of ventilating by heating may be, its result should be the following: —A sufficiency to each cell of fresh air, or, if necessary, of air tempered for each prisoner, without the inconvenience of draughts. The extraction from each cell of a quantity of foul air equivalent to the quantity of pure air introduced, and of the carrying on of the heating and ventilating without facilitating the means of communication, whether of sound or otherwise, between the different cells.

"Mr. Rotch said, that excellent as the Pentonville prison was, he could not help saying that many things were wanting to render that establishment perfect. All the medical men to whom he had spoken on the subject were of opinion, that the temperature should be lowered at night-time. The mode of ventilation was not good in Pentonville: and he would just observe, that if people were satisfied with what was simply good, they would never have better. The question of ventilation was a most important one, particularly for nations which, unlike England, had no colonies to which criminals might be transported, and which were, therefore, under the necessity of detaining the criminals for a long time in prison. It must not be said that there was no way of bringing the fresh air into prisons conducted on the cellular system; but rather urge architects *to find out a plan to that effect before the next congress was held.* The system of ventilation in Clerkenwell prison had been lately changed, because it was found to be a bad one. Mr. Rotch here showed the meeting a plan for procuring ventilation: the principle appearing to be, that fresh air should be applied from the lower parts of the building, whilst the foul air should escape from the roof of the house. He would just state one fact, to show that at Pentonville some improvements were required. About three weeks ago, he had been informed by one of the furnace or oven men of that prison, that it required thirty-six hours to lower the temperature.

"Colonel Jebb admitted that it would be better to admit air into the prison by means of open windows; but then such windows would admit of communication between the cells. He did not think that the present system at Pentonville could be well changed at present, without endangering the health of the inmates. Should the medical men, however, decide otherwise, alterations would be made. He thought that the present mode of ventilation would not act prejudicially on the health of the inmates during the eighteen months or so they remained in the model prison.

"The article in favour of the establishment of a central observatory of inspection was adopted; as was also one relating to cells, with the exception of a sentence which fixed their space at from 28 to 35 cubic metres."

The congress also adopted the following propositions:—

"*Chapels.*—The chapel should be so disposed as that each prisoner should join in the exercise of worship—seeing and hearing the minister officiate, without being himself seen; regard being had, at the same time, to the fundamental principle of the separation of prisoners amongst themselves.

"*Parlours.*—A certain number of cell-parlours should be made, for the use of prisoners not authorized to meet their relations or friends in their own cells.

"*Domestic Service—Administration—Lodging of persons employed in Prisons.*—Whatever plan may be adopted, independent of the localities above mentioned, each prison on the cellular system should contain a bath-room, with a number of separate baths in proportion to the number of inmates; a kitchen, with its accessories; a baking-house; and a wash-house: a certain number of magazines for provisions, fuel, clothes, general stores, and manufactured goods, according to the destination of the prison; a clerk's office; and a meeting-room for the committee of surveillance; lodgings for the director or chief officer, the guards, or watchers; and, in penal prisons, for the sub-director, the superintendent of works, the almoner, the doctor or his assistant, and of such other persons as may be placed in each prison by the administration."—*Builder October* 9, 1847.

In the new prison which has been built at Holloway, for the Corporation of London, it has been endeavoured to carry out these ideas. It is constructed upon the radiating principle, having four wings diverging from one centre, with two other wings in front of the former: one of these wings is for juvenile offenders, with school-rooms attached; the other for females, with work-rooms and laundry; the other four radiating wings constitute the male adult prison. These have large work-rooms attached, and an apparatus for lifting water. The wings are twelve cells in length, or about 100 feet, and 3 stories high. The corridors are 16 feet wide, and are open up to the arched ceiling, with galleries leading to the upper cells. The cells are 13 feet by 7 feet, fitted up with water-closets, wash-hand basin, cupboard, table, stool, &c: these are warmed by means of hot-water pipes laid under the corridor-floor, the air passing over them and through the flues provided in the thickness of the wall, and entering the cell over the door. The ventilation is to be effected by means of a shaft, 146 feet high, of large dimensions. Inside this shaft is a tube of boiler-plate the whole height of the shaft, 5 feet diameter at bottom and 3 feet at top. In addition to a furnace at the bottom of the tube, the smoke from the various chimneys, together with the spare heat from the kitchen boilers, is conveyed into it, and will necessarily raise the temperature of the column of air in the shaft, and make it pass off with great rapidity. The theory is, that as no air can enter the shaft without previously passing through the cell, a constant supply of fresh air will thereby be conveyed to the prisoners.

The chapel is a spacious room 70 feet by 40, and 48 feet to the ridge of the roof, with two deep recesses for the females and juveniles, and will contain sittings for 380 prisoners. Provision is made for having a constant supply of fresh air passing through the chapel to the ventilating shaft. The arrangements for taking the prisoners from the various cells to the chapel, have been well considered. The females and juveniles enter by separate doors near the altar, while the male prisoners enter by four different passages at the opposite end. The kitchen is of ample dimensions, and being close to the base of the ventilating shaft, the steam and smell from the victuals will be readily carried off. The well-house is to be fitted with one of Mr. Bessemer's disc pumps, and to be worked like a capstan, in a building 30 feet diameter. The shaft is 217 feet deep, bore 102 feet, making a total depth of 319 feet. The depth to the water is 153 feet. The tanks, to contain 14,000 gallons, are placed over the front towers at a great elevation, from which the cells and other places are supplied: the whole depth of bore is in chalk.

The whole extent of frontage next the Camden-road is of Kentish rag, with Caen-stone dressings. The style is castellated Gothic. The sides of the chapel building, and the back wings, are of brick; the windows to the cells have Parkspring-stone sills, with splayed brick reveals. The whole of the parapets are coped with Caen-stone. The roofs are flat, covered with asphalte, upon plain tiles and iron rafters. As the extracting flues for ventilation are immediately under the roof-covering, two thicknesses of plain tiles have been put 6 inches apart, to prevent the atmosphere acting in any way against the free current of air passing through them.

The porter's lodge, which stands about 66 feet in front of the entrance-building, is also of rag, with Caen-stone dressings, and contains accommodation for two families. Between the last-named building and the road, stand the two houses intended for the governor and chaplain, with large gardens attached.

The accommodation afforded in the prison is as follows—

Females	60	
Juveniles	61	
Male adults	283	
		404
Reception cells		14
Punishment ditto		18
		436

with fourteen work-rooms, equal to ninety-six cells; offices for the governor, chaplain, surgeon, steward, clerks, &c.; apartments for the surgeon and deputy-governor, and for master and two turnkeys in juvenile wing, matron and two turnkeys in female wing. The ground, consisting of ten acres, is surrounded by a brick wall 18 feet high with a strip of land 20 feet broad round its exterior.

The prison is built upon land originally purchased by the City for the purposes of a cemetery during the raging of the cholera in 1832. It is a little to the westward of the Holloway-road, upon the side of a hill, having a declivity of 4 feet in 100. Previous to the commencement of the works, the City authorities entered into an arrangement with the commissioners of sewers, who built a new sewer for the purpose of securing good drainage for the prison.

The building has been erected from the design and under the able superintendence of Mr. Bunning, the City architect. Mr. Jay is the contractor employed; Mr Lawrie, the clerk of the works.

The original estimate for the building was £92,293; but the committee considered that sum too large, and orders were given to cut it down. The pruning knife was applied, and it was reduced to the extent of £14,635. The contract now stands as follows:—Buildings, £77,655; warming, ventilating, water-pipes, gas fittings, locks, bells, cooking apparatus, laundry fittings, forming the grounds, fittings and furniture, about £14,000; so that, after allowing for any additions the corporation may think proper to make, the expense of the whole may be called something under £100,000.

Prison-discipline is a problem the wisest of our legislators have not been able to solve. When Pentonville prison was erected, it was thought that complete separation, by its severity, would lessen crime. The result, however, has scarcely justified the belief. The government have had ample opportunity of forming an opinion upon the merits of the separate system; consequently, within the last twelve months, some relaxation has been made, and about 10 per cent, as we understand, are now in association.

With so many perplexing opinions before them, the City authorities were at a loss upon what principle to arrange their prison, but they adopted a middle course, and they have now the means of confining the vicious in separate cells; and have a sufficient number of work-rooms for classified association.

It is expected that this prison will be ready for occupation in the early part of the year 1852. *Builder*, 1851.

PROBLEM, (from πρόβλημα) in geometry, a proposition in which some operation, or construction, is required; as to divide a line, to make an angle, to draw a circle through three points not in a right line, &c.

Messieurs, of the Port Royal, define a *geometrical* problem, a proposition given to be demonstrated, in which something is required to be done; and what is done, to be proved to be the thing required.

A problem, according to Wolfius, consists of three parts: the proposition, which expresses what is to be done; the resolution or solution, wherein the several steps, by which the thing required is to be effected, are orderly rehearsed; the demonstration, in which is shown, that by doing the several things prescribed in the resolution, the thing required is obtained.

Accordingly, the general tenor of all problems is this: the things prescribed in the resolution being done, the thing required is done.

PRODUCING, in geometry, the continuing a right line, or drawing it out to any assigned length.

PROFILE, (French) in architecture, the figure or draught of a building, fortification, or the like; in which are expressed the several heights, widths, and thicknesses, such as they would appear, were the building cut down perpendicularly from the roof to the foundation. Hence the profile is also called the *section*, sometimes the *orthographical section;* and by Vitruvius, also the *sciagraphy.*

Profile in this sense, amounts to the same with *elevation;* and stands opposed to *a plan*, or ichnography.

Profile is also used for the contour, or outline of a figure, building, member of architecture, or the like; as a base, a cornice, &c.

Hence, *profiling* is sometimes used for designing, or describing the member with rule, compass, &c.

PROJECTION, the art of forming the representation of a body upon a plane, by drawing straight lines through a given point, or parallel from the contour, and from the intermediate lines of the body, if any, so as to cut the plane; then colouring the respective compartments according to the degree of light, shade, and line of each surface.

If the projection be made by drawing straight lines from a point, it is called *a perspective representation ;* but if formed by parallel lines, it is called an *orthographical representation.*

The projections of points, lines, and plane figures, are found by placing the originals in a given original plane, in a certain position to the intersection of such plane with the plane of projection: and thence the projections of the faces of solids are easily discovered, either by finding the intersection of their planes with the plane of projection, or by finding the representation of one of the planes, and the representation of lines making any given angle with the original of the plane to be represented; and thus the seat, inclination, and length of the original line must be known. Each of these methods has its advantage: but that in which the representations are obtained, by finding the intersections of the different planes forming each of the solid angles, having the inclinations of their planes, is the most natural, as well as the most universal in its application; though the other method, where the objects to be represented are prisms, is more expeditious; since, if the representation of one of the ends be found, the whole solid may be also obtained by finding the representation of one of the arrises, or edges, of the planes which form the sides; or, in the case of a cylinder or cylindroid, by finding the representation of the axis, then drawing lines from all points of the base, or from a sufficient number of points in the base, parallel and equal in length to the axis, and completing the other end equal and similar to the one projected, will complete the representation of the whole solid.

Every solid, whose properties are known, may be projected in any given position to the plane of projection; and no other method offers such ready means of projecting points or lines in space, which have a relation to a given or original plane, where the original plane and the plane of projection are given in position.

In the doctrine of shadows, nothing can be more easy, or more convenient, than the methods furnished by this principle; the universality of the rules is such, that they apply equally to perspective and to orthographical representations, and are much more convenient than the method of finding the vanishing lines of their planes and those of the planes of shade.

Definition 1.—The plane on which the object is represented, is called *the plane of projection.*

In orthographical projection, the rays by which the projection is formed, are here understood to be perpendicular to the plane of projection.

Definition 2.—If the projection be made on a plane parallel to the horizon, or on a plane representing the horizon, it is called *the plane of the object.*

Definition 3.—If the projection be made on a plane perpendicular to the horizon, or on a plane representing a vertical plane, it is called *the elevation of the object.*

Definition 4.—The *plane of position of an inclined line and a plane*, is another plane passing along the line perpendicular to the plane.

Definition 5.—The *inclination of a line to a plane*, is the angle on the plane of position comprehended between the line and the plane.

Definition 6.—The plane on which any object is given, is called *the primary plane.*

Definition 7.—A *point on a plane* is said to be *given*, when its situation is known in respect of some given line, relatively to some fixed point in that plane.

Definition 8.—The *position of a line to a plane* is said to be *given*, when the seat of the line is given upon the plane, and when the angle which the line makes with its seat is known.

Definition 9.—In the representation of figures, in planes inclined to the plane of projection, the situation of the figure, in respect to the intersection of its plane with the plane of projection, is supposed to be known. The intersection is therefore given on the plane of projection, and the space on the one side is to be considered as *the original plane*, while that on the other is *the plane of projection.*

Axiom.—If any point, line, or plane, coincide with the plane of projection, that point, line, or plane, so coincident, is both the original and the projection of that point, line, or plane.

Proposition I.—The projection of a point is in a straight line drawn from the original point perpendicular to the intersection.

For, suppose a plane to pass through the original point, perpendicular to the primary plane and to the plane of projection, its intersection with each of them will be perpendicular to that of the primary plane and the plane of projection; but lines perpendicular to the same straight line, drawn from the same point, are in the same straight line, and therefore the projection of a point is in a straight line drawn from the original point perpendicular to the plane of projection.

Proposition II.—The orthography, or projection of a straight line, is also a straight line. Thus, let a plane pass through the original straight line perpendicular to, and intersecting the plane of projection; here, as the intersection of one plane with another is a straight line, the orthographic representation must be so likewise.

Proposition III.—All original parallel straight lines are represented by parallel straight lines; because the intersection of one plane with another is a straight line; and, when a plane cuts several parallel planes, the intersections of these planes with the cutting plane, are parallels.

Proposition IV.—The orthographical representation of a line parallel to the plane of projection, is a line equal and parallel to its original.

Proposition V.—The orthographical representation of a line parallel to the intersection, is a line equal and parallel to the original.

Proposition VI.—The orthographical representation of a plane figure parallel to the plane of projection, is a figure equal and similar to the original.

Proposition VII.—All planes perpendicular to the plane of projection, are described as straight lines.

Proposition VIII.—All straight lines in the primary plane perpendicular to the intersection, have their representations also perpendicular to the intersection.

Proposition IX.—Every straight line in a plane perpendicular to the plane of projection, is represented by the intersection, or a part of the intersection, of that plane.

Proposition X.—The intersecting point of every line in any original plane is that point in the intersecting line of the original plane, which is cut by producing the original line to the intersecting line of the plane.

Proposition XI.—If, through any point in the original plane, a plane be drawn perpendicular to the intersection, so as to meet, or intersect, the plane of projection, the representation of the point will be in the line of section where it is cut by a perpendicular to such line, in the plane perpendicular to the intersection.

Proposition XII.—If two points in the intersection of one plane with another be found, or known, the intersecting line of the first plane in the second, is the line which joins the two points.

Proposition XIII.—If the intersecting lines of two planes, inclined to each other, be given, or found, upon a third plane, the point of concourse of the two intersecting lines will be a point in the intersection of the two first planes.

Proposition XIV.—If two points be given in the projection of a straight line, the whole line is given in position.

PROBLEM I.—*Given a point on a plane, inclined to the plane of projection, to find the orthography, or projection of the point.*

Plate I. *Figure* 1.—Let I N be the given intersection of the inclined plane; and let A be the given point thereon; draw A *a* perpendicular to the intersection, I N, cutting it in B; make *a* B C equal to the inclination of the original plane to the plane of projection; make B C equal to B A, and draw C *a* perpendicular to A *a*; then will *a* be the projection of the point A.

Demonstration.—Conceive the triangle *a* B C to be turned up on the base B *a*, perpendicular to the plane of projection; also conceive the original plane, with the point A, to be turned on the line I N, as a hinge; and the line B A will always be in a vertical plane, whose intersection is A *a*; and since B C is equal to B A, and B C is also in the same vertical plane when turned up, B A may be made to coincide with B C; therefore let B A coincide with B C; and, because B C is equal to B A, the point A will fall upon C: but, because C *a* is perpendicular to B *a*, and the plane *a* B C is by supposition perpendicular to the plane of projection, therefore *a* C is perpendicular to the plane of projection; consequently *a* is the projection of the point A.

Corollary.—Hence the projection of a line may be obtained by finding the projection of two points in that line, and then joining the two projected points.

PROBLEM II.—*To find the projection of a straight line in the original plane.*

Figure 2.—Let A B be the given straight line; produce A B to its intersecting point, C; by PROBLEM I. find *a*, the representation of A; join *a* C; draw B *b* perpendicular to I N, cutting *a* C at *b*; then *a b* is the projection of the line required.

PROBLEM III.—*To find the orthographical projection of an angle.*

Figures 3 and 4.—Let A B C be the given angle; find *b*, the projection of the point B; produce A B and C B to their intersecting points, D and E; join E *b* and D *b*, and produce them to *a* and *c*, if necessary, as in *Figure* 3 (*Figure* 4 does not require it); then *a b c* is the projection of the angle required.

PROBLEM IV.—*The indefinite projection of a straight line being given; to find the projection of any original point therein.*

Figure 2.—Let *a* C be the indefinite projection of A B, and let it be required to find the projection of the point B, in the original line A B. Draw B *b* perpendicular to I N, cutting *a* C in *b*; and *b* will be the projection of the point B.

PROBLEM V.—*To find the projection of a given triangle.*

Figure 5.—Let A B C be the triangle given; find the projection, *a b c*, of the angle A B C; by Problem III. and by Problem IV. find the points *a* and *c*, the projections of the points A and C; join *a c*, and *a b c* will be the projection required.

PROBLEM VI.—*To find the projection of a parallelogram.*

First, when the sides are obliquely situate.

Figure 6. Let A B C D be the given parallelogram; find *a b c*, the representation of the angle A B C (being any one of the three angles that is most convenient) by Problem III. and the representations *a* and *c*, of the points A and C, by Problem IV.: draw *a d* parallel to *b c*, and *c d* parallel to *b a*; and the parallelogram *a b c d* will be the representation of the original parallelogram A B C D.

2. When the parallelogram is a rectangle, with its sides parallel and perpendicular to the intersecting line.

Plate II. *Figure* 1.—Find the representation of the points C, D in one of the sides, C D perpendicular to the intersection, by Problem I.; draw *d a* and *c b* parallel to the intersection I N; draw B *a* parallel to D *d*, cutting *c b* at *b*; then the rectangle *a b c d* will be the representation of the rectangle A B C D. as required.

3. When two of the sides are parallel and two oblique.

Figure 2.—Find the representation *a*, of the point A, by Problem I.; produce the side A B to its intersecting point, E; join the intersecting point E and the point *a*; draw B *b* perpendicular to the intersecting line, cutting E *a* at *b*; draw *b c* parallel to I N; draw C *c* parallel to B *b*; draw *c d* parallel to *b a*, and *a d* parallel to *b c*; and the parallelogram, *a b c d*, will be the representation of the original parallelogram A B C D, as required.

Note. Both of these might have been included in one problem; they are thus particularized, in order to give the reader a clear view of the subject.

PROBLEM VII.—*To find the representation of a regular pentagon.*

Figure 3.—Find *a*, the representation of the point A, by Problem I.; produce A E and A B to their intersecting points, and join each of those points with the point *a*; find the projections, *b* and *c*, of the points B and E, by Problem IV.; produce the diagonals, A C and A D, to their intersecting points, and find the representations, *c* and *d*, of C and D, by Problem IV.; join *c d*; and *a b c d* will be the representation required.

PROBLEM VIII.—*Given the intersecting line, and the projection of one of the angles of a pentagon, and the projected length of one of the sides: to project the whole figure.*

Figure 4.—Let *b a e* be the projection of one of the angles of a pentagon, say the most remote; produce *a b* and *a e* to F and G, their intersecting points; then, upon F G, describe the segment, F A G, of a circle, to contain the angle of a pentagon, that is, $\frac{3}{5}$ of two right angles; draw *a* A perpendicular to F G, to cut the segment in A; join A F and A G: let *a b* be the projected side given; draw *b* B perpendicular to F G, cutting A F at B; upon A B describe the regular pentagon A B C D E; and project the other parts, *b c*, *c d*, *d e*, as in the preceding example.

PROBLEM IX.—*To find the projection of a circle.*

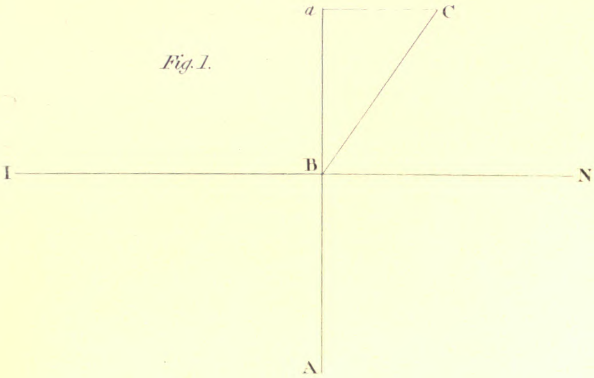
Plate III. *Figure* 1.—Draw the diameter B D parallel, and the diameter C E perpendicular to the intersecting line; find *a*, the projection of the point A; and draw the diameter, *b d*, parallel to the intersecting line; find *b*, the projection of the point B; join B E, and produce it to f; join *b* f, cutting *a* A at *c*; then, with half the major axis, *a b*, and half the minor axis, *a e*, describe the ellipsis, *b c d e*, the projection required.

PROBLEM X.—*To find the projection of the segment,* B C D E B, *of a circle.*

Figure 2.—Through the centre, A, draw the diameter, C F, parallel to I N; complete the semi-circumference, C D F; find the axis *a c* and *a d*, as in the last problem; produce the chord B E, to meet the intersecting line, I N, in f; find the representation of the point *g*; join f *g*, and produce it to *b*; then, with the semi-axis *a c* and *a d*, describe an ellipsis, or so much of it as may be necessary; and the part, *b c d e b*, will be the representation of the segment, B C D E B, as required.

PROBLEM XI.—*To find the projection of an ellipsis,* B C D E B; B D *and* C E *being the two axes cutting each other at* A.

Figure 3.—Find the representations, *b d* and *c e*, of the axes; then with the diameters, *b d* and *c e*, describe the



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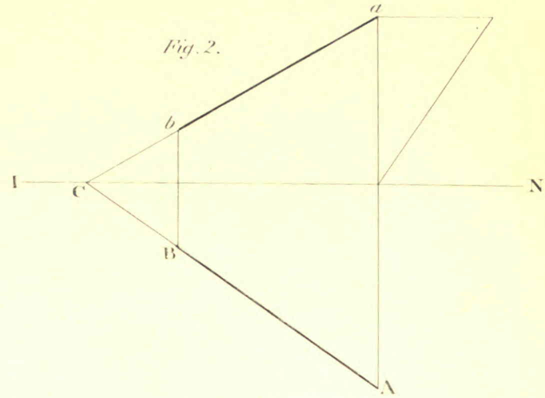

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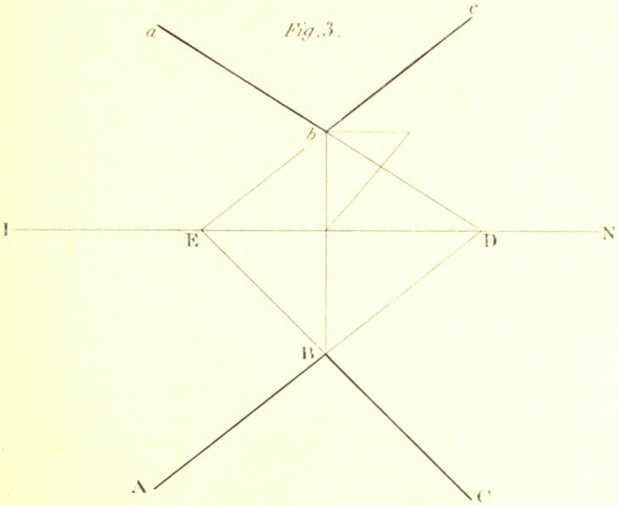

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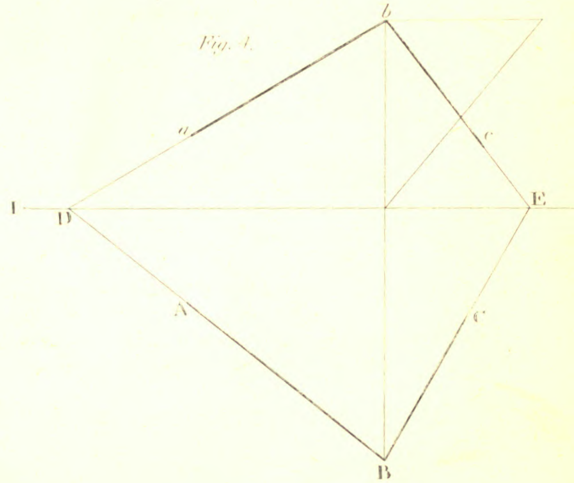

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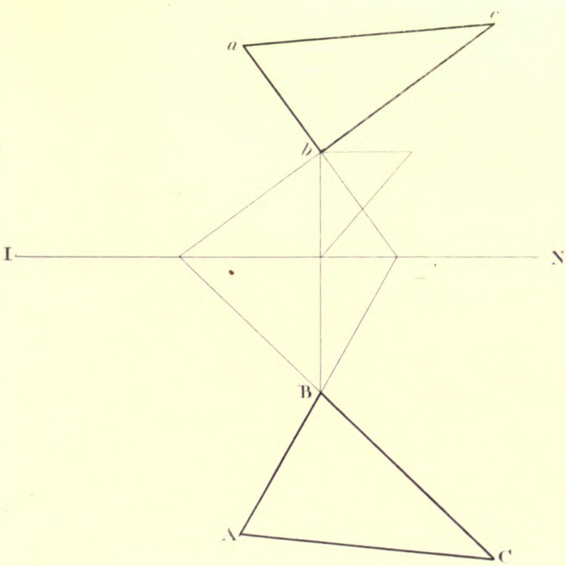

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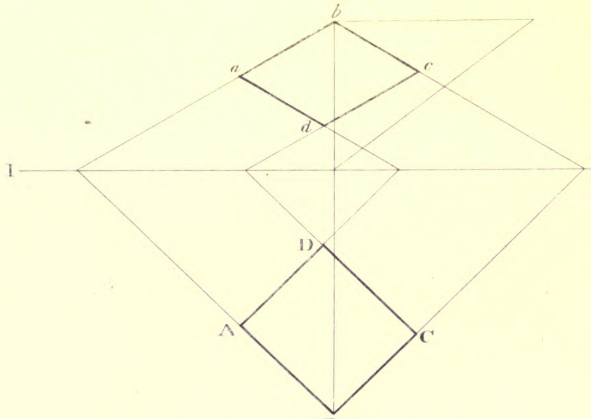
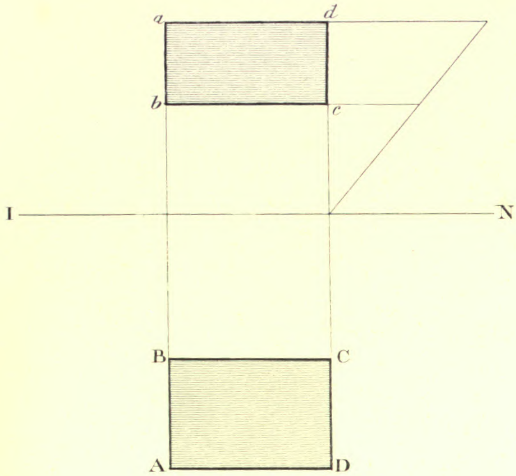


Fig. 6.

Invented by P. Nicholson.
Drawn by M. A. Nicholson.

PROJECTION. Pl.

Fig 1.



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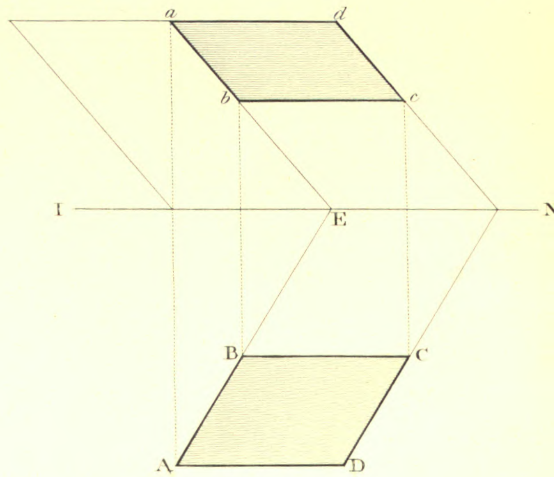

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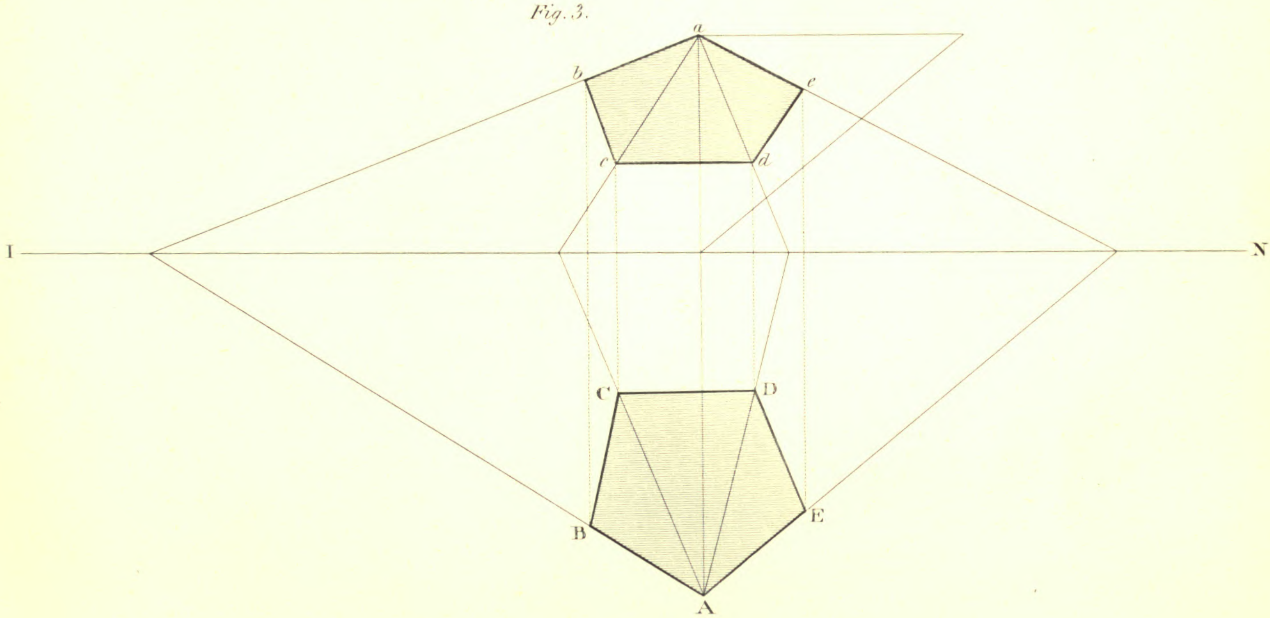

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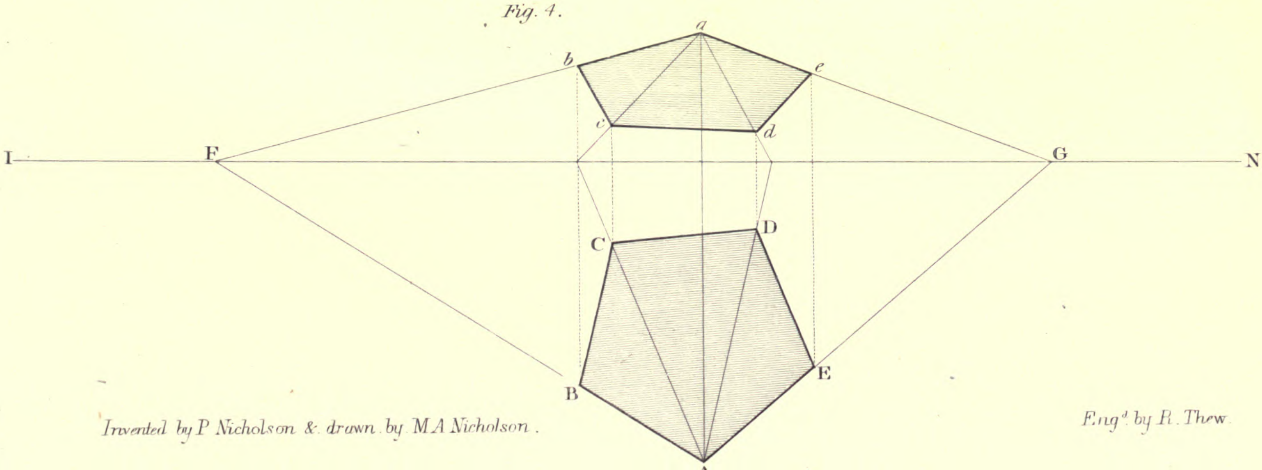
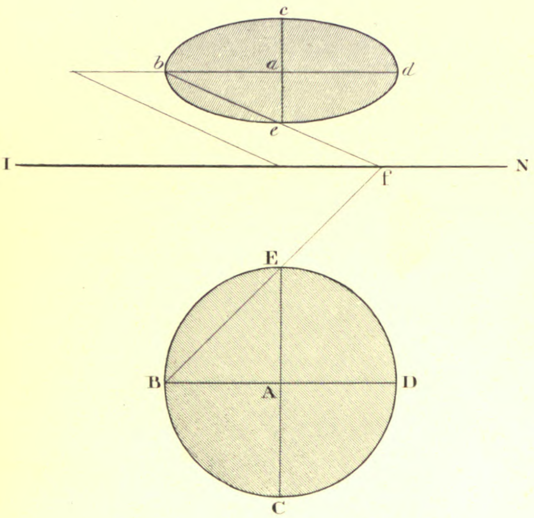


Invented by P. Nicholson & drawn by M.A. Nicholson.

Engd by R. Thew.

Fig. 1.



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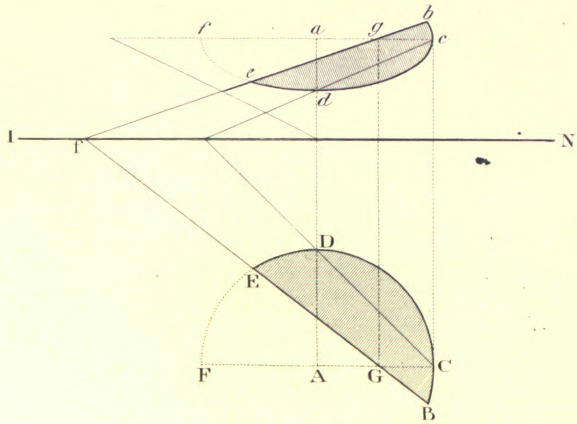

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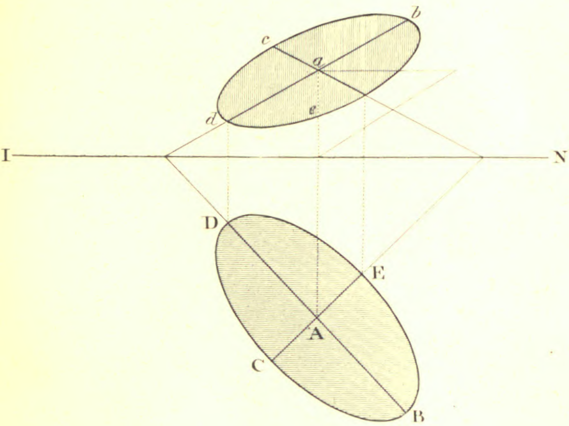

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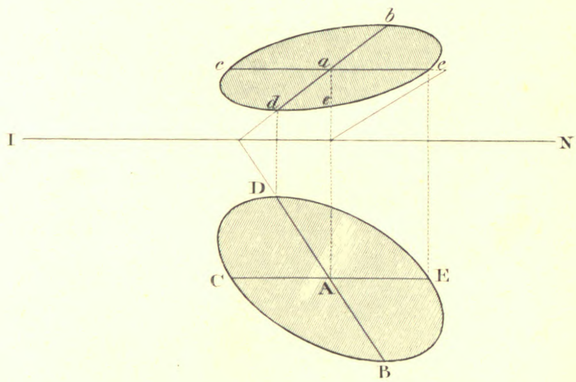

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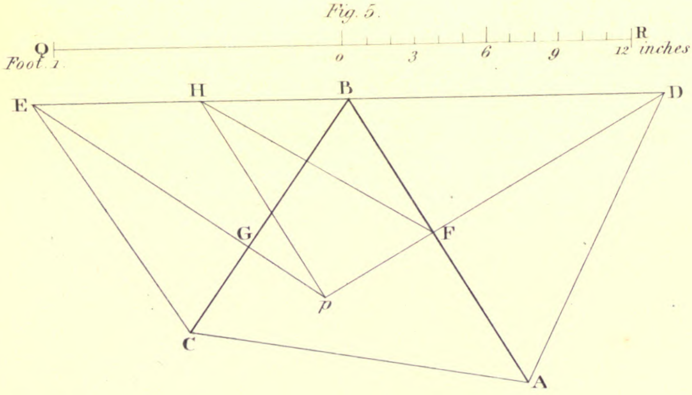

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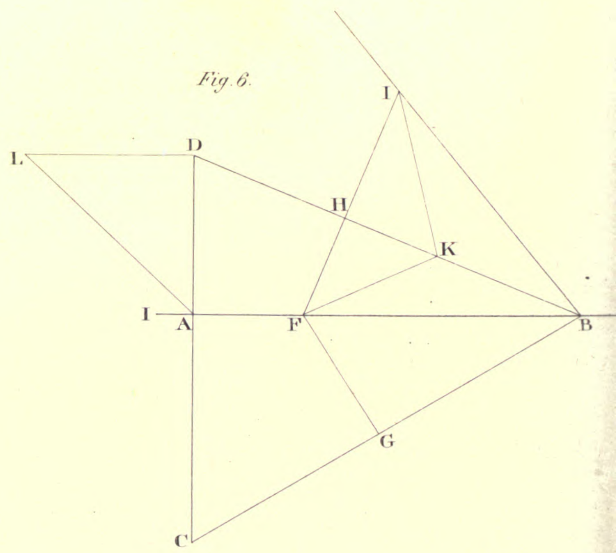
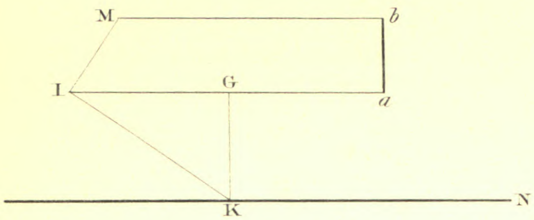


vented by P. Nicholson &
rawn by M. A. Nicholson.

Eng.d by R. Thew.

PROJECTION.

Fig. 1.



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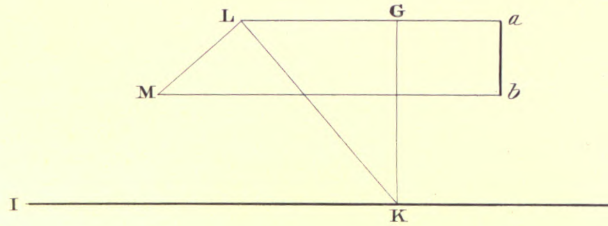

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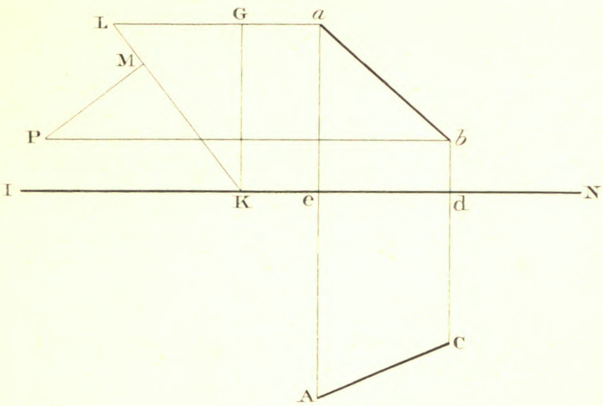

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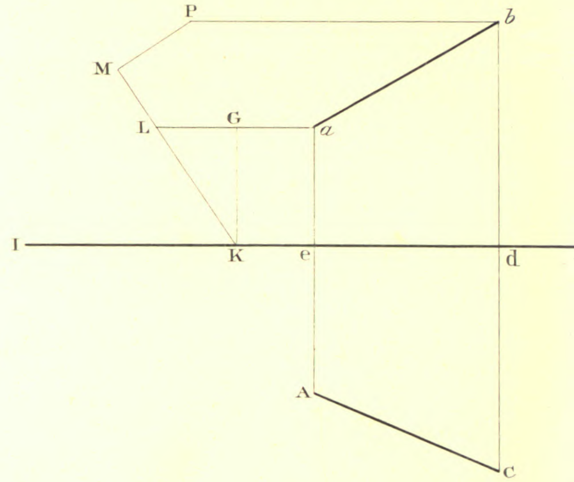
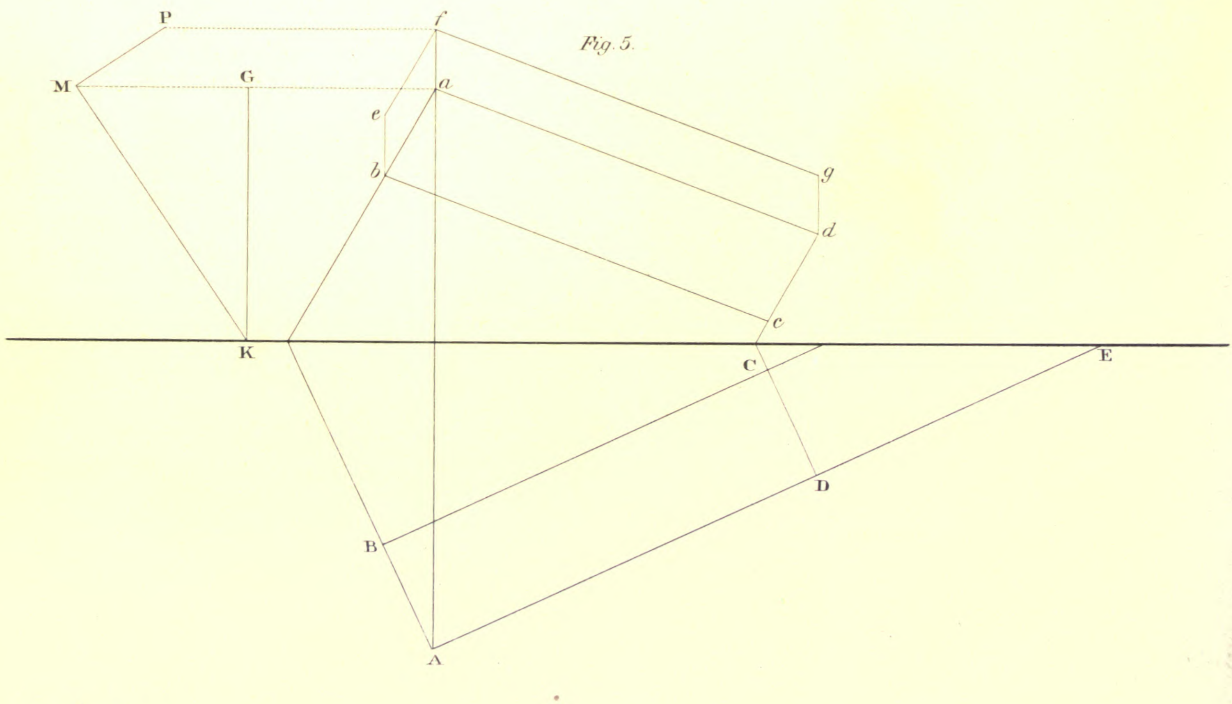


Fig. 5.



Invented by P. Nicholson, and.
Drawn by. M. A. Nicholson.

Eng.d by R Th

ellipsis *b c d e*. This may be done as in Problem I., Method V. of the article Ellipsis (Vol. I., page 365), or by finding the two axes, as in Method I, (page 365), of the same article.

Problem XII.—*Any two conjugate diameters,* B D *and* E C, *of an ellipsis, being given; to find the representation of the ellipsis.*

Figure 4.—Find the representations. *b d* and *e c*, of the diameters B D and E C; and *b d* and *e c* will also be conjugate diameters; then, by Problem I., Method I., of the article Ellipsis (Vol. I., page 365), describe the ellipsis *b c d e b*, which will be the representation of B C D E B, as required.

Problem XIII.—*To find the projection of any point in space, upon a plane given in position; and to determine the distance of the point from the plane.*

Figure 5.—Make choice of any three points, A, B, C, on the plane; measure the distance of the point in space from each of the points A, B, C, and the distance of the points A, B, C, from each other; then the projection may be found on paper, thus: let Q R be a scale, representing feet and inches; let A B be measured 1 foot $4\frac{1}{2}$ inches, B C 1 foot $1\frac{1}{2}$ inch, and C A 1 foot 2 inches; describe the triangle, A B C, according to these dimensions from the scale; let the distance of the point in space from A be 1 foot 4 inches; with the centre, A, and distance of 1 foot 4 inches, describe an arc at D; let the distance of the point in space from B be measured 1 foot 3 inches; then, with the centre, B, and distance of 1 foot 3 inches, describe an arc cutting the former at D, and join A D and B D; with the same distance, from B, describe an arc at E; let the distance of the point in space from C be measured 1 foot; then, with the centre C, and distance of 1 foot, describe an arc, cutting the former at E, and join B E and C E; draw D *p* perpendicular to A B, and E *p* perpendicular to B C; and *p* will be the projection of the point in space.

To find the altitude of the point in space.—Let D *p* cut A B at F; draw *p* H perpendicular to F *p*; with the centre F, and distance F D, describe an arc, cutting *p* H at H; and *p* H will be the height of the point required.

Problem XIV.—*Supposing a tetraedral, or three-sided solid angle to be placed with one of its sides upon the plane of projection, and one of the other two sides, and the two inclinations adjoining that side, with the intersection of that side, to be given; to find the projection of the given side; and the intersection of the remaining side, upon the plane of projection.*

This problem is the same as if one of the sides, and the two adjoining inclinations, of a tatraedral, were given; to find the projection of the given side on one of the others, and also to find the side of the solid on which the projection is made.

Figure 6.—Let A B C be the given side, and A B the edge which intersects or meets the plane of projection in I N; from any point, C in B C, draw C D perpendicular to I N, cutting I N at A; find B D, the projection of B C; that is, make D A L equal to the inclination of the given plane towards the plane of projection; make A L equal to A C; draw L D perpendicular to C D; join D B; and D B A will be the projection of A B C, as required.

To find the intersection of the other side, with the plane of projection.

In B C, take any point, G; and draw G F perpendicular to B C, cutting A B at F; draw F I perpendicular to B D, cutting B D at H; with the centre F, and distance, F G, describe an arc, cutting B D at K; join F K; make the angle, F K I, equal to the other inclination; join B I; and B I will be the intersection of the other side, as required.

Problem XV.—*Given the representation, a, of a point, situate in a plane, whose original is given: to find the representation of a line from the original point, perpendicular to the original plane.*

Plate IV. *Figures* 1, 2.—Draw O K perpendicular to the intersecting line, and make O K L equal to the inclination of the plane to that of projection, if not already made; draw *a* L perpendicular to O K, and L M perpendicular to K L; make L M equal to the line; draw *a b* parallel to O K, and M *b* parallel to L *a*; then *a b* will be the projection required.

Problem XVI.—*Given the representation, a, of the intersection of a line with the original plane, and the seat in, and inclination of, the line, to the original plane; to find the representation of the line.*

Figures 3, 4.—Draw O K perpendicular to I N; make the angle O K L equal to the inclination of the plane to that of projection, and produce K L to M, if necessary; draw A *a* perpendicular to I N, and C *b* parallel to A *a*; make K M equal to C D; draw M P perpendicular to K L: make M P equal to the tangent of the seat, A C, made radius; draw C *b* parallel to A *a*, and P *b* perpendicular to A *a;* then join *a b*, and *a b* will be the representation of the line required.

Problem XVII.—*Given the representation, a b c d, of one side of a parallelopiped, with the inclination of the plane, and the other dimension perpendicular to the original of that plane; to find the representation of the whole solid, supposing the planes of the original solid at right angles to each other.*

Figure 5.—Find the representation, *a f*, of a line perpendicular to the original of the plane represented, by Problem XV., and complete the parallelograms *a f g d* and *a b e f*, which will form the representation of the whole solid.

Problem XVIII.—*To find the inclination of two adjoining planes of the regular solids.*

Plate V. *Figures* 1, 2, 3, 5.—Draw the base, A B C, A B C D, or A B C D E of the pyramid which forms one of the solid angles; draw the triangle B G C, the development of one of the sides of the pyramid; draw G F perpendicular to B C; bisect the angle A B C, and let the bisecting line meet O F in F, their point of concourse; draw F H perpendicular to B F; from B, with the radius B G, describe an arc, cutting F H at H; draw F I perpendicular to B H, cutting B H at I; in F B make F L equal to F I; let F H and B C meet in M; also let F H and B A meet in K; join M L and K L; then will K L M be the angle of the planes as required.

As the sides of the tetraedron are equilateral triangles, and as three of the triangles form each solid angle, both the base of the pyramid, A B C, and the developed side, B G C, will be equilateral triangles in *Figure* 1.

In the construction for *Figure* 2, as the sides of the hexaedron are squares, and as each solid angle is formed by three of the right angles, the base of the pyramid will be an equilateral triangle, and the vertical angle of the developed side will be a right angle.

In the construction for the octaedron, *Figure* 3, as each side is an equilateral triangle, and as four of the angles of the triangle form the sides of the solid angle, the base of the pyramid will be a square, and the developed side will be an equilateral triangle.

In the construction for the dodecaedron, *Figure* 4, No. 2, as each solid angle is formed by three planes, and as each of the planes is a pentagon, the base of the pyramid will be an equilateral triangle, and the vertical angle of the developed side will be equal to the angle formed by the two sides of a pentagon.

In the construction for the icosaedron, *Figure* 5, as each solid angle is composed of five sides, and as all the sides of the solid are equilateral triangles, the base of the pyramid is a pentagon, and the developed side an equilateral triangle.

In the construction for the dodecaedron, *Figure* 4, the angle of the pentagon was found by dividing a circle into five equal parts, and joining the chords of two adjoining parts, as A B, B C, *Figure* 4, No. 1. Then, to obtain the vertical angle, draw A C as a base; bisect the angle A B C, which will also bisect the straight line A C in E; make E F equal to the half of B C, No. 2, and draw F G parallel to B C, cutting B D at G; make E G, No. 2, equal to E G, No. 1; and in No. 2 join G B and G C, which will give the vertical angle B G C.

PROBLEM XIX. *To project the dodecaedron.*

Figure 6.—Find *a b c d e*, the orthography of one of the planes, by Problem VII.; find the angle which two contiguous planes of the solid make with each other, by Problem XVIII.; find the intersection of each of the planes adjoining to the plane whose projection is found, by Problem XIV., and thus three of the arrises of the solid will be projected; then, to project the planes adjoining the extremities of the arrises, or edges, *a b*, *a e*, *a h*, suppose that contiguous to *a b*, produce *b c* to meet the intersecting line X Z in *o*, and produce *b f* to meet X Y in *p*; join *o*, *p*; then, having the projection of the angle *c b f*, and the projected lengths, *c b* or *b f*, of one of the sides, and the intersecting line, *o p*, of the plane of that side, find the orthography, *c b f m l*, of the whole figure, by Problem VIII. In like manner, find the orthography of the figures *g h i q r*, *k s t d c*, and the representation of the solid will be completed.

PROBLEM XX.—*To divide the representation of a circle into parts representing the original circle divided into equal parts.*

Plate VI. *Figure* 1.—Let A B C D be the original circle, and let *a b c d* be its orthographic representation. Suppose the first part of the original circle to commence at the given point, E; let E F, F G, G H, &c. be the equal parts in the original circle, and let O be its centre; join E O, F O, G O, H O, &c.; let the diameter, B D, be perpendicular to the intersecting line, I N, and let A C be parallel to I N; then *b d* and *a c* being the representations of B D and A C, draw *b a* and B A, and let B A cut the radii E O, F O, G O, H O, &c. in the points K L M N, &c.; draw K *k*, L *l*, M *m*, N *n*, &c. cutting the representative chord, *a b*, at *k l m n*, &c. Let *o* be the representative centre; draw *o k*, *o l*, *o m*, *o n*, &c., and produce *o k*, *o l*, *o m*, *o n*, &c. to meet the circumference of the representative circle in *e*, *f*, *g*, *h*, &c.; then will *e f*, *f g*, *g h*, &c. be the representations of the equal parts E F, F G, G H, &c. of the original circle: and if the representative radii, *e o*, *f o*, *g o*, *h o*, &c. be produced to meet the opposite parts of the curves at *e'*, *f'*, *g'*, *h'*, &c., *e' f'*, *f' g*, *g' h*, &c. will also represent equal parts.

In the same manner, if B C, and its representation, *b c*, be joined, the other two representative quadrants may be divided, so as to represent equal parts in the original quadrants remaining; and thus the whole representative circle will be orthographically divided into parts, representing the whole of the original circle divided into equal parts.

To find the orthographical representation of a water-wheel.

Figure 2.—Let No. 1 be the face of the wheel, or its section, perpendicular to the axis: let I N be the intersecting line: draw the ellipsis *a b c d*, representing the original circle, A B C D, divided into equal parts, as in the preceding problem: through the points of division draw the portions of the radii, as intercepted between the orthographic circumferences: draw the ellipsis *e f g*, which will give the orthography of the opposite outer circle: then draw the edges of the boards perpendicular to the intersecting line, I N, so as to be terminated by the orthographic circles *e f g* and *c d a*; then, two of the sides of the float-boards being thus found, the other two may be completed by parallel lines.

The ring which supports the float-boards is represented in the same manner as the orthographic circles, which contain the representations of the float-boards themselves. The radiating pieces, to which the float-boards are attached, are made to tend to the centre, on the side that adjoins the float-boards, and the opposite face is tapered off; and, to accomplish this regularly, it is made to touch the representation of a circle in the same plane.

To project a straight line in a plane, supposing the plane which contains the line to be wrapped round the surface of a cylinder.

Plate XIII. *Figure* 1.—Let A B C D be a cylinder orthographically projected; and let B A be continued to G, so that A G may be equal to the semi-circumference of the cylinder; also let F E be the line to be projected, the point E being in the line A D, and the position of E F to A G being supposed to be given.

Continue the axis of the cylinder to any convenient distance beyond the base A B: at any convenient point in the axis thus produced, describe a circle equal to the radius of the cylinder; draw the diameter H J parallel to A B: divide the semi-circumference H I J into any number of equal parts, as 8; also divide A G into the same number of equal parts; from the points of division in the semi-circumference H I J, draw lines parallel to the axis of the cylinder through the projection A B C D.

Again, from the points of division A G, draw lines perpendicular to the said line A G, to cut the line E F in as many points as A G; from the points of section in E F, draw lines parallel to A B, to cut the former lines drawn parallel to the axis; then the line E F of contrary flexure, is the projection required.

In the same manner the concave line D E, *Figure* 2, is projected from the surface of a cylinder upon a plane into the line D *e*.

To project any line upon the surface of a cone.

Figure 3.—Let A B C be the orthographical projection of the cone on a plane parallel to the axis, and let A B E be the development of the projected surface: then any line B F on this development, will be projected from the conic surface in the following manner:

On B C describe a semicircle B D C, and divide the arc B D C into any number of equal parts; from the divisions of the arc B D C, draw lines perpendicular to B C, to meet it in as many points of section as there are divisions in B D C; from the points of section in the base B C, draw lines to A; from the points of section in the base B E of the development, draw straight lines to A, to cut the line B F intended to be projected; from the points of section in B E, describe arcs from the centre A to cut A B in as many points of section as the number in B F; from every point of section in A B draw lines parallel to B C, to cut each former line respectively; through the corresponding points, draw a curve, as shown by the dark line, and this will be the projection of the line on the conic surface.

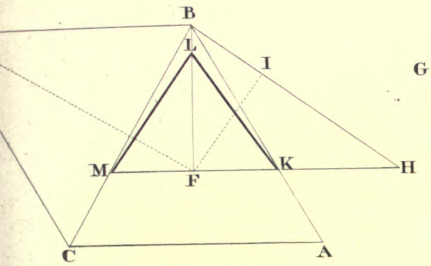
Corollary.—Hence the projection may be found according to any given fanciful form, as in *Figure* 4, where *f g* is the projection of F G.

Not only architectural designs, but mechanical drawings, depend upon orthographical representation; it enables the architect, engineer, or mechanic, to construct the object intended to be executed. As drawings of every kind are greatly facilitated by a knowledge of the formation of bodies, so, in drawing machines, it is necessary to know the methods of representing any system of lines upon cylindric and conic surfaces, as this knowledge will determine whether the lines represented are parallel to each other or tend to a point.

In drawing machinery, as in other kinds of orthographical

PROJECTION.

Fig. 1.



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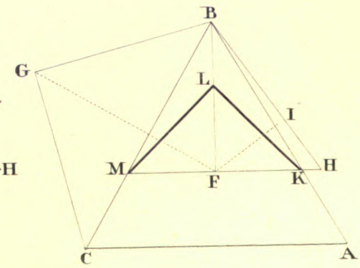

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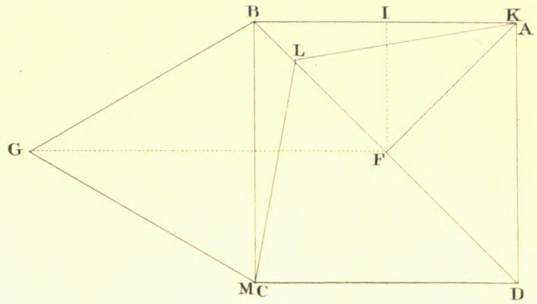


Fig. 4. N°. 1.

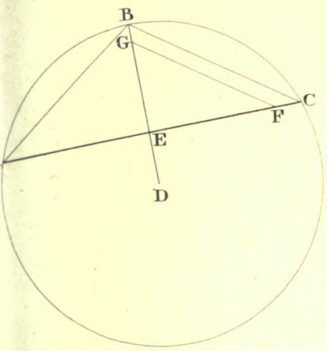


Fig. 4. N°. 2.

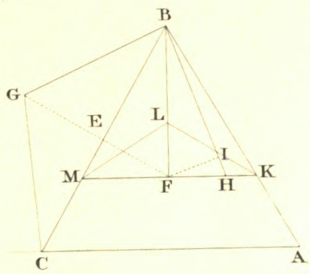


Fig. 5.

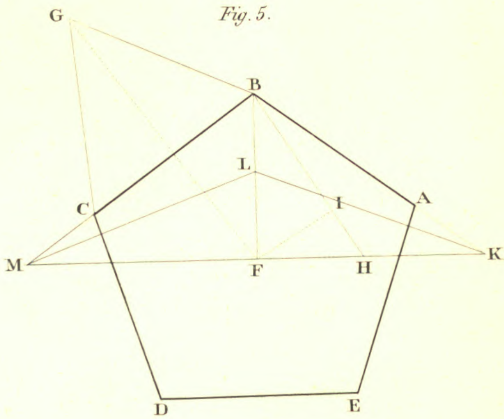


Fig. 6.

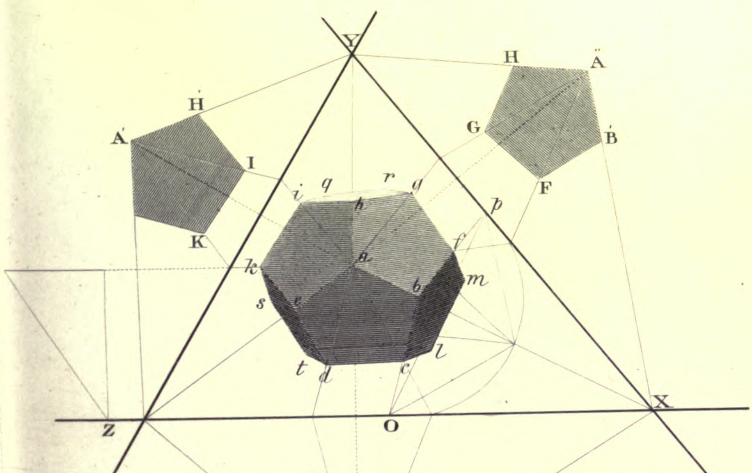
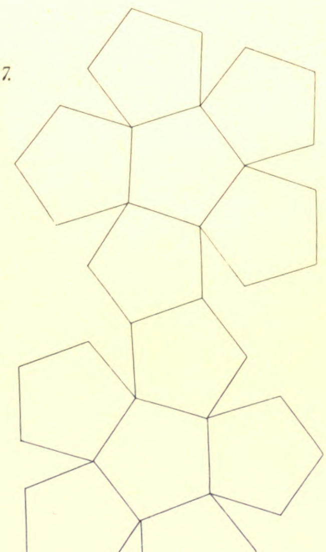


Fig. 7.



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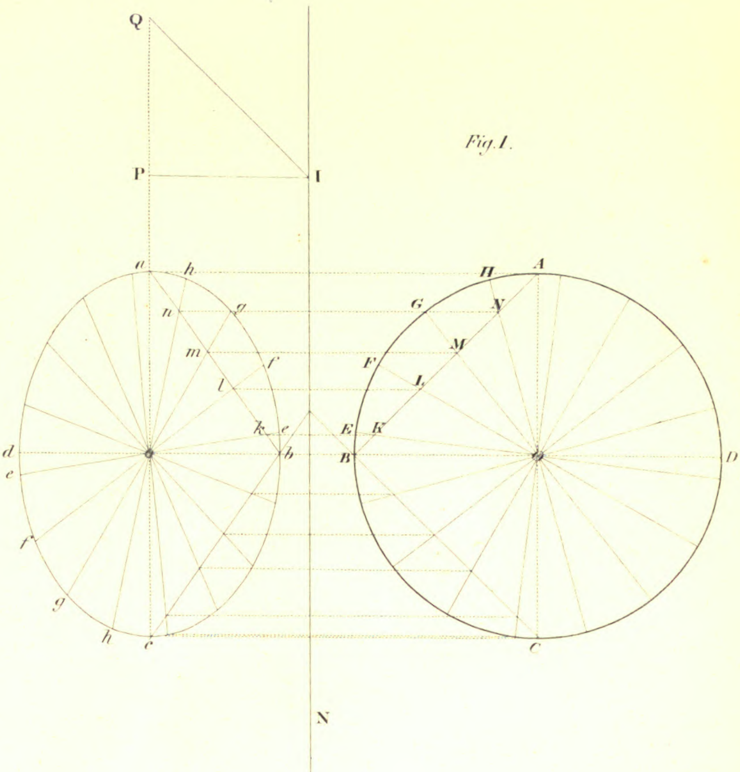

Fig. 1.

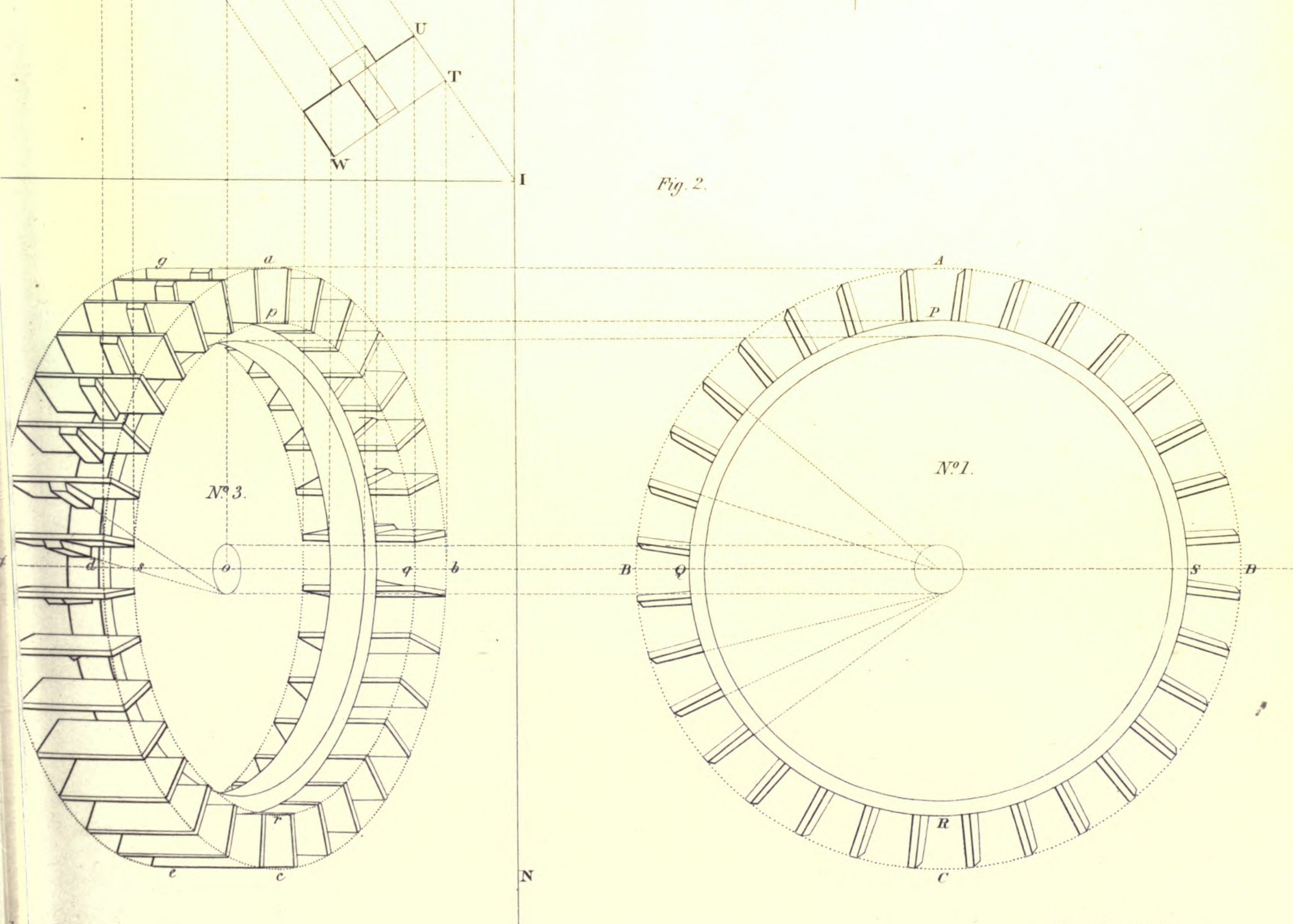

Fig. 2.

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Fig. 3.

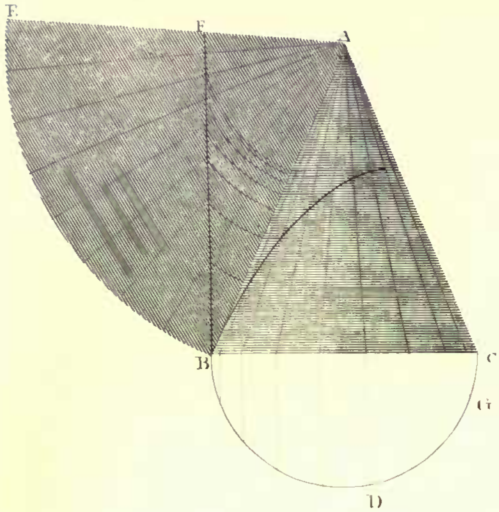


Fig. 4.

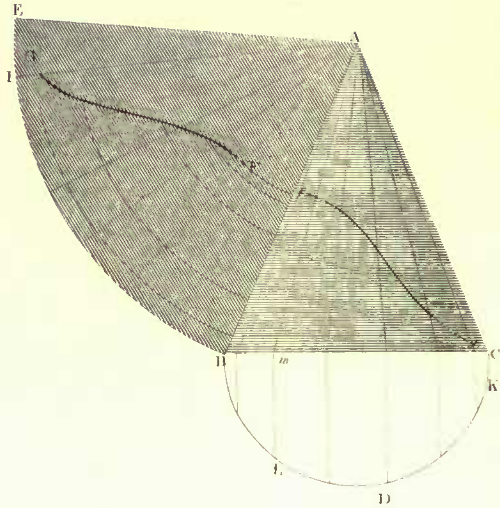


Fig. 1.

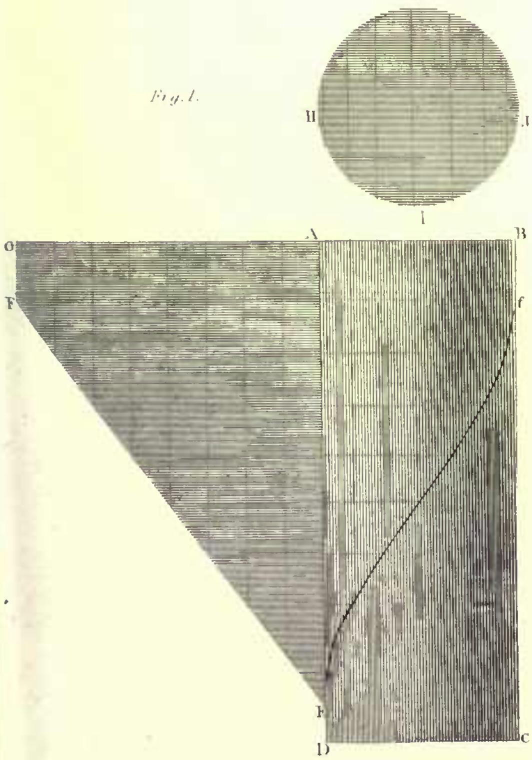
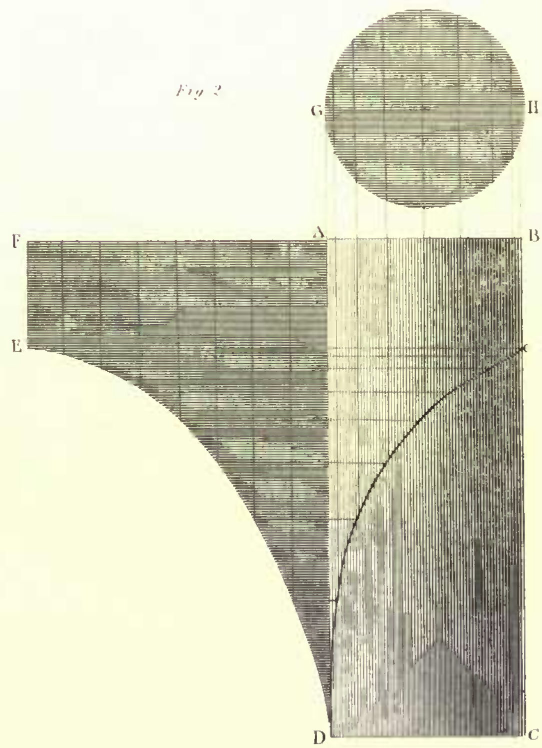


Fig. 2.



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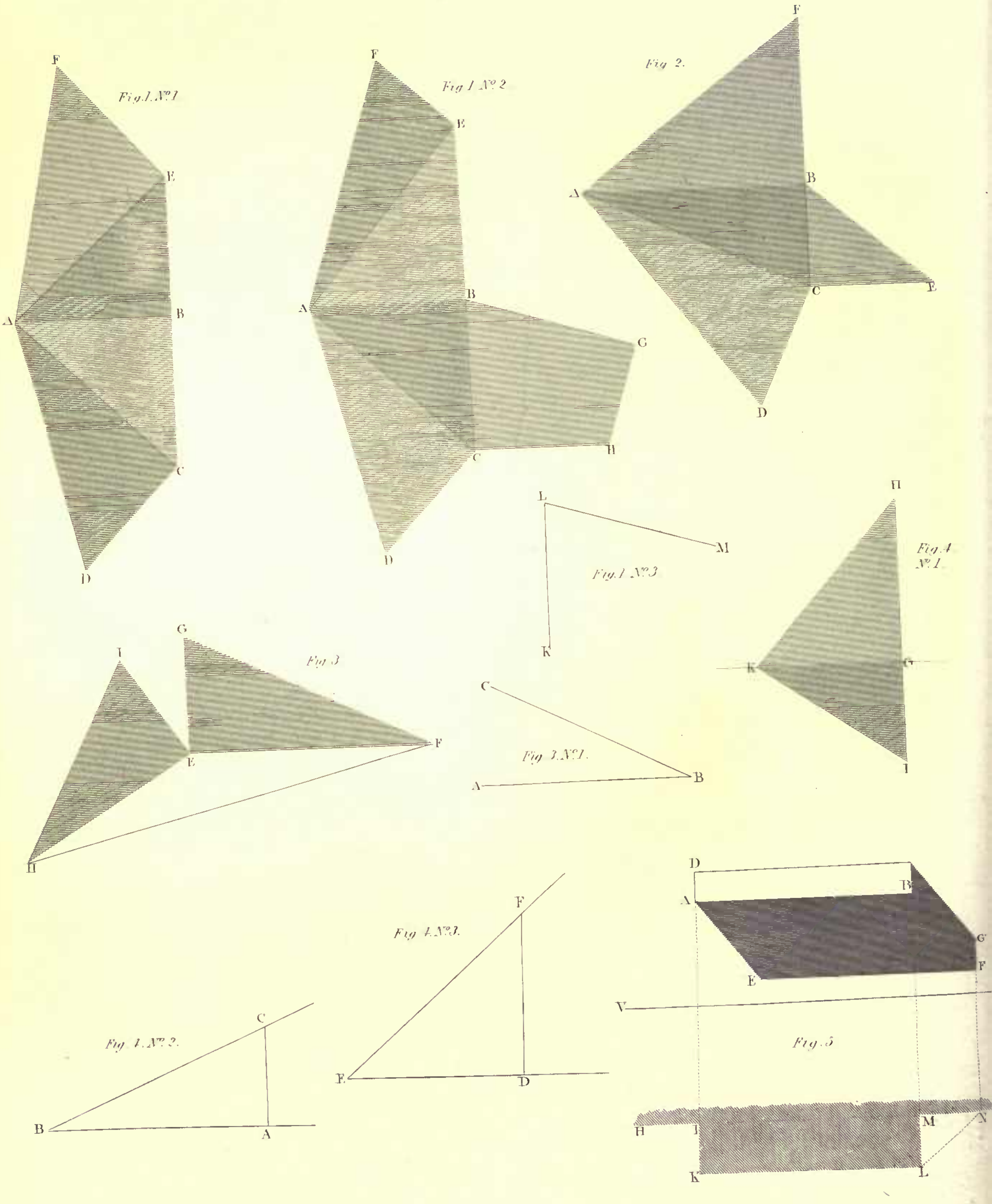
PROJECTION.



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representations, the object is represented upon two planes, one parallel, and the other perpendicular to the horizon.

As the faces of the different parts of a machine are generally in vertical planes parallel to each other, the elevation is also made on a vertical plane parallel to the faces of the work, or to the greatest number of faces, in order to facilitate the execution, as this position not only gives the altitude of the parts, but is also convenient in ascertaining the magnitude of lines in every direction in these planes, and the angles which the lines form with each other; for if the faces of the work stand at oblique angles with the projecting plane, there can be only one direction, namely, that of measuring in a vertical line, in which the true dimensions can be ascertained; every other will be fore-shortened, and the angles formed by the lines of representation will also vary from the original angles of the object.

As the axes of wheels are sometimes obliquely situate, it becomes necessary to represent them in various positions. The several kinds of representations are sections through the principal parts (as through the axis of a wheel), plane or horizontal projections, and elevations.

Though a plan and elevation are sufficient to construct any machine with proper attention, yet from the greater facility of comprehending the nature of the design, and applying the measures to practice, two elevations are sometimes given, particularly in a complex machine. One of these elevations expresses the parts in the longest horizontal dimension of the work, and the other represents the parts comprehended in its breadth, or horizontal extension.

In the representation of a machine, the wheel-work is the most difficult of any part, except when the whole of the surfaces of the wheel are planes, with two or more faces parallel to the projecting plane, and all the other surfaces perpendicular to it, as in this case the boundaries of the parallel planes are represented by figures similar to the original faces, and the whole of the other surfaces are projected into straight lines or circles. This is so very simple, as not to require any directions; but if the wheel, or its faces, have an oblique position to the projecting plane, several considerations are necessary to effect a true representation. A ground section through the axis of the wheel, placed at the required angle, with the intersection of the plane of elevation, and an elevation of the wheel on a plane parallel to the faces, will be required. It is likewise necessary to observe, that, in this oblique projection, all the parallel arrises of any original object are represented by parallel lines, and all equal distances in the original object are represented by other distances equal among themselves; also, all straight lines whatever in the original plane, divided into parts, are represented by a series of parts respectively in the same proportion. The proportion of any line is to its original, as radius to the cosine of the inclination of the original line and the plane of projection. The representation of an original circle is an ellipsis; and as the plane of projection is vertical, the elevation of an ellipsis will be represented with its greater axis perpendicular to the intersecting line.

Problem XXI.—*Given the seat and altitude of a line on plane, and the intersection of the plane with another plane a given angle, to find the sun's seat on such plane, as also angle of altitude.*

Plate VIII. *Figure* 1.—Let A C, No. 1 and 2, be the seat the line; A B the intersection of the last named plane. A C take any point, C; draw C D perpendicular to A C; draw C E perpendicular to A B, cutting A B at B. In No. 2, draw C H perpendicular to B C; make C H equal to C D, and angle C B G equal to M L K, No. 3, the inclination of the planes; draw H G perpendicular to B G; make B E equal to B G, and join A E; then A E will be the seat of the sun's rays on the plane, as required. Draw E F perpendicular to A E; make E F equal to G H, and join A F; then E A F will be the angle of altitude of the line on the same plane.

In No. 1, the two planes are at right angles to each other; in this case, the problem may be constructed without the quadrilateral B C H G; thus, having drawn C E perpendicular to A B, cutting A B at B; make B E equal to C D, and complete the triangle A E F, as in No. 2; then A E will be the seat of the line, and E A F the angle of altitude, as before.

This may easily be conceived, by supposing, that upon the triangle A B C, No. 2, the triangle A C D, and the quadrilateral B C H G, are raised perpendicularly; then C H and C D will coincide, and the point H will coincide with the point D; turn the triangle A B E upon A B, and the side B E, being perpendicular to A B, will describe a plane upon B E, perpendicular to the plane A B C; and because B C and B E are in the same straight line, B C will be in that plane; and because the plane B C H G, is supposed to be raised perpendicular to the plane A B C upon B C, the plane supposed to be described by B E will be in the same plane with B C H G, when raised perpendicularly to the plane A B C; therefore, move the plane A B E till B E coincide with B G, supposed to be raised with the plane B C H G; the planes A C D, B C H G, and A B E, being thus supposed to be raised, turn A E F round A E, till E F falls upon G H; then the point F will fall upon H; and the straight line A F will also be coincident with A D; for the triangle A E F will be at a right angle with the triangle A E B; therefore E F will be at right angles to the plane A B E.

Problem XXII.—*Given the seat and altitude of the sun's rays on a plane, and the angle which the seat of a line parallel to the plane of projection makes with the seat of the sun's rays; to determine the inclination of the plane of shade obstructed by the original line towards the plane of projection.*

Figure 2.—Let A C be the seat of the sun's rays given upon the plane of representation; make C A D equal to the altitude of the sun's rays; draw C D perpendicular to A C; make C A B equal to the angles made by the seat of the sun's rays with the seat of the original line, which occasions a plane of shade; from C draw C B perpendicular to A B, and C E perpendicular to C B; make C E equal to C D, and join B E; then C B E will be the inclination of the plane required. Produce C B to F; make B F equal to B E, and join A F; then let the triangles C A D, C B E, B A F, be turned up, and A F and A D will coincide; and the triangle C B E will measure the inclination of the plane A B F to C B A. This problem is of the utmost use in finding the shadows of parallel lines to planes in various positions; as also in finding the shadows of cylinders where the axis is parallel to the plane of projection; and in determining the points and lines of light and shade in cylinders and cylindric rings.

Problem XXIII.—*Given the seat and altitude of a line and the seat and altitude of the sun's rays; to determine the shadow of the line on that plane.*

Figure 3.—Let H E be the seat of the line; make the angle, E H I, equal to the altitude of the line, viz., of A B C, No. 1; E being any point in H E; draw E I perpendicular to H E; draw E F parallel to the seat of the sun's rays; and draw E G perpendicular to E F; make E G equal to E I; make the angle E G F equal to the complement of the sun's altitude, and join H F, which will be the shadow of the line required.

This problem will be of great use in finding the shadows of objects upon inclined planes.

Problem XXIV.—*Given the inclination of a line to two planes at right angles to each other; to find the seat of the line on each of the planes, and the intersection of the planes.*

Figure 4.—Let A B C, No. 2, be the inclination, or angle, made by the line with one of the planes, and D E F, No. 3, the angle it makes with the other.

From the angular point, B, No. 2, take B C, of any length, and from the angular point, E, No. 3, take E F equal to B C; in No. 2, draw C A perpendicular to A B; and, in No. 3, draw F D perpendicular to E D; in No. 1, draw any line G K; and through G, any point in G K, draw H I perpendicular to G K; make G H equal to the sine, D F, of one of the angles of No. 3, and G I equal to the sine, A C, of the other, No. 2; from H, with the radius, A B, No. 2, describe an arc, cutting G K at K; and join H K and K I; then G K will be the intersection of the planes, and K H and K I will be the seats of the line on each of them.

In the following problems, respecting shadows, two planes of projection are always supposed to be given, viz., the seat of the rays of light on each of the planes, and the intersection of the planes, unless otherwise announced.

Practical examples of shadows.

Example 1.—*To find the shadow of a rectangular prism attached to a wall, one of the sides of the prism coinciding with the surface of the wall.*

Figure 5.—Let H I K L M N be the plan, the straight line, H I M N, that of the wall, and I K L M that of the prism; let A B C D be the elevation of the prism, and V W the intersection of the plane of elevation with that of the ichnography, parallel to H N, and K L in the plan.

To find the shadow of any point, B, *on the elevation, corresponding to* L *on the plan.* Draw the ichnography, L N, of a ray of light; also, from B, draw B F, the elevation of the ray, at any given angle with the intersection V W; join B L; draw F N parallel to B L; and the point F will be the shadow of the point B on the elevation.

In the same manner, find E and G, the shadows of the points A and C; join E F and F G; and A B C G F E A will be the shadow required.

Or, find the shadow, F, of the point B, as before; draw the indefinite representations, A E and C G, of the extreme rays; then, because the arrises, or edges, of the prism are parallel to the wall, or to the surface on which the shadows are thrown, the representations of the edges of the shadows will be parallel to the representations of the arrises on the plane of elevation; therefore draw F E parallel to A B, and F G parallel to B C; and A E F G C will be the edge of the shadow, as before.

Example 2. *Plate* IX.—The shadow of *Figure* 1 is found in the same manner as in the last example; the body which throws the shadow being a prism, with its planes parallel and perpendicular to the surface on which the shadow is thrown; A N M L C is therefore the outline of the shadow thrown by a prism, represented by F G H I on the plan, and by A B C D on the elevation. The figure here introduced represents a cantiliver projecting from a wall.

Example 3.—*To find the shadow of a cantiliver, formed as in the last example, the plane of elevation being placed obliquely to the surface on which the shadow is thrown.*

Figure 5.—Let E F I K be the representation of the surface on which the shadow is projected, placed obliquely to the line V W, the intersection of the orthographic planes; let F G H I be the plan of the cantiliver, and A B C D its elevation, the points A and D on the elevation corresponding with the point H on the plan, and the points B and C corresponding with the point F. The end of the cantiliver is represented by D *e f* A, and the root by C *g h* B; the point I, on the plan being represented by *g* and *h* on the elevation, and the point F, on the plan, by B and C on the elevation. To find the shadow of any corresponding lines, F G and B *h;* draw G L the parallel of the seat of the sun's rays on the plan, meeting the shadowed surface, E K, in L; draw L *m* perpendicular to V W; from *h*, the corresponding point of G, draw *h m*, the elevation of the ray; join B *m;* draw *g o* parallel to B *m*, draw *m n* parallel to A B, and *n o* parallel to A D; then *h m n o g* will be the shadow required: for the representation of the two edges of the shadows are parallel to the representation of the two edges of the end of the cantiliver.

Example 4. *Figure* 3.—Let A B D E be the intersection of any vertical surface on which a shadow is to be thrown; also let B C D be the plan of a triangular prism projecting from that surface; and G H I F its elevation; find *p n*, the shadow of the perpendicular line, as before; and join *n* G; then will *p n* G be the shadow of the prism, as required.

Example 5. *Figure* 4.—G H I K L is the elevation of several rectangular prisms joined to each other in the form of a pediment; O H I K L is the outline, and *l m n* the inner line, forming the tympanum; A B E F is the plan of the surface on which the shadow is to be thrown, parallel to the intersecting line, V W; B C D E is the plan of the pediment, of which the line C D, representing the face, is parallel to A F. Draw G O, H P, I G, and *n r*, the elevation of the rays; also, draw the ray D *v* on the plan, meeting A F at *v*; *v* P G perpendicular to the intersecting line, cutting the rays, H P and I G, of elevation, at P and G: draw P O parallel to G H; then O O P O I will be the extremity of the shadow, as in Example 1. To find the shadows from the inner edges, *l m* and *n m*, make *n r* equal to G O, or H P, or I O, as each of the points, G, H, I, *r*, is equally distant from the surface; draw *r s* parallel to *n l*, and *r t* parallel to *n m;* then will *s r t* represent the shadow from the under arrises of the inclined parts.

Example 6.—*Figure* 5, is the shadow of several rectangular prisms crossing each other at equal angles; one of the faces of each is parallel to the plane on which the shadow is thrown, and also to the plane of elevation; the opposite, or parallel faces, are attached to the plane on which the shadow is thrown, and, therefore, the other faces are perpendicular to such plane. The shadows are to be found as in the last example, viz., by drawing indefinite rays from all the angular points on the elevation, and finding the length of one of them; then the rest will be completed by parallel lines from the termination.

Example 7.—*To find the shadow of a rectangular ring.*

Figure 6.—Find the point, *l*, the shadow of the centre, *k;* through *l* draw O P perpendicular to *k l;* then, with the radius of the interior circle, describe the arc, W X U, meeting the said inner circle in W and U; also, from *l*, with the radius of the exterior circle, describe the semicircle, O Q P; draw O M and P N parallel to *l k*, and these lines will touch the circle in M and N; then M O Q P N will represent the exterior shadow required.

Problem XXV.—*Given the sun's seat and inclination on the plane of the horizon, and the intersection of two planes at right angles with each other, and perpendicular to the horizon; to find the representation of the sun's rays on each of the vertical planes.*

Plate X. *Figure* 1.—Let A D and D B be the intersection of the two vertical planes, and A B the seat of the sun's rays on the horizon; make the angle, A B C, equal to the angle of the sun's altitude; draw A C perpendicular to A B and A E perpendicular to A D: make A E equal to A C, and join E D, which will represent the ray of the sun, on the plane of which the intersection is A D: produce A D to G; make D G

PROJECTION.

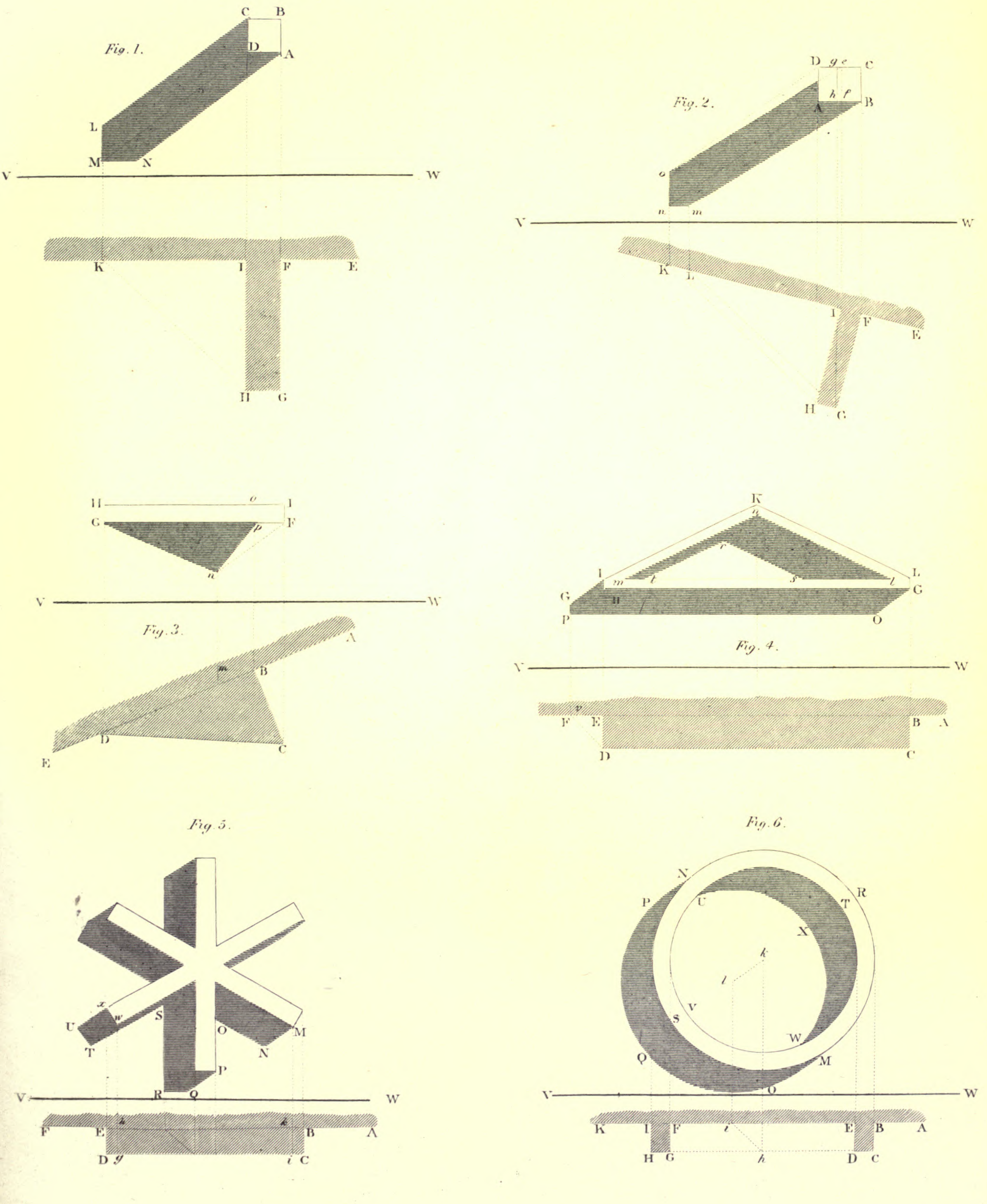

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Fig. 1

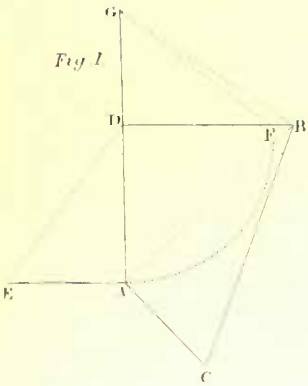


Fig. 2.

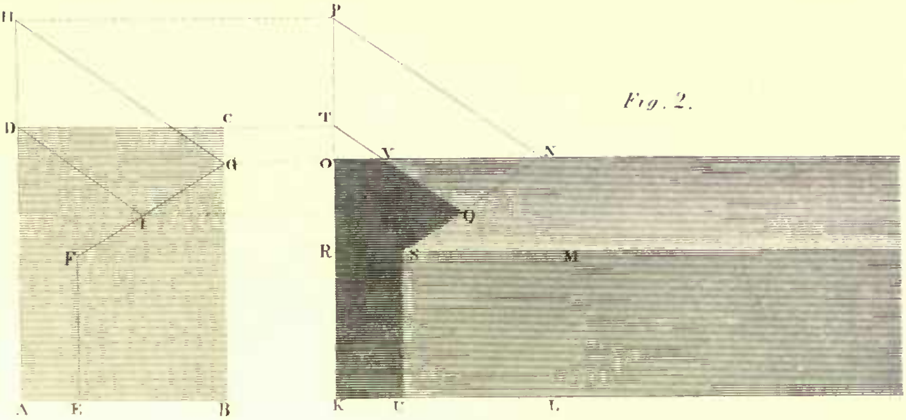
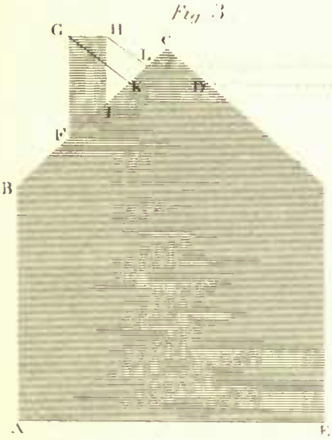


Fig. 3



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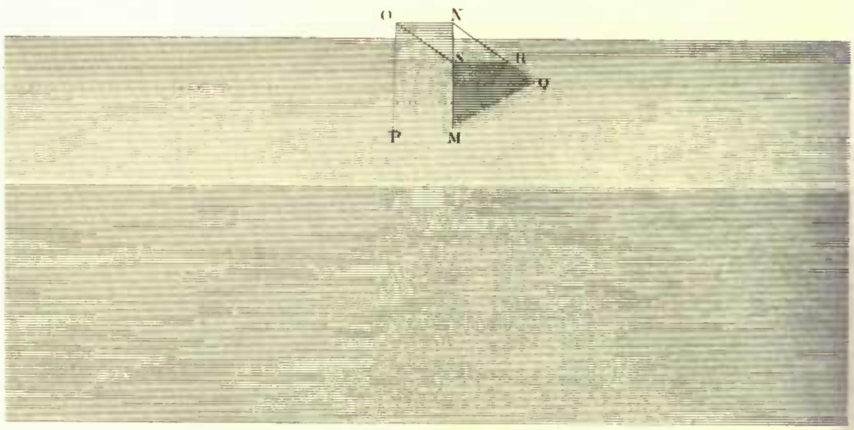


Fig. 4

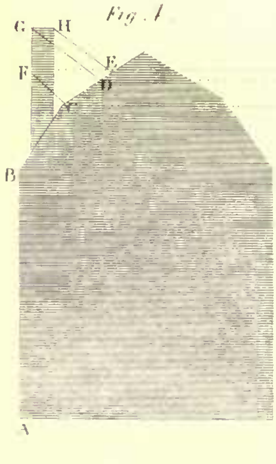


Fig. 4.

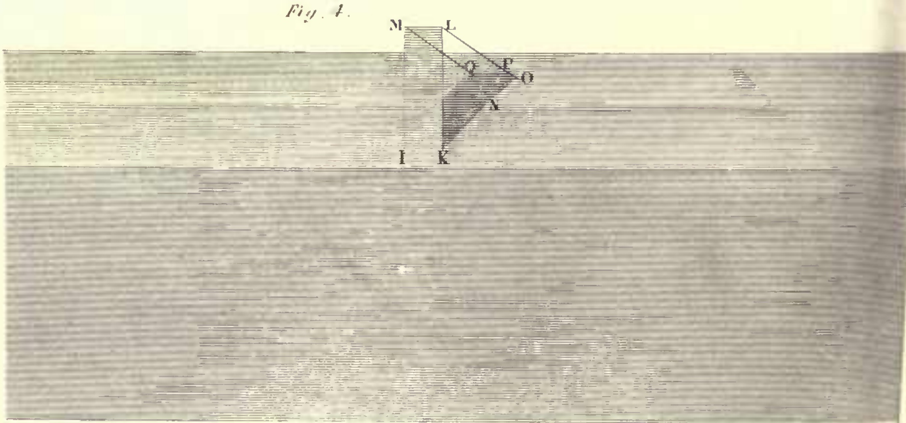


Fig 1. Nº 3

Fig. 1. Nº 1.

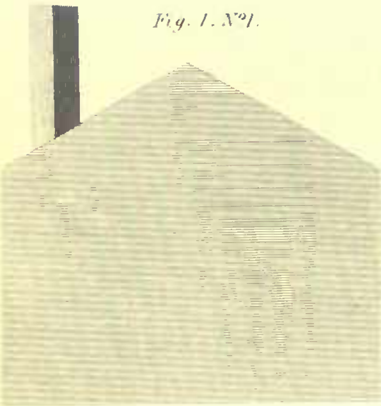


Fig 1. Nº 2

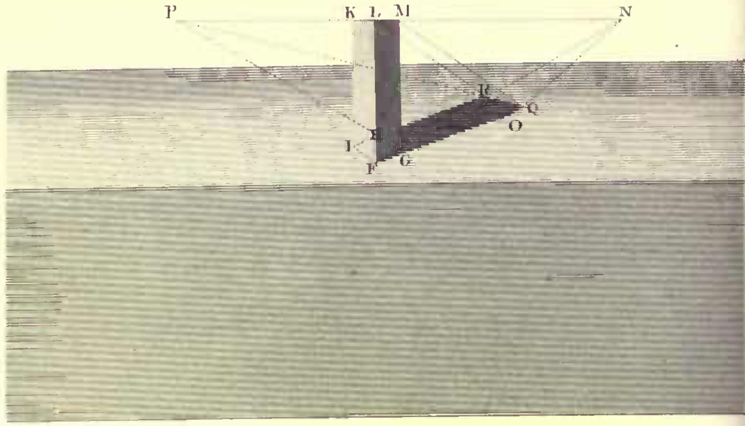


Fig 2

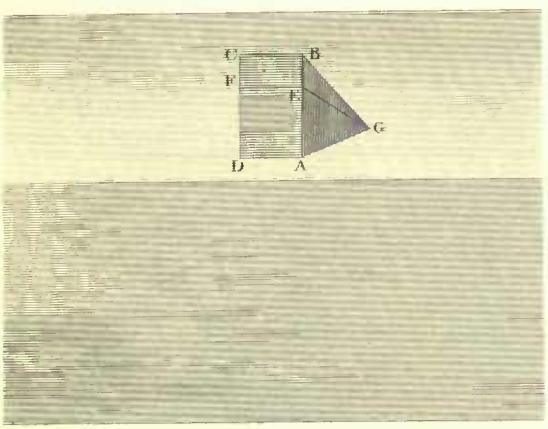


Fig. 3

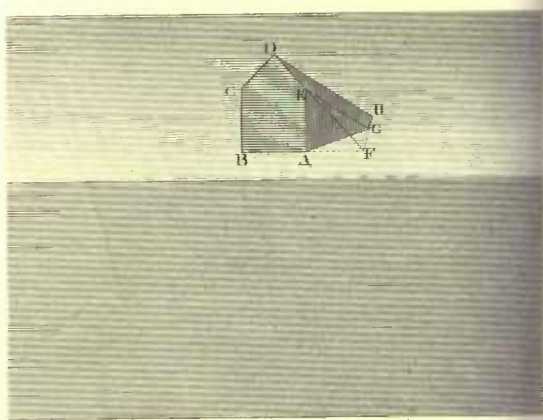


Fig. 4

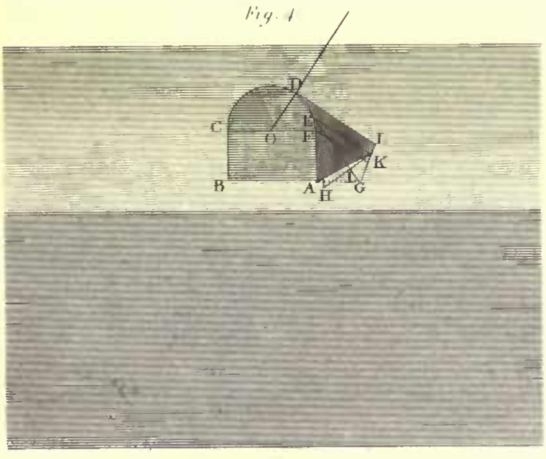
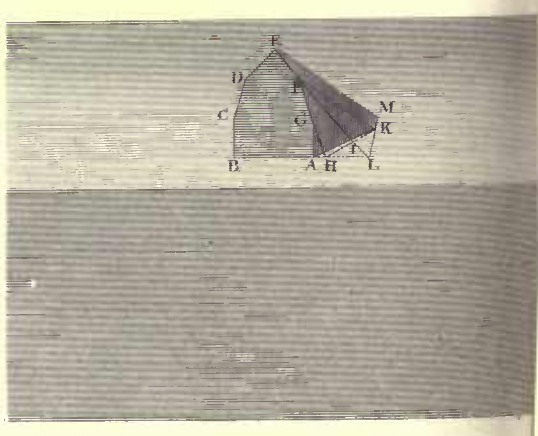


Fig 5



equal to A C, and join G B; and G D will represent the sun's ray, on the plane of which the intersection is D B.

This problem is necessary in the three preceding examples, when the seat and inclination of the sun is given on the horizon, in order to find the orthography of the ray upon both elevations, viz., upon the front and end.

PROBLEM XXVI.—*To find the representation of the shadow on a prismatic solid, by a plane cutting the prism perpendicular to its arrises; given the elevation of the prism on a plane parallel to its arrises, and parallel to one of its sides: as also the figure of the plane which throws the shadow, with the section of the surfaces of the prism on that plane, and likewise the sun's rays, both on the plane and on the elevation.*

Place the figure of the plane and the elevation so that any two of their corresponding points, or parts, may be in a line perpendicular to the intersection. Draw the representation of the rays from all the angular points on the figure of the plane, to meet the sectional line of the prism; draw the corresponding representations of the rays on the elevation, and from the points where the representation from the angles of the plane meet the section, draw lines parallel to the representations of the arrises of the prism to cut the corresponding rays on the elevation; then, by joining the successive points, the shadow required will be determined.

Example 1. *Figure* 2.—Let A B C D be the plane, and E F, F G, the intersection of two other planes at right angles to A B C D; let K L N O be the elevation of the prism; the lines O N, R M, and K L, representing the arrises corresponding to the angular points, G, F, E, on the section,—that is to say, the point G is in the same straight line with O N, the point F with R M, and the point E with K L; also, let K L M R represent the plane parallel to the plane of elevation, and let K P represent the line of intersection; make K U equal to the breadth of the shadow at the bottom; draw the ray, D I, on the figure of the plane, and D T perpendicular to K P, cutting K P at T; and T will represent the point which throws the shadow on the elevation; draw T Q, the ray of the sun, on the elevation; I Q parallel to D T, and U S parallel to K P, cutting R M at S; join S Q; then K U S Q V O will be the representation of the shadow required.

Example 2.—*Figure* 3 shows the shadow of a chimney-shaft upon the roof of a house, the sides of the shaft being parallel and perpendicular to the front.

Example 3.—*Figure* 4 shows the shadow of a chimney-shaft upon a roof, which has two inclinations; the sides of the shaft being situate as in *Example* 2. The principles of performing these two examples are the same as in the preceding problem, *Example* 2.

PROBLEM XXVII.—*To find the indefinite shadow of a line perpendicular to the horizon on an inclined plane: given the inclination of the plane to the horizon, and the seat of the sun's rays: the intersection of the inclined plane with the horizon being parallel to the intersection of the plane of representation and the horizon.*

Plate XI. *Figure* 2, No. 3.—Draw any straight line, A B C; make A B to A C, as the sine is to the cosine of the plane's inclination; make the angle, C A D, equal to that of the seat of the sun's rays, with a line perpendicular to the intersection of the horizon and the plane of representation; draw C D perpendicular to A C, and join B D; and B D will be the indefinite representation required.

PROBLEM XXVIII.—*To find the shadow of a plane rectilinear figure intersecting another plane figure: a point through which the shadow is to pass on the plane which receives the shadow, and the orthography of the rays of the luminary, being given.*

If the line which throws the shadow meets the intersection of the planes, draw a straight line from the point of concourse through the given point, and the line thus drawn will be the indefinite representation of the shadow. But if the line which throws the shadow does not meet the intersection of the planes, continue the line or the intersection of the plane, or both of them, as the case may require, to meet each other, and draw a straight line from the point of concourse through the given point, as before; and the line thus drawn will be the shadow required.

PROBLEM XXIX.—*Given the orthography of a determinate line, and the indefinite representation of its shadow, also, the orthography of the sun's rays, to find the limits of the shadow.*

From one, or either of the terminations of the line, as the case may require, draw the orthography of a ray to cut or meet the indefinite shadow of the line, and the length comprehended between the point, or points, thus found in the shadow, will be the extremity, or will terminate the length, as required.

Example 1.—*To find the shadow of a chimney-shaft on the roof of a house.*

Plate XI. *Figure* 1.—Find the indefinite shadow of the vertical line, F L, No. 2, thus: let A C, No. 3, be parallel to F L: find B D, as in PROBLEM XXVII: draw F O, No. 2, parallel to B D, No. 3: now let the parallel of the orthography of the sun's rays be given: from L draw L O, the orthography of the sun's rays, and the point O is the termination of the shadow, F O; produce F G and L M to meet each other in N; draw O N, and it will give an indefinite representation of the shadow of the edge, L M, of the top; draw the orthography, M Q, of the ray, parallel to L O, cutting O N at Q; continue the intersection, G H, and the edge M L, of the top, to meet each other in P; draw Q P, and it will give the indefinite representation of the edge of the top, and of the other vertical plane not seen; draw H R parallel to F O, and F O Q R H will represent the shadow required.

Example 2.—*Figure* 2, is the shadow of a dormer window with a rectangular front, and the top inclined towards the front: find the indefinite shadow, A G, as in the last example, and the orthography, F G, of the sun's rays; join B G, and A G B will represent the shadow, as required.

Example 3.—*Figure* 3, is the shadow of a dormer window, with a pediment top: find A G, the shadow of A E, as before; then D E being the next line that projects a shadow, A B is the intersection of the plane, A B C D E; therefore, produce D E and B A to meet in F; join F G, which produce to H; find the termination, H, by the rays, H; and A G H E will represent the shadow, as required.

Note.—If the lines D E, E G, had been in the same straight line, or had formed a salient angle, instead of a re-entrant one, the upper side of the shadow would have been the same as in the last example.

Example 4.—*Figure* 4, exhibits the shadow of a dormer window with a semicircular head: find the shadow, A I of the perpendicular line A F; let O be the centre of the semicircular head; draw D L to touch the head of the window at D, parallel to the orthography of the sun's rays; draw O D perpendicular to D L, and D will be the point of contact.—Now, let it be required to find the shadow of any intermediate point, E, of the arc of the circle: A B is the intersection of the plane A B C D E F; therefore draw the chord, E F, and produce A B and E F to meet each other in H; produce H I to K; and draw the orthography, E K; and the point K will represent the shadow of the point E. In like manner, draw the chord D E, and produce D E and B A to meet each other in G; join G K; produce G K to L; and L will represent the shadow of the point D: draw a curve from the point I, through K to L, touching the straight line A J and D L at the points I and L; and A I K L D will represent the shadow, as required.

Example 5.—*Figure* 5, exhibits the shadow of a dormer window with a kirb-roof top; find the shadows, M, K, I, of the points E, F, G, as in the last example; and A I K M E F G A will represent the shadow required.

It is hardly possible to conceive a method more expeditious, than the foregoing, of finding the indefinite representation of the shadow, by producing the line which throws it, and the intersection of the plane, till they meet each other in the plane in which the shadow is thrown.

Example 6.—*Plate* XII. *Figure* 1, No. 1, is the elevation of a prismatic object, as the walls of a building, which form two prisms attached to each other; the lower prism is terminated with an inclined plane, in the manner of a roof. The plan, No. 2, shows the end of the higher prism, to which the lower prism is attached, to be at an obtuse angle with the plane of the front.

Let the ray, B F, No. 2, be drawn on the plan from the corner B, to meet the side C D at F; then F is the projected point of B on the plan; draw *f g*, the elevation of the point F, cutting the top of the lower wall at *g;* draw *l m*, the elevation of the sun's ray, as in the preceding examples; produce the intersection, *h i*, of the inclined plane to meet the line, *b l*, which projects the shadow in *k;* through the points, *k* and *g*, draw *k g m*, meeting the elevation of the sun's rays at *m.* Now, as the line, *l o*, of the top of the end of the prism projects the next shadow, produce *l o*, and the intersection, *i h*, to meet each other in *n;* draw *m n*, cutting the upper termination, *h q*, of the inclined plane at *r;* and *f g m r h i e f* will represent the shadow required.

Example 7, *Figure* 2, No. 1, is a plane figure, representing the gable of a house, of which B A is the base; F G, G H, H U, are the intersections of several planes; F G, parallel to B C, is the intersection of a vertical plane, as the face of a wall; G H and H U are the intersections of two inclined planes, forming two sides of a kirb-roof. Now, to find the shadow, by the intersecting points of the lines which project the shadow with the plane on which the shadow is thrown, it is evident that the line, B C, will project a shadow on the plane, whose intersection is F G, parallel to F G; and as B C, No. 2, represents B C, No. 1, draw *p q* parallel to B C, cutting the lower inclined plane at *q*. Then, supposing the side, B C, also to throw a shadow upon the lower inclined plane, produce its intersection, H G, No. 1, and the line, B C, which throws the shadow, to meet in K; produce C B, No. 2, to *k*, and draw *k k* parallel to B A; then through the points, *k* and *q*, draw *k q r;* draw C C from C, No. 1, to C, No. 2, parallel to B A, No. 1; from the point, C, No. 2, draw the elevation, C *r*, of the sun's rays. C D, No. 1, is the next line, which throws the shadow still upon the lower inclined plane; therefore, produce C D and G H to meet each other in M; draw M *m* parallel to B A, cutting B C at *m;* draw also the indefinite shadow, *r m*, cutting the intersection of the two inclined planes at *s*, No. 2; then the line, C D, will also project a shadow upon the upper inclined plane; therefore, produce H U and C D, No. 1, to meet each other in N; draw N *n* parallel to B A, cutting B C at *n;* draw the indefinite shadow, *s n;* then *d*, No. 2, being the corresponding point of D, No 1, draw the elevation of the ray, *d t*, No. 2; and the point, *t*, No. 2, will be the shadow of D, No. 1. D E, No. 1, is the next line that projects a shadow, and U is the intersection of D E and H U, and *u* the corresponding point to U, No. 1; therefore join *t u* and B *p q r s t u* will represent the shadow required.

Example 8, *Figure* 3, represents an example, similar to *Figure* 1, but with two inclined planes; the plan is here omitted, as being only used in the projection of the first ray; the ray, G L, parallel to A B, is drawn at pleasure at any distance from F H, to meet the intersection, H P, of the two adjoining planes in L; produce J H to meet the line A B, which throws the shadow in D; draw D L, and produce D L to S; draw the elevation of the ray B S; then B C is the next line which throws the shadow; produce B C and H J to meet each other in E; draw the indefinite shadow, S E, to cut the intersection, I Q, of the two inclined planes at M; then B C will also project a shadow upon the upper plane; therefore, produce B C, and the intersection, J K, of the upper plane, to meet each other in T; draw the indefinite shadow, M T, cutting the top, K R, at N; then F G L S M N K will represent the projection of the shadow by the edges A B, B C, of the plane, A B C, as required.

This figure may either represent the vertical plane, A B C, or perpendicular to the first vertical plane, F O P H, according as the sides are parallel or oblique to the plane of representation.

Example 9. *Figure* 4.—Let A B C D E, be the figure of a gable; K L M N the upright of a wall; A B the base of the gable; N M the base of the wall; and suppose that the edge, B C, is joined to N K at any given angle, so that the point B may coincide with the point N. Now, let it be required to find the shadow of the gable, A B C D E, upon the wall, K L M N, the side, B C, of the gable being placed parallel to the edge, N K, of the wall: as the vertical sides, A E and B C, of the gable are parallel, the shadow thrown upon the plane, K L M N, will also be parallel to the edge, N K; therefore, taking N *g* at pleasure, draw *g h* parallel to N K; then, *e* being the corresponding point of E, draw *e h*, the elevation of a ray of the sun, and the point *h* will be the shadow of the point E. E D being the next line that projects the shadow, produce E D and B C, the intersection of the plane, to meet in F; find *f*, the corresponding point of F, and draw the indefinite shadow, *h f;* find *d*, the corresponding point of D, and draw the elevation, *d i*, of a ray, cutting *h f* at *i;* C being the concourse of the line which throws the shadow with the intersection, B C, of the plane, find *c*, the corresponding point of C, and join *c i;* then *c i g h* will represent the shadow of the lines A E, E D, and D C.

Example 10. *Figure* 5.—A B C D E represents the gable of a building, as in the preceding example; S T U V the upright wall and inclined side of a roof; F G and G I the respective intersections of the wall and the roof; then supposing the edge, E D, of the gable to be attached to S *b*, it is required to find the form of the shadow; the intersection, F G, of the plane being parallel to A B, the breadth of the shadow will also be parallel; therefore, taking the distance, S *n*, upon S V at pleasure, draw *n o* parallel to S T; then, *b* being the corresponding point of B, draw the elevation, *b o*, of the ray: B C being the next line which projects the shadow, produce the intersection, F G, to meet B O in L; find *l*, the corresponding point of L, and draw the indefinite shadow, *o l*, cutting *b* W at *p;* B C now projects the shadow upon the inclined plane; therefore, produce the intersection, G I, and the edge, B C, that throws the shadow, to meet in K; find *k*, the corresponding point of K; through *k* and *p* draw the indefinite shadow *k p q;* *c* being the corresponding point of C, draw the elevation, *c q*, of a ray: find *i*, the corresponding point of I; and join *i q*, which completes the shadow on both planes.

Problem XXX.—*A cylinder being capped with a square abacus, jutting alike over each of the sides, to find the representation of the shadow; the elevation and plan being given, as also the plan and elevation of the sun's rays.*

PROJECTION.

Fig. 1.

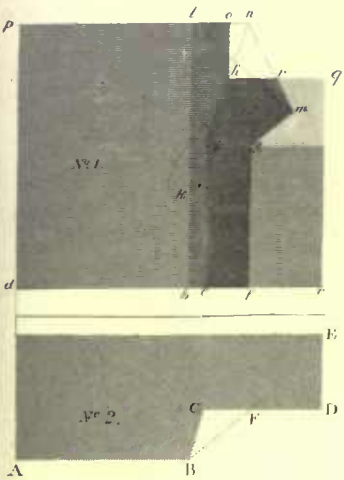


Fig. 2.

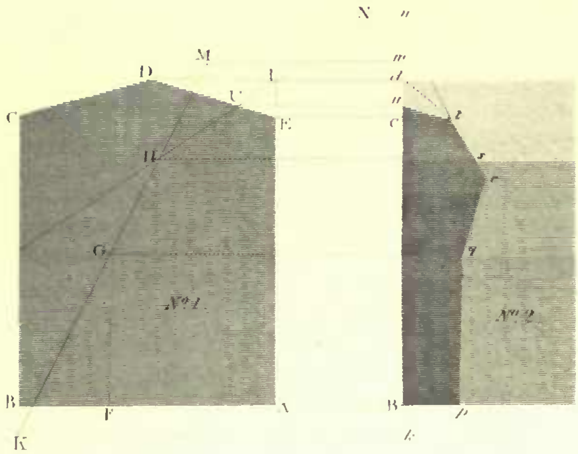


Fig. 3.

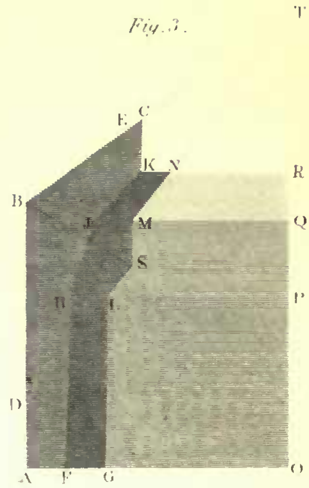


Fig. 4.

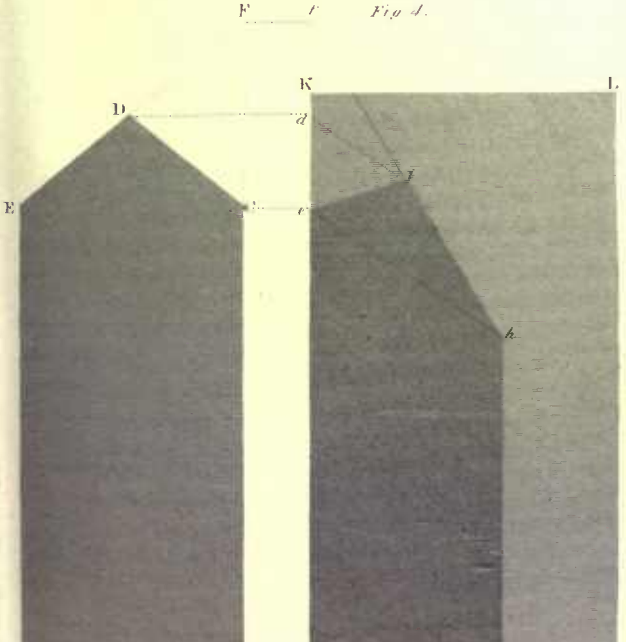
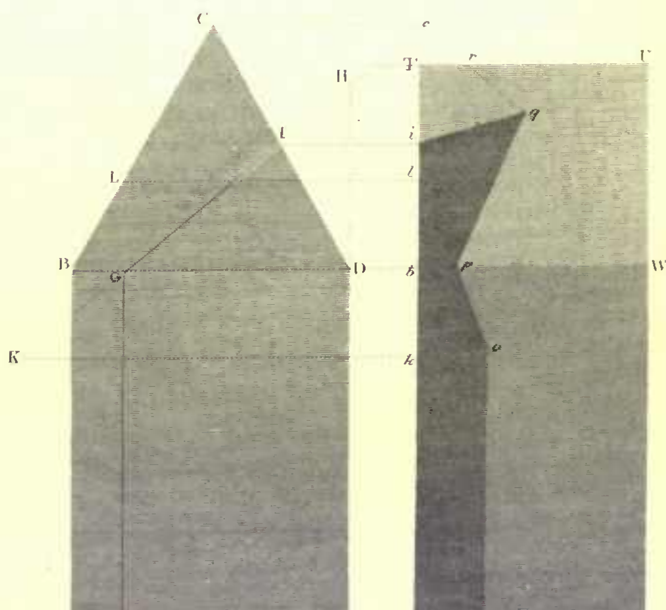


Fig. 5.



...wn by P. Nicholson.

Engraved by J. C. Buttre.

Fig 1 N°1

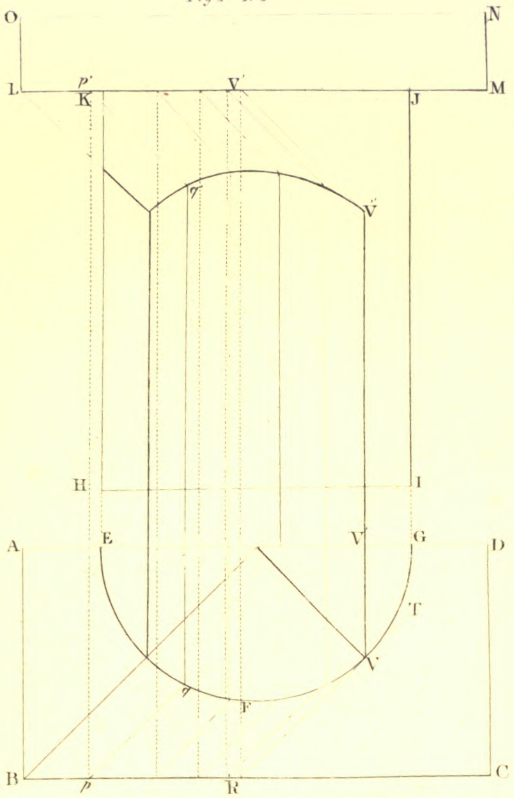


Fig 1 N° 2

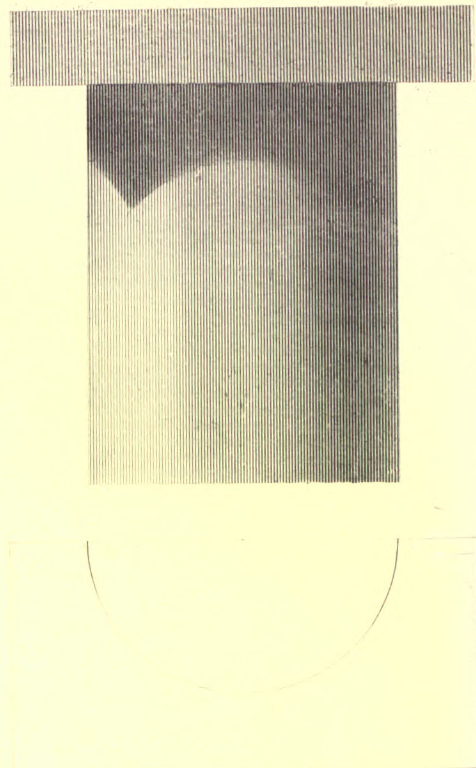


Fig 2. N°1.

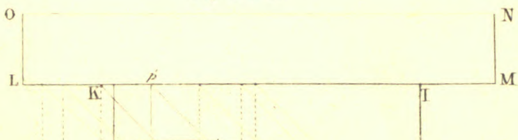
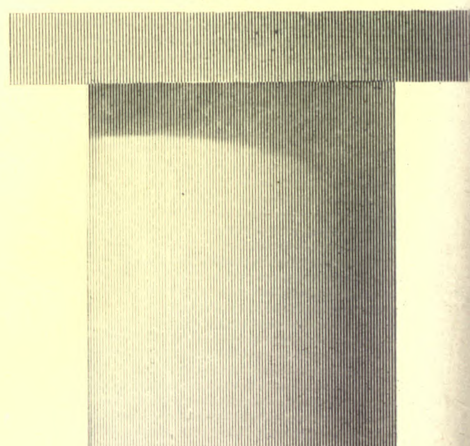


Fig 2 N° 2



Drawn by P. Nicholson *Engraved by*

Plate XIII. *Figure* 1, No. 1.—Let A B C D be half the plan of the abacus, E F G half the plan of the cylinder, H I J K the elevation of the same, and L M N O that of the abacus; to project the shadow of any point, p', in the elevation of the abacus, p being its corresponding place on the plan; draw the plan of the ray, $p\ q$, meeting the semi-circumference E F G at q; also from p' draw $p'\ q'$ the indefinite elevation of the ray; and draw $q\ q'$ parallel to I J, or H K, and q' will represent the shadow of the point p'. Find as many other points as may be necessary, in the same manner; then, through all the points thus found, draw a curve, which will be the shadow required.

If the ray, R T, be drawn to touch the circle in V, on the plan, and if V′ V″, the elevation of V, be drawn, then V′ V″ will be the line of separation of light and shade.

If the rays of the sun be in two planes, one perpendicular to the plane of representation, but inclined 45 degrees to the horizon, and the other equally inclined to the horizon and to the plane of representation; that is to say, making 45 degrees with each; then all the points, q', will be in the circumference of a circle, whose diameter is equal to the diameter of the cylinder.

No. 2, shows the elevation completely shadowed.

Problem XXXI.—*A cylinder being capped with another concentric cylinder, to find the representation of the shadow.*

Figure 2, No. 1.—Proceed to find all the points, q', as in the last problem, and a curve being traced through them will give the shadow required. The point p', on the elevation, corresponding to p, on the plan, may be thus found: draw B R parallel to A C, and A R perpendicular to A C; draw p S parallel to A R, cutting B R at S. In L M make L p' equal to R S, and p' will be the corresponding point of p. No. 2 shows the elevation completely shadowed.

Projection, *Stereographical.* See Stereography.

Projection of Shadows, *see* Shadows.

PROJECTURE, in architecture, the out-jettings, or prominence, which the mouldings and members have, beyond the plane, or naked, of the wall, column, &c. They are called by the Greeks, *ecphoræ;* by the Italians, *sporti;* by the French, *saillés;* by our workmen frequently, *sailings over;* and by the Latins, *projecta*, from *projicio, I cast forward;* whence the English, *projecture.*

Vitruvius gives it as a general rule, that all the projecting members in buildings have their projectures equal to their heights: but this is not to be understood of the particular members, or mouldings, as dentils, coronas, the fasciæ of architraves, the abacus of the Tuscan and Doric capital, &c., but only of the projectures of entire cornices, &c. The great point of building, according to some modern architects, consists in knowing how to vary the proportions of projectures, &c., agreeably to the circumstances of the building.

Thus, say they, the nearness and remoteness, making a difference in the view, require different projectures; but it is evident the ancients had no such intention.

The projecture of the base and cornice of pedestals, M. Perrault observes, is greater in the antique than in modern buildings, by one-third; which seems to follow, in good measure, from the ancients proportioning this projecture to the height of the pedestals; whereas the moderns make the projecture the very same in all the orders, though the height of the pedestal be very different. The reason of this change, which the moderns have made of the antique, the same author refers to a view of the appearance of solidity.

PROLATE (from the Latin *prolatus*, flat) an epithet applied to a spheroid produced by the revolution of a semi-ellipsis about its longer diameter. If the solid be formed by the revolution of a semi-ellipsis about its shorter diameter, it is called an *oblate spheroid;* of which figure is the earth we inhabit, and, perhaps, all the planets too; having their equatorial diameter longer than the polar.

PRONAOS, (from προναος) in ancient architecture, a porch in front of a temple, church, palace, or other spacious building.

PROPORTION, (French) the just magnitude of the members of each part of a building, and the relation of the several parts to the whole; *e. gr.* of the dimensions of a column, &c., with regard to the ordonnance of the whole building.

One of the greatest differences among architects, M. Perrault observes, is in the proportions of the heights of entablatures with respect to the thickness of the columns, to which they are always to be accommodated. *See* Entablature. There is scarcely any work, either of the ancients or moderns, in which this proportion is not different; some entablatures are even nearly twice as high as others: yet it is certain, that this proportion ought, of all others, to be most regulated: none being of greater importance, as there is none in which a defect is sooner observed, nor any in which it is more shocking.

Proportion is likewise understood of the magnitudes of the members of architecture, statues, or the like, with regard to the distance whence they are to be viewed.

The most celebrated architects are much divided in their opinions on this subject; some will have it, that the parts ought to be enlarged in proportion to their elevation; and others, that they ought to remain in their natural dimensions.

PROPORTIONAL COMPASSES, an instrument consisting of two equal and narrow slips of metal, terminating at each extremity in a point, the slips being connected together by a cylindric pin, which, when they are made to coincide, is moveable along a slit through both pieces: so that the axis, or centre of the pin, and the two extreme points of each piece, may be in the same straight line, and fixed at any point which will keep its situation in each of the pieces, whether the instrument be opened at any angle, or shut.

The two surfaces of the instrument which appear when it is shut are called *the sides.*

The four parts of the instrument, from the centre of motion, are called *legs.*

It is evident from the definition given, that two legs will be equal to each other, and of the same invariable length, whatever angle these legs make with each other; and that the two which include the opposite angle will also be equal to each other, and their length also invariable at any angle formed by them.

The application of the proportional compass with regard to the division of lines, and the circumferences of circles into any number of equal parts, has already been shown under the articles Compasses and Instruments. In this place it is proposed to treat of its application to perspective, and some other branches of geometry and architecture.

Problem 1.—*To set the proportional compasses in the ratio of a line divided into any two parts.*

Figure 1.—Take a line equal to the length of the instrument, and divide it in the ratio required; then apply the shorter or longer part of the line thus divided on the length of the instrument when shut, from the extremity of the longer or shorter legs to an intermediate point, to which bring the axis of the pin, and the compasses will be set in the ratio required. Thus, let A D, be a straight line, divided in E; make A B equal to the length of the instrument; join D B, and draw E C parallel to D B, cutting A B at C; shut the instrument; take either distance, C A or C B, say the shorter, C B, and apply it from the shorter end of the instrument; push the slider along the slit until the centre of the pin coincides with the other extremity, and the instrument will be set in the ratio required.

As this problem is essential to most of the following, the reader is requested to understand it thoroughly before he proceeds farther.

PROBLEM II. *Figure* 2.—*Given any number of lines*, A B, C D, E F, G H, *&c., to find a series of other lines, which will have the same ratio in every two corresponding lines, given one line* a b, *of the series required, corresponding to* A B *of the series given.*

Set the proportional compasses in the ratio of A B to *a b* by Problem I.; then if A B be greater than *a b*, take the distance, C D, with the remote extremities, and make *c d* equal to the distance contained between the near extremities, and *a b* will have the same ratio to *c d*, which A B has to C D: in like manner, take the distance, E F, with the remote extremities, and make *e f* equal to the distance contained between the points of the near extremities, and *c d* will have the same ratio to *e f*, that C D has to E F; or *a b* will have the same ratio to *e f*, that A B has to E F, and thus the remaining lines, *g h*, &c., will be found in the same manner; but if the line, A B, in the given series, be less than *a b*, in the given line of the series required, the lengths, C D, E F, &c., must be taken with the shorter ends of the compasses, and the lines, *c d*, *e f*, &c., made respectively equal to the corresponding distances contained between the extremities of the longer ends.

PROBLEM III.—*To divide a given line in the same proportion as another given line is divided.*

Figure 3.—Let A X be a given line, divided into the parts, A B, B C, C D, D X, and let it be required to divide the line, *a e*, in the same proportion.

Set the compasses in the ratio of the whole lines A X and *a e*, then take the distances, A B, B C, C D, D E, with the same legs which were applied in taking the distance A X, and with the other legs corresponding to the distance *a e*, make *a b*, *b c*, *c d*, *d e*, respectively equal to the distance between the points of these legs, and *a b*, *b c*, *c d*, *d e*, will have the same ratio to each other, that A B, B C, C D, D X, have to each other.

PROBLEM IV.—*To divide a straight line*, A X, No. 2, *in continued proportion; given the extreme part*, A B.

Set the compasses in the ratio of A X to B X by Problem I.; contract the points of the longer legs to B X, then, with the shorter legs, cut off the distance X C; again contract the distance between the points of the longer legs to X C, thus found, and with the shorter legs cut off the distance X D; and thus, by setting the distance between the points of the longer legs to the last distance found, the shorter legs will give the succeeding part by transferring the distance between the shorter legs from X towards A. By continuing this operation, as many points may be found as are necessary for the purpose required; then A B : B C : C D : D E : E F : F G, &c; that is, A B : B C : : B C : C D; and B C : C D : : C D : D E, &c.

Any question in the rule of three may be resolved by the proportional compasses and a plane scale. Thus, suppose three articles of the same kind to cost two shillings; what will eight cost? Set the compasses in the ratio of 2 to 3 by Problem I.; extend the points of the shorter legs to 8 on the scale: then apply the longer legs to the scale, and 12, the measure indicated, will be the fourth proportional, as required.

Where there is a great disproportion in the terms of the ratio, it would be more eligible to use two scales; thus, suppose it were required to find a fourth proportional to the numbers 30, 3, and 45, take any convenient scale for the antecedents, 30 and 45, and any convenient larger scale for the consequents, 3; then, by Problem I. set the compasses in the ratio of the distance 30, on the scale of the antecedents, to the distance 3 in the scale of the consequents; then take 45 from the scale of the antecedents with the legs first applied to the same scale, and the other legs will give the distance 4.5, or $4\frac{1}{2}$, the answer as required, by applying the distance between their points on the scale of the consequents.

By this, any proportion, whether in lines or numbers, may be resolved.

PROBLEM V. *Figure* 4.—*Given two straight lines*, A B *and* C D, *tending to an inaccessible point, and a point*, E, *in position, to draw a straight line through the last-named point, so that all the three straight lines*, A B, C D, *and that which is required to pass through the given point, may have the same point of concourse.*

Through the given point, E, draw F G, meeting A B at F, and C D at G; draw H I parallel to F G, cutting A B at H, and C D at I: set the proportional compasses in the ratio of the two straight lines, F G and H I; then, F G being greater than H I, take the distance G E, with the longer legs, and make I K equal to the distance between the points of the shorter legs; draw a straight line through the points E and K; then if the straight lines A B, C D, and E K, be produced, they would have one common point of concourse.

Corollary. Figure 5.—Hence, if A B and C D be two straight lines, and if E, G, I, L, be several points in a straight line, P O, meeting A B in P, and C D in O; then drawing any line, R S, parallel to P O, cutting A B at R, and C D at S, and setting the proportional compasses in the ratio of P O to R S; (P O being longer than R S,) take the distance O E, O G, O I, O L, with the longer legs, and apply the distances contained between the points of the shorter legs respectively from S to F, from S to H, from S to K, and from S to M; and drawing the lines, E F, G H, I K, L M, they would all have one common point of concourse, if produced with A B and C D.

Figure 12 shows the application of this problem and its corollary, in drawing the representations of the horizontal lines which regulate the heights of doors and windows in the perspective representation of a building, when the vanishing points of the sides, A *k* and A *h*, are not in the picture, and when all the points, through which these lines pass, are in the corner of the building, or any other convenient line.

PROBLEM VI. *Figure* 6.—*Given two straight lines*, A B *and* C D, *tending to an inaccessible point, and any number of points*, E, G, I, *in position, not in a straight line; to draw a right line through each of the points* E, G, I, *tending to the same point with* A B *and* C D.

Through the point E, draw any line, A C; through the point G, draw L M, parallel to A C, cutting A B at L, and C D at M; and through the point I, draw N O, also parallel to A C, cutting A B at N, and C D at O; draw any line, I Q, parallel to A C; set the proportional compasses in the ratio of A C to I Q; take the distance C M, C O, with the longer legs, and make Q R, Q S, respectively equal to the distances contained between the points of the shorter ends; draw R T, S U, parallel to P Q, cutting A B in T, U; make Q *e*, R *g*, S *i*, respectively equal to C E, M G, O I; and draw the straight lines, E *e*, I *i*, G *g*, which will tend to the same point with A B and C D.

Figure 7 is added to show the great use of these problems in perspective, and completely exemplifies this problem by showing, that if any section of the original object made by the plane of the picture be obtained, such as the mouldings on the face of a building, it will be very easy to draw lines from all the points of such a section that will tend to the proper vanishing point, two lines tending to the same point being given.

PROBLEM VII. *Figure* 8.—*Given the representation*, $a'' b'' e'' d'' e'' f''$, *of the end of a right cylinder*, (*the original* *having its axis parallel to the picture,) and the vanishing line, u z, of the plane of that end; through a given point, a, in any perpendicular, a'' a, to u z, to draw the representation of the other end of the cylinder.*

Let *a'' a* cut the vanishing line, *u z*, at *u*; draw *b'' b*, *c'' c*, *d'' d*, *e'' e*, *f'' f*, parallel to *a'' a*, cutting *u z* respectively at *v*, *w*, *x*, *y*, *z*; set the proportional compasses in the ratio of *u a''* to *u a*; then *u a''* being greater than *u a*, take the distance, *v b''*, with the longer legs, and make *v b* equal to the distance contained between the points of the shorter ends; find the remaining points, *c*, *d*, *e*, *f*, in the same manner, and through the points, *a*, *b*, *c*, *d*, *e*, *f*, draw a curve, which will be the representation of the other, or lower, end of the cylinder.

Or, if the base, *a*, *b*, *c*, *d*, *e*, *f*, were given, the top would be found in the same manner, by making the ratio of the shorter legs to the longer legs, as *u a* to *u a''*, and taking *v b* with the nearer extremities, and making *v b''* equal to the distance of the remote extremities, and finding the remaining points, *c''*, *d''*, *e''*, *f''*, in the same way. In like manner, any section, *a'*, *b'*, *c'*, *d'*, *e'*, *f'*, may be found.

This application of the proportional compasses is exceedingly useful in the representation of bows, when required in the fronts of buildings, as is shown by *Figure* 9, which exhibits the elementary lines of the perspective of a house. Here the horizontal terminations of the apertures are readily represented, by only drawing perpendicular lines, which may be the vertical terminations of such apertures, and would therefore be required at all events. The same description of words applies to this figure, as in *Figure* 8, to which the problem refers.

Problem VIII.—*Given the representation of any point on the picture, and the intersecting and vanishing lines of the plane it is in, to find the height of a representative line, the original of which is parallel to the picture.*

Set the proportional compasses in the ratio of the distance between the intersecting and the vanishing lines, and the distance of the point from the vanishing line, then take the length of the original line with the longer legs, and the opposite points will give the height of the line required.

Example.—Suppose the distance between the vanishing and intersecting lines to be three inches, and the distance between the representation of the point or foot of the line to be two inches, and the height of the original line to be six inches, required the perspective height of the same. Set the proportional compasses in the ratio of 3 to 2; extend the longer legs of the compasses to six inches, and the extent between the opposite shorter legs will be the height of the line required, which, in this case, will be four inches.

Scholium.—By this method all the heights of the representation of a solid may be found without any additional lines; but, in order to expedite the work, when the original object is of different heights in the same plane parallel to the picture, or where the same height is required to be found upon two or more points, it will be eligible to draw a straight line through one of the points, cutting the one or more lines on which the heights are to be found; and the same setting of the compasses will do for as many heights as are to be raised upon the line so drawn.

Example.—Suppose a cylinder to be represented, its base is an ellipsis, to find any two points in the height of the cylinder; draw a straight line, parallel to the vanishing line, to cut the representation of the base of the cylinder in two points; upon each point of section draw a perpendicular; set the proportional compasses in the ratio of the distance between the intersecting and vanishing lines, and either point and the vanishing line; then take the height of the cylinder between the points of the long legs, and the distance between the opposite points will give the perspective height upon each perpendicular from its respective foot.

In the application hitherto made of the proportional compasses, the sides of the instrument have not required any gradations of parts; but as these are necessary to the perfection of the instrument, the construction of the scales for this purpose is as follows.

Problem IX.—*To construct the scales of sines for the proportional compasses.*

Figure 10.—Let A C be a scale of sines found in the usual manner; and let C A be produced to R, making A R equal to the radius; draw R D at any convenient angle with R C; make R D equal to the length of the proportional compasses, and join C D; draw A 9 parallel to C D, and as 9 at the point C is the chord of 90°, the point 9, in R D, will be the point for the index of the slider to be set to; then if the legs of the compasses be set to any angle, the distance between the points corresponding to D will be to the distance between the points corresponding to R, as the sine of 90° is to radius. In like manner, join D 8, the next point, 8, in the line A C, and draw A 8 parallel to D 8, cutting R D in 8; then the point, 8 in R D, will be the point for the index of the slider to be set to; then, if the ends of the proportional compasses, corresponding to R, be opened to any radius, the extent of the ends corresponding to D is the sine of 80 degrees corresponding to that radius: in like manner, the points 6, 5, 4, 3, 2, 1, will be found in R D, so that 1, 2, 3, 4, 5, 6, 7, 8, 9, in R D, are the gradations on the side of the proportional compasses corresponding to 10°, 20°, 30°, 40°, 50°, 60°, 70°, 80°, 90°; hence if the index be set to any of these numbers, and the points corresponding to R be extended to the radius, the distance between the opposite points will be the sine of that number of degrees. The cosines have the same divisions as the sines, but are numbered the contrary way.

In the same manner, by placing the radius in the same straight line with a common scale of sines or tangents from zero on A, so as to lengthen the line A C, of tangents, by adding the said radius, A R, and forming the extension, R C, drawing R D at any convenient angle with R C and dividing R D as in the problem; then R D will contain the gradations of a scale of tangents, to be inserted on the side of the proportional compasses: so that when the index, or mark, upon the slider is brought to any of these numbers, the end corresponding to R being opened to the radius, the end corresponding to D will be the sine or tangent of the angle corresponding to that number. See the *Figure*.

Figure 11 shows the application of the method to a scale of tangents.

Example 1. *Figure* 13.—To make an angle of 30° at a given point, A, in the straight line A B.

With any convenient radius, A B, describe an arc, B C; set the index to 30° on the line of chords; then extend the points of the instrument corresponding to R, to the radius A B, and with the opposite points set off the distance B C, on the arc, and join C A; then C A B is the angle required.

Example 2.—To find the tangent of 40° to any given radius within the limits of the points corresponding to R.

Set the index to 40° on the line of tangents, and extend the points R to the radius; then the extent between the opposite points will be the tangent of 40°, as required.

Example 3.—To find the sine of 20° to any given radius within the limits of the points corresponding to B.

Set the index to 20° on the line of sines, then extend the points corresponding to R to the radius given, and the extent between the opposite points will be the sine of the angle, as required.

Example 4.—To find the cosine of 50°, the radius being given within the limits of the instrument.

Set the index to 50° on the line of cosines; extend the points corresponding to R to the radius, and the opposite points will be the cosine of the angle required.

Example 5.—The chord, sine, cosine, or tangent, of any number of degrees being given, to find the radius.

Extend the points corresponding to D to the chord, sine, cosine, or tangent, and the opposite points corresponding to R will be the radius of the circle required.

PROBLEM X.— *To draw the representation of a house, by making the centre of the picture the dividing point, having the dimensions of the building given.*

Figure 12.—Let V L be the vanishing line, *h k*, the intersecting line, and c, the centre of the picture; and let the building touch the intersecting line in A; also, let the vanishing points of the sides be supposed to be given.

Set the proportional compasses to the cosine of the angle which the one side of the building (viz., say that on the right) makes with the intersecting line by *Example* 4, Problem IX., say 30°; then, with the ends of the instrument corresponding to R, take the original measure from a plan; or, if the measures are known in feet, &c., take them from a scale, without being at the trouble of drawing a plan; take the distance of the corner of the building, and the nearest side (say 3 feet 6 inches) from the scale, with the remote points, and with the opposite points set off the distance A b on the intersecting line; take the breadth of the window from the scale (say 3 feet) with the remote points, and with the opposite points set off the distance b c, on the intersecting line; take the breadth of the next pier from the scale (say 4 feet) with the remote points, and with the opposite points set off the distance c d: proceed in this manner to h, so that the whole extent, A h, will represent a distance of 24 feet. Next proceed to the end of the building, which is supposed to be on the left hand; here, as the angle of the building is supposed to be a right angle, and as the right-hand side was supposed to make an angle of 30° with the intersecting line, the left-hand side will therefore make an angle of 60°; set the index of the proportional compasses to 60° in the line of cosines; then, from the scale, take the breadth of the end (say 20 feet) with the remote ends, and with the opposite ends set off the distance, A k; set the breadth of the piers from k to j, and from A to i, in the same manner, draw the lines A h and A k to the vanishing points of the sides.

From the points, b, c, d, e, f, g, h, as also from i, j, k, draw lines to c, cutting A *h* at *b*, *c*, *d*, *e*, *f*, *g*, *h*, and A *k* at *i*, *j*, *k*: from the points of section draw perpendiculars to V L; set the heights of the apertures, and the height of the building itself, upon the corner A A′; say that the sills of the lower windows are three feet high, the windows six feet, the space between the lower windows and the upper, four feet, the upper windows four feet also, and the distance to the parapet three feet; therefore make A *l* equal to three feet, *l m* equal to six feet, *m n* equal to four feet, *n o* equal to four feet, and *o* A′ equal to three feet, exactly to the scale or natural measures of the building: from these points of section draw lines to the vanishing points, and complete the whole representation. In setting up the heights, common dividers may be used. By the last setting of the proportional compasses, if the thickness of the walls are taken from the scale by the remote ends, marked R, and the distance of the two opposite points be set upon the intersecting line from the points, c, e, g, towards A; and if, from the points of section, lines be drawn to c, the centre of the picture, to cut the representative base line, A *h*, of the building, and perpendiculars be drawn from the points of section in A *h*, these perpendiculars will give the reveals of the windows; that is, they will show the thickness of the walls on the sides of the windows.

PROBLEM XI.—*Given the vanishing line of a plane, its centre and distance, and the inclination of a line in that plane to the intersection; to find the vanishing point of the line without drawing any lines in the vanishing plane, in order to find the vanishing points of the original line, as given in position to the intersecting line.*

Figure 14.—Let the angle made by the original line with the intersection be 30°; subtract 30° from 90°, and 60° will remain; bring the index of the proportional compasses to 60° on the line of tangents; extend the extremities of the compasses, marked R, to the radius; then set the distance of the opposite extremities from c to *v*, on the vanishing line, V L, and *v* will be the vanishing point of the line, as required.

The proportional compasses will answer to any distance of the eye from the vanishing line, however great, by taking one-half, one-third, one-fourth, &c. of the distance of the vanishing line, as most convenient, with the extremities marked R; then repeating the distance between the points of the opposite extremities, twice, three times, four times, &c., accordingly.

By this method, the vanishing point of every original line, of any plane figure, may be found without having the point of sight placed in a perpendicular to the vanishing line from the centre of the picture. This will be very convenient, as the extension is entirely confined to the vanishing line, and thus it requires the paper to be of no greater breadth than what is sufficient for the picture intended.

Example.—Let it be required to find the vanishing points of a rectangle, supposing the right-hand side to be placed at 40° with the intersecting line.

Subtract 40° from 90°, the number contained in a right angle, and the remainder, 50°, will give the angle made by the primary, or shortest radial, and the radial of the right-hand side, or the angle made by the original side of the rectangle on the right-hand, and a perpendicular in the original plane to the intersecting line; then the angle contained between the primary radial and the radial of the left-hand side of the rectangle will be 40°. Now, suppose the length of the picture to be 12 inches, and the spectator to stand at 2 feet, or 24 inches, from the centre of the vanishing line; and suppose the proportional compasses to be $6\frac{1}{2}$ inches, which is the usual length: divide 24 into 6 equal parts, each of which, in this instance, will contain 4 inches; slide the index of the instrument to 50° on the line of tangents; then with the legs R, take the extent of 4 inches, or the sixth part of 2 feet, and repeat the distance of the opposite points on the vanishing line, from the centre, c, of the picture, towards the right-hand, six times, to *v*, and *v* will give the vanishing point. To find the vanishing-point of the left-hand side: as the radial of this side makes 40° with the primary radial, slide the index of the instrument to 40° on the line of tangents; then, with the legs marked R, take the extent of 4 inches, or the sixth of 2 feet; repeat the distance between the points of the opposite ends from the centre of the picture towards the left hand, six times to v, and v will be the vanishing point on the left-hand side of the rectangle.

The vanishing points of all lines whatever may be found in this manner, having the angle formed by the intersecting line and the original: for this is always equal to the angle formed by the radial and the parallel of the eye; and because the distance of a vanishing point from the centre of the picture is the tangent of the angle made by the primary radial and the radial of the line, the primary radial being radius, the proportional compasses, being set as above, will give the true vanishing point.

Scholium.—None of the lines on the proportional compasses, except the tangents, require the slit to be less than half the length of the shank, deducting that part of the slide from the centre of the pin; the tangents, therefore, cannot be inserted higher than 45°; and, indeed, the higher tangential numbers would be of little use, as the radius would be shortened by every such increase: and it would be attended with greater inaccuracy and more labour. If the gradations, however, do not exceed 45°, the distance of the extremities of the compasses may still be extended to six inches: but, in order to find the tangent of any greater number of degrees than 45, we have only to subtract that number of degrees from 90, and the remainder is the complement of the angle; then it will be as the tangent of the complement is to radius, so is radius to the tangent itself.

From these observations it will be very easy to find the vanishing point of any line, whatever number of degrees the radial of that line forms with the primary radial, as may be seen in the following problem.

Problem XII.—*To find the vanishing point of a line, the radial of which makes a greater angle with the primary radial than* 45°, *the vanishing line and its centre being given, as also the primary radial.*

Subtract the given angle from 90°; set the index of the compasses to the tangent of the remaining angle; take a convenient aliquot part of the distance of the eye from the vanishing lines, and set the legs marked R, to that distance; upon any imaginary straight line, A E, with the ends R, set off the distance A B; take the distance A B, with the opposite ends, and set off the distance A D; then let V L be the vanishing line, and C its centre; and, according as the original line, or its radial, is on the right or left, the distance, A D, must be set to the right or left of the centre of the picture, as often as the radial is supposed to contain the distance of the points upon the legs marked R.

Example.—Suppose the radial of the line to make an angle of 50° with the primary radial, and the length of the primary radial to be three feet; to find the distance of the vanishing point from the centre of the picture.

Subtract 50° from 90°, and the remainder is 40°; set the index to the tangent of 40°; take the ninth part of the primary radial, or 4 inches, and extend the ends opposite to those marked R, to 4 inches, or the ninth part of the distance, and repeat the distance of the legs marked R, on the vanishing line, nine times from the centre to the right or left hand accordingly; and the extremity of the distance so repeated from C, is the vanishing point required.

The reason of this operation is evident; since the radius is a mean proportional between the tangent of the angle and the tangent of its complement, and, therefore, as the tangent of the complemental angle is to the radius, so is the radius to the tangent itself.

If the object to be drawn be a rectangle, making unequal angles with the intersecting line, the angles made by the radials of the sides and the primary radial, being equal to the angles made by the sides of the rectangle and the intersecting line, or a line drawn through the outer corner parallel to the intersecting line; set the proportional compasses to the tangent of the least angle; extend the legs marked R to the distance, or to any part of the distance that the compasses will admit of; set the distance of the opposite legs, or repeat that distance as often as the primary radial contains parts, from the centre to the right or left, and the point of extension will give the vanishing point of that side of the rectangle; extend the ends opposite to R to the primary radial, or that portion of it before-mentioned, that the compasses will admit of, and the extension between the extremities of the legs marked R, being set from the centre on the other side of the vanishing line, or repeated according to the number of parts into which the primary radial is divided, will give the vanishing point of the other side of the rectangle, viz., of that side which makes the greatest angle with a line perpendicular to the intersection; and therefore the vanishing point so found must be upon the same side of the centre of the picture that the angle itself is upon, being nothing more than the tangent of that angle.

Scholium.—The vanishing points of a rectangular building may be found arithmetically upon the foregoing principles, viz., as the tangent of the angle made by the radial of one side and the primary radial is to the primary radial itself, so is the primary radial to the tangent of the angle made by the radial of the other side and the primary radial. Now, admitting the shortest tangent to be to the primary radial as 2 to 3, and the length of the primary radial 3 feet 6 inches, or 42 inches; to find the vanishing points, it will be

```
3 : 2 : : 42
             2
           ---
       3 ) 84
           ---
           28 inches, the distance of
```

the vanishing point of the least angle.

```
And again, 2 : 3 : : 42
                      3
                    ----
                2 ) 126
                    ----
                    63 inches, the distance of
```

the vanishing point of the greater angle.

Or, because the distance is a mean proportional between the two tangents, it will be

```
28 : 42 : : 42
            42
            --
            84
           168
          ----
   28 ) 1754 ( 63 inches, the tangent
        168       of the greater angle
        ---       as before.
         84
         84
```

When the distance of the vanishing points is required, the square root of the sum of the squares of each tangent, and the primary radial, will give the distance from each respective vanishing point; but if the vanishing points be inaccessible, subtract each tangent from the respective distance so found, and set the remainder on each side of the centre of the picture.

This method of finding the distance would be thought by many artists very troublesome; but the following, by the proportional compasses, is very easy: Suppose one radial to make an angle of 30°, the other will be 60° with the primary radial; add 30° to 90°, the sum will be 120°; take the half of 120, which is 60; then 30 from 60, there remains 30; the tangent of 30°, set upon the other side of the primary radial, will give the distance of the vanishing point. Again, add 60 to 90, the sum is 150, the half is 75°; subtract 60 from 75, and the remainder is 15°; then the tangent of 15°, set from the centre of the picture on the other side of the angle of 60°, will give the distance of the vanishing point of the line that makes 30° with the intersection.

Again, suppose one of the angles to be 40°, the other will be 50°; add 40 to 90, the sum is 130; the half of 130 is 65; subtract 40 from 65, and the remainder is 25°; then the tangent of 25°, set on the other side of 40 from the centre of the picture, will give the distance of the vanishing point of the line, the radial of which makes 40° with the primary radial. Again, add 50 to 90, the sum is 140, the half is 70; subtract 50 from 70, and the remainder is 20°; then, the tangent of 20° being set from the centre of the picture upon the other side of the angle formed by the primary radial, the other radial, containing 50°, will give its distance.

In general, suppose the lesser angle to be called v, and the greater w; then $\frac{v + 90}{2} - v = \frac{90 -}{2} = 45 - \frac{v}{2}$, and the tangent of this angle, set upon the other side, will give its vanishing point.

Again, $\frac{w + 90}{2} - w = \frac{90 - w}{2} = 45 - \frac{w}{2}$, gives the distance of the other vanishing point, set on the contrary side of the centre; thus, if $w = 60$, then $45 - \frac{w}{2} = 15$, therefore set the tangent of 15° as directed; and thus the tangent of the remainder of half the angle contained by the primary radial and the radial from 45°, gives the vanishing point; or, take the tangent of half the complement of the said angle, and set it on the vanishing line from the centre of the picture on the other side, and it will give the vanishing point.

Problem XIII.—*Given the angle made by the radials of any two original lines with each other, and the angle which one of them makes with the primary radial; to find a dividing point common to the same measures or scale, so as to cut off a portion from the indefinite representation of each line, such that the portions may be the representations of the two original lines.*

Note.—When one of the angles which the primary radial makes with the one radial is given, that made by the primary radial with the other may be found by subtracting the one given from the whole angle contained by the radials. This being obtained, proceed as follows:—Subtract the lesser angle formed by the one radial and the primary radial from half the angle contained by the radials of the original lines; then, if the tangent of the remaining angle be set on the vanishing line, on the side of the primary radial which has the greatest angle, it will give the dividing point required.

Thus, call the whole angle A; the half is $\frac{A}{2}$; call the lesser angle made by the primary radial with one radial, B, then $\frac{A}{2} - B$ is the difference; find the tangent of $\frac{A}{2} - B$; then the greater angle made by the primary radial with the other radial being $A - B$, set the tangent of $\frac{A}{2} - B$ from C, on the vanishing line on the side of $A - B$, and the extremity of the distance will give the dividing point required.

Example 1.—Suppose the angle contained between the two radials to be 100°, and the lesser angle to be 40°, then the greater will be 60: now the half of 100 is 50: subtract 40°, the lesser angle, from 50, there remains 10: set the index of the proportional compasses to 10° on the line of tangents; take the length of the primary radial with the legs marked R, and set off the distance contained by the opposite points from the centre of the picture on the vanishing line, on the side of the primary which has the angle of 60°, and the extremity of the distance is the dividing point.

Example 2.—Suppose the angle contained by the radials to be 80°, the lesser angle to be 30°, and consequently the greater 50°; the half of 80° is 40°; subtract 30° from 40 and 10° remain. Set the index of the proportional compasses to the tangent of 10°; take the length of the radial with the legs marked R, and set the distance of the point contained by the opposite legs from C on the vanishing line, on the side of the angle of 50°, and the extremity will give the dividing point.

Problem XIV.—*Given the sun's altitude on a plane, the height of a line, and the length of its shadow on that plane, the orthographical representation of a cornice, with a section of the same, also the seat of the sun's rays; to find the shadow of the cornice.*

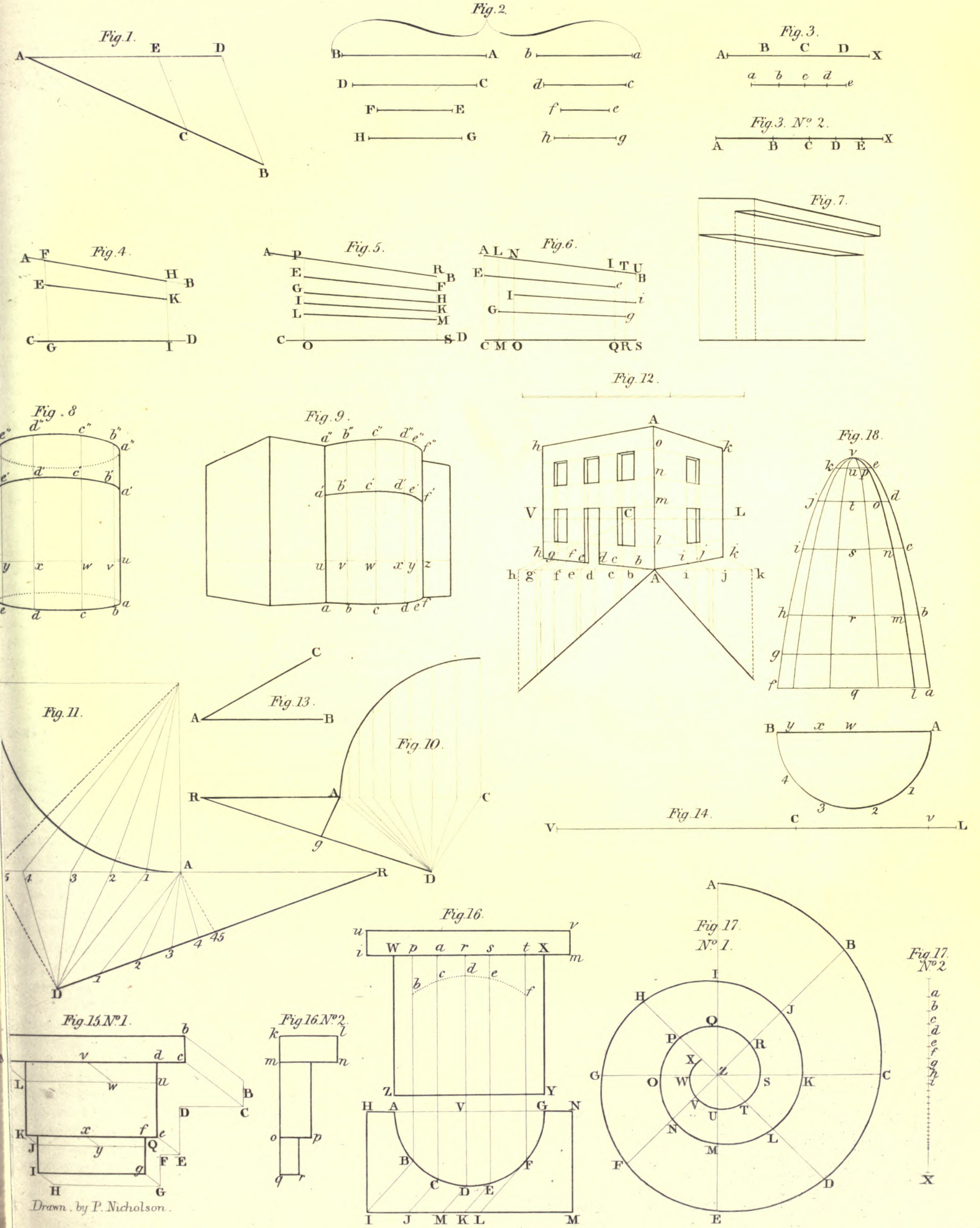
Figure 15.—Let No. 1 be the cornice or architrave, and No. 2 a profile, or section, perpendicular to the arrises, or edges of the mouldings; draw *b* B for the indefinite representation of the shadow of a line represented by the point *b*, No. 1, and let *b* B be the distance that the shadow is thrown from the point *b*, so that B will be the shadow of *b*; from all the external angles draw *c* C, *e* E, *g* G, I H. Now *k l*, No. 2, is the length of the line represented by the point *b*, No. 1, set the proportional compasses in the ratio of *k l*, No. 1, to *b* B No. 2: make *c* C equal to *b* B: take *o p*, No. 2, with the shorter ends, and make *e* E, No. 1, equal to the distance between the points of the remote ends; take *q r*, No. 2, with the shorter legs, and make *g* G, No. 1, equal to the distance between the points of the remote ends; join B C; draw C D parallel to M *c*, and draw E D parallel to *e d*; draw E F parallel to *e* K, and G F parallel to *g f*; draw G H parallel to *g* I and *b* B C D E F G H I will be the shadow from one side: draw the lines M L, K J, parallel to *b* B, *c* C, &c., to meet K *h* and I at L and J; then will M L and K J be the shadows upon the other side. To find the shadows upon the planes of the faces in the representation, *c* M, of the arris line, take any point, *v*, and draw *v w* parallel to *b* B, or *c* C, &c.; also, in the representation, *e* K, of the next arris line, take any point, *x*, and draw *x y* parallel to *b* B or *c* C; take the distance *d c*, with the shorter ends of the proportional compasses, and make *v w* equal to the distance between the points of the longer legs; also, take the projection, *f e*, with the shorter legs, and make *x y* equal to the distance contained between the points of the remote ends; through the points *w* and *y* draw L *u* and J *t* parallel to M *c*, which will terminate the breadth of the shadow upon the face.

The reason of this operation is evident, since the distance that a shadow will be thrown by a line perpendicular to a plane, is as the length of the line: and the shadow of a line parallel to a plane will be projected on the plane parallel to the line which projects the shadow; and every two parallel lines in the original object are also represented by parallel lines.

Problem XV.—*The representation of a cylinder with a square abacus, or cap, being given, to find the shadow of the cap upon the cylindric surface, the axis of the cylinder being parallel to the plane of projection; also, the shadow of a line perpendicular to the axis of the cylinder, and in a plane passing along the said axis, and through the luminary.*

Figure 16.—Let A B C D E F G be the plan of the semi-cylinder, and H I M N that of the cap; let W X Y Z be the elevation of the semi-cylinder, and *i m v u* that of the cap; let I B be the projection, or representation, of a ray on the plan from the corner of the abacus at I, cutting the plan of the cylinder at B; draw L F parallel to I B, to touch the semicircle in F, and cutting I M at L; draw F V perpendicular to L F, V being the centre of the semicircle; and F will be the point of contact: in I M take any number of intermediate points J, M, K, and draw J C, M D, K E, parallel to I B, cutting the

PROPORTIONAL COMPASSES.



Drawn. by P. Nicholson.

semicircle in C, D, E; draw B p, C a, D r, E s, F t, parallel to the axis of the cylinder, cutting the under edge, $i\ m$, of the abacus in p, a, r, s, t; set the proportional compasses in the ratio to the distance to which I B will throw the shadow, and suppose I B to be greater than the length of its shadow; take the distance, I B, with the longer legs; make $p\ b$ equal to the distance contained between the points of the opposite ends; take the distance, J C, with the longer legs, and make $a\ c$ equal to the distance contained between the shorter legs; take the distance, M D, with the longer legs, and make $r\ d$ equal to the distance contained between the opposite points; and the points, b, c, d, will be obtained. In the same manner, the points e and f will be found; through the points, b, c, d, e, f, draw a curve, which will be the shadow of the lower edge of the abacus; the sun's rays will be in a tangent plane to the cylinder surface at F f: and the part of the edge of the shadow which falls upon the representation of the cylindric surface, from i to b, will be straight.

In the same manner, if the representation of a cylinder capped with a cylindric abacus, having the same axis with the cylinder, be given, and the representation of the sun's rays on the plan, supposing the axis of the cylinder perpendicular to the plane of projection, the shadow of the abacus may be found upon the cylindric surface; and thus for every other prismatic object.

PROBLEM XVI.—*To describe the logarithmic spiral by a series of points found in the curve; the centre, and two opposite points in a straight line passing through the centre, being given in the curve.*

Figure 17.—Let Z, No. 1, be the centre; let the straight line, A E, pass through Z; let A and E be two opposite points, the one, A, on the one side, and the other, E, on the other side of the centre, Z; through Z draw G C at right angles to A E; bisect the angle A Z C, by the straight line B F; also bisect the angle E Z C, by the straight line D H; find Z C, a mean proportional between Z A and Z E; also find Z B, a mean proportional between Z A and Z C; draw any straight line, Z X, No. 2, and set the proportional compasses in the ratio of Z A to Z B; take the distance, Z A, with the points of the longer legs, and set that distance from X to a, No. 2, and make X b equal to the distance contained between the shorter legs; contract the points of the longer legs to X b, and with the shorter legs set off the distance X c; contract the distance between the points of the longer legs to X c, and make X d equal to the distance contained between the points of the shorter legs; and the parts, $a\ b$, $b\ c$, $c\ d$, of the straight line, X a, will be in geometrical progression. In the same manner, the points e, f, g, h, i, &c., may be found, which will continue the series of parts as far as there may be occasion; make Z A, No. 1, equal to X a, No. 2, Z B equal to X b, Z C equal to X c. In the same manner, the points, D, E, F, G, H, I, &c., may be continued through any number of revolutions; and a curve drawn through all the points will give the spiral required.

Scholium.—As the tracing of the curve depends very much on the eye of the person who performs this operation, by the following method a curve may be drawn with a pair of compasses, provided the points do not approach very rapidly to the centre. To describe any quadrant, take the length of the radius that bisects it from one extremity of the curve, describe an arc, and with the same radius from the other extremity describe another arc cutting the former; then, from the point of intersection with the same distance, describe an arc between the two extremities, and it will pass through the middle point, very nearly; thus, take the distance Z B as a radius; from the extremity A, of the arc A B C, describe an arc near the centre; from the point C, with the same radius, describe another arc, cutting the former near the centre Z; then, from the point of intersection, describe the arc A C, which will pass through the point B, very nearly. In the same manner the successive arcs, C E, E G, G I, &c. may be described; and the curve thus formed will be so near as not to be detected by the eye.

PROBLEM XVII.—*To draw the representation of the meridians of a solid of revolution upon a plane parallel to the axis of the solid; given an axal section, that is, a section of the solid, passing along the axis, upon a plane parallel to the said axis.*

Figure 18.—Let $a\ b\ c\ d\ e\ v\ k\ j\ i\ h\ g\ f$ be the axal section, $q\ v$ the axis itself, and $a\ f$ the base perpendicular to $q\ v$; in $q\ v$ take any number of points, r, s, t, u; through these draw $b\ h$, $c\ i$, $d\ j$, and $e\ k$, perpendicular to $q\ v$, meeting the curve on the one side at b, c, d, e, and on the other at h, i, j, k; then it is obvious that the lines $b\ h$, $c\ i$, $d\ j$, $e\ k$, will be bisected; now, supposing the meridians to be formed on the surface of the solid by the intersection of five planes at equal angles round the axis, and that one of these planes is parallel to the plane of projection, and let $a\ v\ f\ a$ be the representation of that plane; draw A B parallel to $a\ f$; produce $v\ q$ to meet A B at w; from w as a centre, with the radius $q\ a$, or $q\ f$, describe the semicircle A 1 2 3 4 B; divide the semicircle into five equal parts by the points of section 1, 2, 3, 4; draw 3 x and 4 y perpendicular to A B, cutting A B at x and y; make $q\ l$ equal to $w\ y$; set the proportional compasses in the ratio of $q\ a$ to $q\ l$; take the distance $r\ b$, with the longer legs, and with the opposite legs set off the distance $r\ m$; take the distance $s\ c$, with the longer legs, and with the opposite points set off the distance $s\ n$; take the distance $t\ d$, with the longer legs, and with the shorter legs set off the distance $t\ o$; lastly, take the distance $u\ e$, with the longer legs, and with the shorter legs set off the distance $u\ p$; then draw the curve $l\ m\ n\ o\ p\ v$, which will be one of the meridians, as required. In the same manner all the others may be found.

Besides the uses of the proportional compasses, which have already been shown, they may be applied to trigonometry in finding the sides and angles of triangles; suppose, in a right-angled triangle, that the two legs were given, to find the angles; the analogy is, as the one side is to the other, so is radius to the tangent of the angle opposite the latter side; set the proportional compasses in the ratio of the two sides containing the right angle; then the index will show the tangent of the angle on the line of tangents.

Again, suppose the hypothenuse and one of the legs were given, to find the angles; the analogy in this will be, as the hypothenuse is to the given leg, so is radius to the sine of the angle opposite to that leg; set the proportional compasses in the ratio of the hypothenuse to the given leg, and the index will be against the sine of the angle.

Lastly, suppose the angles and the hypothenuse to be given: the method of proceeding in this case is exactly the reverse of the last; thus, set the proportional compasses to the sine of the angle, then extend the longer legs to the hypothenuse of the angle, and the shorter legs will contain the length of the leg required.

In the same manner, if the angles and one of the legs were given, to find the other leg; set the proportional compasses to the tangent of the leg required, then take the length of the given leg with the longer legs, and the distance between the points of the shorter legs will be the leg of the triangle, as required.

PROPYLÆA, (Greek προ, before or in front of, and πυλον a gate) the entrance to a temple or other large building, consisting mostly of a gateway flanked by towers or other erections. The Egyptian temples were universally adorned with magnificent propylæa, which consisted of lofty truncated pyramids of solid masonry, covered on the faces with hieroglyphics.

The term is also particularly applied to the entrance of the acropolis of Athens, which was erected by Pericles, and was of unusual magnificence.

PROPYLON, an entrance or vestibule.

PROSCENIUM, (Greek) in the ancient theatre, an eminence on which the actors performed their parts. The proscenium answered to our stage. It consisted of two parts among the Greeks; one, particularly so called, where the actors performed; the other was the *logeion*, where the singers and the mimics acted their parts. Among the Romans, the proscenium and pulpitum were the same.

PROSTYLE, (from the Greek προςυλος, formed from προ *before*, and ςυλος, *column*) in the ancient architecture, a range of columns in the front of a temple.

PROSTYPA (from προστυπα) images carved in such a manner as to be only half raised above the ground, or plain, on which they are formed. They seem to adhere to it, and have only one side exposed to view. To *prostypa* is opposed *ectypa*.

PROTHYRIS, (Greek) in ancient architecture, a word sometimes used for a cross-beam, or over-thwart rafter; as likewise, for a quoin or corner of a wall; otherwise called *anco*. *See* CONSOLE.

PROTHYRUM, (from προθυρον) a porch at the outer door of a house, or portal.

PROTRACTOR, (from the Latin *protractus*, to draw out) an instrument used in surveying, by which the angles taken in the field with a theodolite, circumferentor, or the like, are plotted, or laid down, on paper.

This protractor consists of a semicircular limb of brass, silver, horn, or the like, divided into 180°, and subtended by a diameter, in the middle of which is a little notch, or lip, called the *centre of the protractor.*

For the convenience of reckoning both ways, the degrees are numbered from the left hand towards the right, and from the right hand towards the left.

But this instrument is made much more commodious by transferring the divisions on the same circumference to the edge of a ruler, whose side is parallel to the diameter, which is easily done by laying a ruler on the centre, and the several divisions on the semi-circumference, and marking the intersections of that ruler on the line: so that a ruler with these divisions marked on three of its sides, and numbered both ways, as in the protractor (the fourth, or blank side representing the diameter of the circle) is of the same use as a protractor, and much better adapted to a case.

On the limb of the protractor are sometimes also placed numbers, denoting the angles at the centres of regular polygons: thus, against the number 5, denoting the sides of a pentagon, is found 72, the angle at the centre of a pentagon, &c.

The uses of this instrument are, 1. *To lay down an angle of any given quantity, or number of degrees, at any point, and with any given line.*

Example.—Lay the centre of the protractor on the given point, and the diameter of the protractor on the given line: make a mark against the given degree (say 50) on the limb of the protractor; through which, from the given point, draw a line, and it will give the angle required.

2. *To find the quantity of a given angle.*—Lay the centre of the protractor on the point of the angle, and the diameter on one of the lines forming it. The degree of the limb cut by the other line (*viz.* 50) is the number of degrees of the angle required.

3. *To inscribe any given regular polygon (a pentagon for example) in a circle.*—Lay the centre and diameter of the circle, and make a dot against the number of degrees of the angle at the centre, *viz.* 72.. Through this dot and the centre of the circle draw a line, cutting the circumference of the circle. To the point of intersection, from the point where the diameter cuts the circumference, draw a right line; this line will be a side of the pentagon, which, being taken in the compasses, and set off as often as it will go in the circumference, will give points, which, being connected by lines, will form the pentagon required.

4. *To describe any regular polygon* (e. gr. *an octagon*) *on a given line.*—Subtract the angle at the centre, which the protractor gives (say 45°) from 180; and the remainder, 135, will be the angle included between two sides of the octagon, one-half of which is 67½. Applying then the diameter of the protractor over the given line, with the centre over one extreme; make a dot against 67½, to which, from the centre, draw a line: apply the protractor to the other end of the line, with the centre over the extreme, and there set off another angle of 67½°. From the point where the two lines thus drawn intersect, as a centre, describe a circle with the interval of the given line. The given line will be one side of the octagon; and this set off as often as it will go in the circumference thus drawn, will give points, which, being connected, will form the octagon required.

PROTRACTOR, *Improved*, an instrument much like the former, but furnished with a little more apparatus, so that an angle may be set off to a minute; which is impracticable on the other.

The chief addition is an index fitted on the centre, and moveable on it, so as to play freely and steadily over the limb.

Beyond the limb, the index is divided, on both edges, into sixty equal parts of the portions of circles, intercepted by two other right lines drawn from the centre, so that each makes an angle of one degree with lines drawn to the assumed points from the centre.

To set off an angle of any number of degrees and minutes with this protractor, move the index, so that one of the lines drawn on the limb, from one of the fore-mentioned points, may fall upon the number of degrees given; and prick off as many of the equal parts on the proper edge of the index as there are minutes given; thus, by drawing a line from the centre to the point so pricked off, an angle is obtained with the diameter of the protractor, of the proposed number of degrees and minutes.

PSEUDO-DIPTERAL, (from ψευδο-διπτερος) a temple with eight columns in front, and a single row of columns all round.

The word signifies *false* or *imperfect* diptere; and is used to distinguish this from the diptere, which was surrounded with a double row.

PSEUDO-PERIPTERAL, (Greek, ψευδο-περιπτερος, *false peripteral*,) a term applied to temples in which the columns at the sides are engaged in the wall, instead of being detached from it, as in the true peripteral buildings, the walls of the cella being carried forward to the inter-columniations of the portico.

PTEROMA, the space between the walls of the cella of a temple, and the columns of the peristyle; called also *ambulatio*.

PUDDLING, the method of backing a wall with clay rammed into a compact mass, by means of a beater.

PUG-PILING, the same with *dove-tailed* or *pile planking*.

PUGGING, a coarse kind of mortar laid upon the sound-boarding between joists, in order to prevent sound reaching from one apartment to another.

PULLEY, (from the French, *poulie*) one of the five mechanical powers; consisting of a wheel, or rundle, having a channel around it, and turning on an axis, serving; by means of a rope which slides in its channel, for the raising of weights.

The Latins call it *trochlea;* and the seamen, when fitted with a rope, a *tackle.* An assemblage of several pulleys is called *a system of pulleys,* or *polyspaston:* some of which are in a block, or case, which is fixed; and others in a block which is moveable, and rises with the weight. The moveable wheel, or rundle, is called the *shieve* or *shiver;* the axis on which it turns, the *gudgeon;* and the fixed piece of wood, or iron, into which it is put, the *block.*

The common methods of arranging pulleys in their blocks, may be reduced to two. The first consists in placing them one by the side of another, upon the same pin; the other, in placing them directly under each other, upon separate pins. Each of these methods is liable to inconvenience. Mr. Smeaton, in order to avoid the impediments to which these combinations are subject, proposes to combine these two methods in one. Accordingly, the pulleys are placed in each block, in two tiers; several being upon the same pin, as in the first method, and every one having another under it, as in the second; so that, when the tackle is in use, the two tiers that are the most remote from each other, are so much larger in diameter than those that are nearest, as to allow the lines of the former to go over the lines of the latter, without rubbing. From this construction arises a new method of reviving the line upon the shieves; for here, whatever be the number of shieves, the fall of the tackle will be always upon the middle shieves, or on that next to the middle, according as the number of pulleys in each pin is odd or even. To do this, the line is fixed to some convenient part of the upper block, and brought round the middle shieve of the larger tier of the under block, from thence round one of the same sort next the centre one of the upper block, and so on, till the line comes to the outside shieve, where the last line of the larger tier falls upon the first shieve of the smaller, and being reeved round those, till it comes at the opposite side, the line from the last shieve of the smaller tier again rises to the first of the larger, whence it is conducted round, till it ends on the middle shieve of the upper block on the larger tier.

As a system of pulleys is of no great weight, and lies in a small compass, it is easily carried about, and can be applied, in many cases, for raising weights, where other engines cannot be used. But they have a great deal of friction; because the diameters of their axes bear a very considerable proportion to their own diameters; and because, in working, they are apt to rub against each other, or against the sides of the block, to say nothing of the stiffness of the rope that goes over and under them.

PULLEY, *Doctrine of the.* 1. If the equal weights W and P hang by the cord B B upon the pulley A, whose block, *b*, is fixed to the beam H I, they will counterpoise each other, just in the same manner as if the cord were cut in the middle, and its two ends hung upon the hooks fixed in the pulley, at A and A, equally distant from its centre.

Hence, a single pulley, if the lines of direction of the power and the weight be tangents to the periphery, neither assists nor impedes the power, but only changes its direction.

The use of the pulley, therefore, is when the vertical direction of a power is to be changed into a horizontal one; or an ascending direction into a descending one; and on the contrary.

This is found a good provision for the safety of the workmen employed in drawing with the pulley.

The change of direction by the means of a pulley has this farther advantage; that if any power can exert more force in one direction than in another, we are here able to employ it in its greatest force. For instance, a horse cannot draw in a vertical direction, but draws with all its advantage in a horizontal one. By changing the vertical draught, therefore, into a horizontal one, a horse becomes qualified to raise a weight.

But the grand use of the pulley is, where several of them are combined; thus forming what Vitruvius, and others after him, call *polyspasta;* the advantages of which are, that the machine takes up but little room, is easily removed, and raises a very great weight with a moderate force.

2. If a weight, W hangs at the lower end of the moveable block, *p*, of the pulley D, and the cord, G F, goes under the pulley, it is plain that the half, G, of the cord, bears one half of the weight, W, and the half, F, the other; for they bear the whole between them. Therefore, whatever holds the upper end of either rope, sustains one-half of the weight; and if the cord at F be drawn up so as to raise the pulley D to C, the cord will then be extended to its whole length, except that part which goes under the pulley; and consequently, the power that draws the cord will have moved twice as far as the pulley D, with its weight W, rises; on which account, a power whose intensity is equal to one half of the weight, will be able to support it, because, if the power moves (by means of a small addition) its velocity will be double the velocity of the weight; as may be seen by putting the cord over the fixed pulley C (which only changes the direction of the power, without giving any advantage to it) and hanging on the weight P, which is equal only to one-half of the weight W; in which case there will be an equilibrium, and a little addition to P will cause it to descend, and raise W through a space equal to one-half of that through which P descends. Hence, the advantage gained will be always equal to twice the number of pulleys in the moveable or undermost block. So that, when the upper or fixed block, *u*, contains two pulleys, which only turn on their axes, and the lower or moveable block, U, contains two pulleys, which not only turn upon their axes, but also rise with the block and weight, the advantage gained by this is as four to the working power. Thus, if one end of the rope, K M O Q, be fixed to a hook at I, and the rope passes over the pulleys N and R, and under the pulleys L and P, and has a weight, T, of one pound, hung to its other end, at T; this weight will balance and support a weight, W, of four pounds, hanging by a hook at the moveable block U, allowing the said block as a part of the weight. And if as much more power be added, as is sufficient to overcome the friction of the pulleys, the power will descend with four times as much velocity as the weight rises, and, consequently, through four times as much space. The two pulleys in the fixed block, X, and the two in the moveable block, Y, are in the same case with those last mentioned; and those in the lower block give the same advantage to the power.

It is necessary to observe, that if the lower pulleys do not rise all together in one block with the weight, as in the cases just recited, but act upon each other, and the weight is only fastened to the lowest of them, the force of the power is very much increased, each pulley doubling it. Thus, a power, whose intensity is equal to 8 lb. applied at *a*, will, by means of the lower pulley, A, sustain 10 lb.; a power equal to 4 lb. at *b*, will, by means of a lower pulley, B, sustain the power of 8 lb. acting at *a;* a third power, equal to 3 lb. at *c*, will, by means of the pulley C, sustain the power of 4 lb. at *b;* a fourth power of 1 lb. at *d*, will, by means of the pulley D, sustain the power of 2 lb. at *c;* and this is not altered by having its rope carried over the upper pulley, or roller, E.

In the former cases, the force of the power is augmented in an arithmetical proportion of the number of ropes or pulleys; but in this, in a geometrical proportion.

3. If a power move a weight by means of several pulleys, the space passed over by the power will be to the space passed over by the weight, as the weight, to the power.

Hence, the smaller the force that sustains a weight by means of pulleys is, the slower is the weight raised; so that what is saved in force, is spent in time.

Pulley mortise, a longitudinal mortise of considerable length, parallel and near to the under side of the bonding joists, in order to insert the ceiling joists.

PULPIT, an elevated stage or desk, from which orations are pronounced, applied more especially to those employed in churches. They are for the most part of wood, but sometimes of stone, of which an early and beautiful example exists at Beaulieu, Hants. The greater number of examples are of Perpendicular work, and these principally of wood, and polygonal in plan; sometimes with a canopy above. Pulpits are sometimes found outside of buildings, as at Magdalen College, Oxford, and in many instances abroad, where also are pulpits of great size and magnificence, capable of containing more than one person.

PULPITUM, (Latin) among the Romans, a part of the theatre, called also *proscenium*, or what we now call the *stage*, on which the actors trod. Though some say it was properly an eminence on the stage for the music; or a suggestum, whence declamations, &c. were spoken.

The French use the word pulpit, *pupitre*, for a reading-desk in a church, library, or the like; those large ones in churches they properly called *lutrins*.

PULVINARIA, (Latin,) cushions upon which the statues of the gods were laid in the temples, at the time when thanks were given for some signal victory.

PULVINATED, (from the Latin, *pulvinatus*,) in ancient architecture, a term applied to a frieze, which swells, or bulges out, in manner of a pillow, *pulvinus:* whence the name.

PUNCHION, or Puncheon, (from the French, *poinçon*,) a little block or piece of steel, on one end of which is some figure, letter, or mark, engraven either in creux, or in relievo; impressions of which are taken in metal, or some other matter, by striking it with a hammer. There are various kinds of these puncheons used in the mechanical arts. Such, for instance, are those of the goldsmiths, cutlers, pewterers, &c.

Punchion, is also a common name for all the iron instruments used by the stone-cutters, sculptors, locksmiths, &c., for the cutting, inciding, or piercing their several matters.

Those of sculptors and statuaries serve for the repairing of statues, when they are taken out of moulds.

The locksmiths use the greatest variety of punchions; some for piercing hot, others for piercing cold; some flat, some square, some round, others oval; each to pierce holes of its respective figure in several parts of locks.

Punchion, or Punchin, in carpentry, a piece of timber placed upright between two posts, whose bearing is too great, serving, together with them, to sustain some heavy weight.

The punchion is usually lower and slighter than either prick-posts or principal posts, and is joined by a brace, or the like, of iron. *See* Post. Those on each side of a door are called *door punchions.*

Punchion is also a piece of timber raised upright under the ridge of a building, in which the little forces, &c., are jointed. Vitruvius calls the punchion *columen.*

Punchion, is also used for the arbor or principal part of a machine, on which it turns vertically; as that of a crane, &c.

PUNT, a sort of oblong flat-bottomed boat, with a square head and stern, whose floor resembles the platform of a floating stage; used by shipwrights for breaming, caulking, or repairing a ship's bottom. It is also used in some canals.

PURBECK STONE, (the *saxum arenarium cinereum Purbecense* of Da Costa, and *psadurium friabile albido fuscum* of Hill,) an alkaline sand-stone, harsh and rough, of a disagreeable ash-colour, very heavy, and moderately hard; of a texture not very compact, but somewhat porous, and composed of an angular grit, cemented together by an earthy spar: it cuts freely, and with a tolerably even or smooth surface. It will not strike fire with steel, and burns to a white colour. The quarries of this stone are in the island of Purbeck, in Dorsetshire, whence it is brought to London in great quantities, and there used in building, and for pavements. Its specific gravity is 2.68. There is also another kind of Purbeck stone, the *saxum fusco-albidum* of Da Costa, and the *sympexium durissimum splendidum albido-fuscum* of Hill, which is alkaline, of a dull disagreeable pale-brownish white colour, and cuts to a very smooth surface: it is of a fine, close, compact texture, not quite destitute of brightness, but full of sparks of pure spar, and intimately mixed with vast quantities of small pectunculi, which are often saturated and filled with the same substance; is very heavy and hard, and water does not pervade its texture; it does not strike fire with steel, and when burnt acquires a clear ashen colour. This stone is brought from Purbeck, and used in building, pavements, &c. Hill informs us, that it is likewise found in many other parts of the kingdom, and that there are large strata of it in Yorkshire.

PURFLED, (from the French, *pourfiler*, to embroider,) ornamental work, whether in stone or other materials, representing drapery, embroidery, or lace-work.

PURLINS, pieces of timber lying across the rafters on the inside, to keep them from sinking in the middle of their length.

Purlins are supported by the principals. The strongest method is to make bridges over, as in the present practice of the construction of roofs.

PUTEAL, (from the Latin, *puteolus*, a well,) among the Romans, a small kind of edifice raised in the place where a thunder-bolt had fallen.

PUTLOGS, or Putlocks, short pieces of timber, about seven feet long, used in building scaffolds. They lie at right angles to the wall, with one of their ends bearing upon it, and the other upon the ledges or poles which stand parallel to the side of the wall of the building.

PUTTY, (from the French, *potee*,) a kind of paste, compounded of whiting, with or without a little white-lead, and linseed oil, beaten together to the consistence of a tough dough; used by glaziers for fastening the squares of glass in sash-windows, &c., and by painters, to stop up the crevices and clefts in timber and wainscot, to prevent the wet from getting in and ruining the work.

PUZZOLANA, or Pozzolana, a kind of substance formed of volcanic ashes, more or less compacted together, so called from Pozzuolo, as also *pulvis Puteolanus*, from Puteoli, situate near mount Vesuvius, from which these ashes are ejected, and in the vicinity of which it abounds. It occurs of various colours, white, red, or black, reddish, or reddish-brown, gray or grayish-black; that of Naples is generally gray; that of Civita Vecchia is more generally reddish, or reddish-brown. The red variety is the proper puzzolana; the black and the white sorts are called, in Italy, *lapillo*, or *rapillo*. The ashes which overwhelmed Pompeii now form an immense bed of white puzzolana. The surface of this substance is rough, uneven, and of a baked appearance. It comes to us in pieces, from the size of a nut to that of an egg. It is wholly destitute of internal lustre and transparency. It is easily frangible, and its fracture is uneven or earthy, and porous; commonly filled with particles of pumice, quartz, scoriæ, &c. Hardness, 3. Very brittle. Specific gravity from 2.570, which is that of the black, to 2.785, rarely 2.8. Its smell is earthy. It is not diffusible in cold-water; but in boiling-water it gradually deposits a fine earth. It does not effervesce with acids. Heated, it assumes a darker colour, and easily melts into a black slag, or, with borax, into a yellowish-green glass. Before it is heated, it is magnetic, but not afterwards. By Mr. Bergman's analysis, it contains from 55 to 60 per cent. of siliceous earth, 19 to 20 of argillaceous earth, 5 or 6 of calcareous earth, and from 15 to 20 of iron. When mixed with a small proportion of lime, it quickly hardens; and this induration takes place even under water. This singular property proceeds, as Mr. Kirwan supposes, from the magnetic state of the iron it contains; for this iron, being unoxygenated, subtilly divided, and dispersed through the whole mass, and thus offering a large surface, quickly decomposes the water with which it is mixed, when made into mortar, and forms a hard substance, analogous to the specular iron-ore, as it does in the iron tubes, in which water is decomposed, in the experiments of M. Lavoisier and Dr. Priestly; for in these the iron swells and increases in bulk; and so does puzzolana, when formed into mortar, as we learn from Higgins *on Cements*. One principal use of lime seems to be to heat the water, as, while it is hot, it cannot pervade the caked argil that invests the ferruginous particles; yet, in time, even cold water may pervade it, and produce hardness; and hence, as M. Dolomieu has observed, lavas become harder when moistened. If the mortar be long exposed to the atmosphere, fixed air, as well as pure air, will unite to the iron, rust will be produced, and the mortar will not then harden, as Dr. Higgins has noticed. Clay, over which lava has flowed, is frequently converted into puzzolana; but volcanic scoriæ never afford it; either because they are much calcined, or retain sulphur, or its acid. The ancients were well acquainted with this substance and its properties: and, among them, its principal use, as it has been also in modern times, was that of mixing it with their cements for buildings sunk into the sea. As it hardens and petrifies in water, it is of particular service in making moles and other buildings in maritime places.

PYCNOSTYLE, (from πυκνοςυλος, formed from πυκνος, *close*, and ςυλος, *column*,) in the ancient architecture, a building where the columns stand very close to each other; one diameter and a half of the column being allowed for the intercolumniation.

The pycnostyle is the smallest of all the intercolumniations mentioned by Vitruvius. Some make it the same with *systyle*; others distinguish the latter by its allowing half a module more in the Corinthian intercolumniation.

The pycnostyle, Mr. Evelyn observes, chiefly belonged to the Composite order, and was used before the most magnificent buildings; as, at present, in the peristyle of St. Peter's at Rome, consisting of nearly three hundred columns; and such as yet remain of the ancients among the lately-discovered ruins of Palmyra.

PYRAMID, (from the Greek, πυραμις—derived from πυρ, fire) a solid standing on a square, triangular, or polygonal basis, and terminating at top in a point; or a body whose base is a regular rectilinear figure, and whose sides are plain triangles; their several verticals meeting together in one point.

Euclid defines it a solid figure, consisting of several triangles, whose bases are all in the same plane, and have one common vertex.

The pyramid is said to be *triangular*, *quadrangular*, *quinquangular*, &c., according as the base is triangular, quadrangular, &c. The pyramid may be called a square, triangular, &c. cone; or the cone may be denominated a round pyramid. When very narrow at bottom, i. e. their base very small, they are called *obelisks* and *needles*.

Some derive the word from πυρος, *wheat*, and αμαω, *colligo*; pretending that the first pyramids were built by the patriarch Joseph, for granaries. But Villalpandus and Bryant, with much better reason, derive the word from πυρ, *fire*; because of their ending in a point like flame; whence the latter writer conceives them to have been originally altars dedicated to the sun.

Wilkins, conversant with the Coptic tongue, suggests another derivation from that language, in which *pouro* signifies a king, and *miri*, a race or generation; and he says, the pyramids were thus called, because they were erected to preserve the memories of the Egyptian kings and their families; and that those who descended from them had recourse to these pillars in order to prove their pedigree: but this supposition can have very little weight, when it is recollected that the memory of the founder of the largest of the Egyptian pyramids was lost long before the days of Herodotus. And as to their having been erected for granaries, their internal capacity is so limited, that the nation could have derived no just benefit from them. We therefore prefer the idea of Villalpandus and Bryant as to the derivation of the term.

Pyramids are now, sometimes, erected to preserve the memory of singular events, or to transmit to posterity the glory and magnificence of princes; but, as they are the symbols of immortality, they are more commonly used as funeral monuments. Such is that of Cestius at Rome, the mausoleum of that distinguished Roman, who was one of the seven officers called *Epulones*, and is said to have lived under Augustus; it was repaired in 1673 by Pope Alexander VII.

The pyramids of Egypt, comprehending the great and small, are very numerous; of these there are about twenty of the largest size. The most remarkable are the three pyramids of Memphis, or, as they are now called, of Gheisa, Geeza, or Gizé. The dimensions of the greatest of these have been differently stated both by ancient and modern writers. Herodotus (lib. ii.) makes the base of it to be 800 Grecian feet long; Diodorus (lib. i.) 700; Strabo (lib. xvii.) less than 600; and Pliny (lib. xxvi. c. 12.) 883 feet. Among the moderns, Sandys found it to be 300 paces; Bellonius, 324; Greaves, 693 English feet; Le Bruyn, 704 French feet, or 750 English feet; Prosper Alpinus, 750 French feet; Thevenot, 682; Niebuhr, 710; Chazelles, 704.80 English feet. In order to reconcile these differences, Dr Shaw observes that none of the sides of this pyramid are exactly upon a level; so that it is difficult to find a true horizontal base; besides, it is impossible to say how much the drifts of sand, to which it is exposed, may have been accumulated above the foundation of it; and, therefore, all calculations depending upon the time and circumstances of the situation, when they were made, must be exceedingly precarious. The perpendicular altitude of it, according to Greaves, is 499 feet; but its oblique height is equal to the breadth of the base, or 693 feet. The whole area of the base contains 480,249 square feet, or $11\frac{10889}{43560}$ English acres. The height, according to Herodotus, is 800 French feet; according to Strabo, 625; according to Diodorus Siculus, 600 and a fraction; as stated by Le Bruyn, 616; by Prosper Alpinus, 625; by Thevenot, 520; by Niebuhr, 440. The ascent to the top of this pyramid is by steps, the lowermost being nearly four feet high and three broad; the second, of the same dimensions, but retiring inward from the first about three feet; and in the same manner the third row is placed upon the second, and the rest in the same order, to the top, which terminates in a small flat or square; and they are so disposed, that a line stretched from the bottom to the top would touch the angle of every step. These steps are called by Herodotus little altars, on account of their form; and their number has been variously assigned: Greaves states them at 207; Maillet at 208; Pococke at 212; Belon at 250; Thevenot at 208, and Chazelles at 498.222 English feet.

This pyramid is situate on a rocky hill, in the sandy desert of Libya, about a quarter of a mile from the plains of Egypt, above which the rock rises 100 feet or more, with a gentle and easy ascent. Upon this advantageous elevation, and solid basis, the pyramid is erected: the height of situation adding to the beauty of the work, and the solidity of the rock affording it a stable support.

We may here observe, that the sides of this pyramid stand exactly facing the four cardinal points, and consequently mark the true meridian of the place: which precise position could not have been well owing to chance, but was, probably, the effect of design and art. We may hence infer that the Egyptians had made an early progress in astronomy.

The entrance is nearly in the centre, and a passage descending at an angle of 27° terminates in an unfinished chamber, below the level of the ground. About 100 feet from the entrance, this passage is joined by an upper one, which ascends at the same angle to the great gallery, where it runs horizontally into what is now called the Queen's Chamber. But the gallery itself, continuing at an angle of 27°, leads to a larger room, called the King's Chamber, in which is a sarcophagus of red granite, 7 feet 4 inches by 3 feet, being only 3 inches less than the width of the door by which it was admitted. At the bottom of the great gallery is the well; and it was by this that the workmen descended, after they had closed the lower end of the upper passage, which was done with blocks of granite. And having gone down by the well, and reached the lower passage, they followed it upwards to the mouth, which they also closed.

Several other chambers and passages, hitherto undiscovered, no doubt exist in the upper part of the pyramid, and one seems to be connected with the summit of the great gallery. It appears to run upwards in a contrary direction to the north, from that end which is above the well; where a block, apparently of granite, projects at the complement of the usual angle of these passages. It probably turns afterwards, and extends in a southerly direction over the great gallery. Above what is called the King's Chamber, is a low room, which should support another similar chamber, and the stone at the south-west corner of it, has probably been let in after the workmen had closed the above-mentioned passage; so that this room served also as an outlet from the upper apartments, as the well from those about the great gallery.

The second pyramid stands at about a bow-shot from the first, towards the south. Herodotus says, after having measured both, that it falls short of the other in magnitude; that it has no subterraneous chambers, and that the Nile is not conveyed into it by a channel, as into the former, but that it is of equal altitude. Diodorus says it resembles the first in architecture, but is inferior in magnitude; each side of the base containing a stadium, or 600 Grecian feet, in length, so that by his computation each side is less than that of the former in length by 100 feet. Pliny makes the difference to be greater by 46 feet. Thevenot makes it but 631 feet square. Strabo supposes these pyramids to be equal; and Greaves assures us, that the basis of both are alike, and that the height of the second is not inferior to that of the first. This pyramid is built of white stones, not near so large as those of the first: the sides do not rise with gradations, but are smooth and equal, and the whole fabric, except on the south side, is quite entire. On the North and West sides of this second pyramid are two very stately and elaborate pieces of architecture, about 33 feet in depth, and about 1,400 in length, cut out of the rock in a perpendicular direction, and squared by a chisel; supposed to be designed for the lodgings of the Egyptian priests. The entrance to the interior is on the north front.

The first passage is built of granite, the rest are cut out of the natural sandstone rock, which rises above the level of the basis of the pyramid. This passage is 104 feet long, 4 feet high, and 3 feet 6 inches wide; descending at an angle of 26°, at the bottom is a portcullis, beyond which is a horizontal passage of the same height as the first, and at the distance of 22 feet, it descends in a different direction, leading to some passages below. Hence it re-ascends towards the centre of the pyramid, by a gallery 84 feet long, 6 feet high and 3.6 feet wide, leading to a chamber also cut out of the solid rock. The chamber is 46 feet in length, 16 feet wide, and 23.6 feet high, and contained a sarcophagus of granite, 8 feet long, 3.6 feet wide, and 2.3 feet deep in the inside. Returning from the chamber to the bottom of the gallery, a passage descends at an angle of 26° to the extent of 48.6 feet, when it takes a horizontal direction for a length of 55 feet; it then ascends at the same angle, and proceeds to the base of the pyramid, where another entrance is formed from the outside.

About the middle of the horizontal passage, there is a descent into another chamber, which is 32 feet long, 10 feet wide, and 8 feet 6 inches high.

The third pyramid stands at about the distance of a furlong from the second, on an advantageous rising of the rock, so that at a distance it appears equal to the former, though it is really much less and lower. Herodotus says it is 300 feet on every side, and to the middle, built of Ethiopic marble. Diodorus gives the same dimensions of its base, and adds, that the walls were raised fifteen stories with black stone, like Thebaic marble, and the rest finished with such materials as the other pyramids are built with; that this piece of work, though exceeded by the two former in magnitude, yet far excels them in respect to the structure, art, and magnificence of the marble; and that on the side towards the north, the name of Mycerinus, the founder, is engraved; but this inscription has been defaced by time. Pliny writes to the same effect, except that he makes this pyramid 363 feet between the angles.

Dr. Shaw apprehends, that neither of these pyramids was ever finished, supposing that the steps already mentioned should have been filled up with prismatical stones, so that each side of the pyramid might be smooth and level, like that of Cestius at Rome.

But, from the description of Maillet and Savary, the first pyramid appears to have been covered with a coating of marble, and thus finished on the outside, but closed; and that it has been since forcibly opened, and the stones which shut the passage, and were of an enormous size, have been removed. This passage was composed of marble, and the stones which form its four sides are of the finest white and hardest marble.

The ancients inform us, that the stones of the pyramids were brought from the mountains of Arabia; and Herodotus (lib. ii. c. 124.) has described the manner in which they were conveyed; but Dr. Shaw imagines, that they were taken from the spot where they were employed; and he observes, that the greatest of them, especially, is not an entire heap of hewn stones, because that portion of it which lies below the horizontal section of the entrance, may probably be no more than an incrustation of the natural rock on which it is founded. Mr. Bryant conjectures that, like the sphynx, which stands directly in the front of the second pyramid, they were immense rocks which stood upon the brow of the mountain; that the Egyptians cased them over with large stones, and brought them, by these means, to a degree of symmetry and proportion. At the same time, they filled up the unnecessary interstices with rubbish and mortar, and made chambers and apartments, as the intervals in the rock allowed, being obliged to humour the indirect turns and openings in the original mass, to execute what they proposed. This he infers from the narrowness and unnecessary sloping of the passages, which are often very close and steep, and also from the fewness of the rooms in a work of so immense a structure. That the pyramids were built upon a rock, in the place where they now stand, was suggested by Mr. Hooke.

The pyramids of Saccara, which are as many as 20 in number, vary in form, dimensions, and construction. They extend five miles to the north and south of the village of Saccara. Some of them are rounded at the top, and resemble hillocks cased with stone. One is constructed with steps, like that of Cheops. They are six in number, each 25 feet high, and 11 feet wide. The height of one in the group is 150 feet. Another, built also in steps, is supposed to be as high as that of Cheops. The stones whereof they are composed are much decayed, and more crumbling than those of Gizeh, hence they are considered older. One of them is formed of unburnt bricks, containing shells, gravel, and chopped straw.

The general opinion, with regard to the intention and use of pyramids, is, that they were sepulchres and monuments of the dead, particularly of kings. This is expressly affirmed by Diodorus, (lib. i.) and Strabo (lib. xvii.); and the opinion is confirmed by the writings of the Arabians. And the reason, says Greaves, of their erecting these magnificent structures is founded on the theology of the Egyptians, who, as Servius shows, in his *Comment upon Virgil* (Æneid, lib. iii.) where he describes the funeral of Polydorus—*Animamque sepulchro condimus*—believed, that as long as the body endured, so long the soul continued with it; and this was also the opinion of the Stoics. The reason of their building their sepulchres in the form of pyramids, was either from a notion that this was the most permanent form of structure, or because they hereby intended to represent some of their gods; particularly, as Greaves conjectures, Osiris, or the sun with many rays; for, under this form, the statues of the gods were frequently exhibited, and the gods themselves worshipped.

Among the Egyptians, the pyramid is said to have been a symbol of human life; the beginning of which is represented by the base, and the end by the apex; on which account it was that they used to erect them on sepulchres.

The tomb of Porsenna, king of Etruria, at Clusium, in Italy, is an ancient monument of square stone, each side of which is 300 feet broad, and 50 feet high. Within the square base, says Pliny, quoting from Varro, there is an inextricable labyrinth; upon this square stand five pyramids, four in the angles, and one in the middle, 75 feet broad at the bottom, and 150 feet high, and terminating in a point; at top, they are covered with a brass circle, from which are suspended bells, which are put in motion by the wind, so that their sound may be heard at a great distance. Upon this circle are four other pyramids, each 100 feet high; above which, upon one plane, are five other pyramids.

Pyramids are found in various parts of the world; indeed, the form of structure seems to have been not uncommon. Pyramidal tombs are found in Abyssinia, and even in Mexico, and the same form is observable in the constructed temples and pagodas of India and China. *See* EGYPTIAN and MEXICAN ARCHITECTURE.

PYRAMID, *Properties of the.* 1. All pyramids and cones standing on the same base, and having the same altitude, are demonstrated to be equal.

2. A triangular pyramid is the third part of a prism, standing on the same base, and of the same altitude.

3. Hence, since every multangular may be divided into triangulars, every pyramid is the third part of a prism, standing on the same basis, and of the same altitude.

4. If a pyramid be cut by a plane parallel to its base, the section will be similar to the base.

5. All pyramids, prisms, cylinders, &c., are in a ratio compounded of their bases and altitudes: the bases, therefore, being equal, they are in proportion to their altitudes; and the altitudes being equal, they are in proportion to their bases.

6. Similar pyramids, prisms, cylinders, cones, &c., are in a triplicate ratio of their homologous sides.

7. Equal pyramids, &c. reciprocate their bases and altitudes: i. e. the altitude of the one is to that of the other, as the base of one is to the base of the other.

8. A sphere is equal to a pyramid whose base is equal to the surface, and its height to the radius of the sphere.

PYRAMID, *to measure the surface and solidity of a:* Find the solidity of a prism that has the same base and height with the given pyramid: divide this by three; and the quotient will be the solidity of the pyramid. Or, multiply the base by the perpendicular height; and one-third of the product will be the content.

The surface of a pyramid is obtained, by finding the areas of the base and of the lateral triangles. The sum of these is the area of the pyramid. The external surface of a right pyramid, standing on a regular polygonal base, is equal to the altitude of one of the triangles which compose it, multiplied by the circumference of the base of the pyramid.

PYRAMID, *Frustum of a.* *See* FRUSTUM.

PYRAMID, *Truncated.* *See* TRUNCATED.

PYRAMIDOID, a solid generated by the revolution of a pyramid about its base.

Q.

QUADRA, in building, any square border, or frame, encompassing a basso-relievo, panel, painting, or other work.

The word is also used, erroneously, for a frame or border, of any other form; as round, oval, or the like.

QUADRÆ, the fillets on either side of the scotia of the Ionic base. Also the plinth or lower member of the podium.

QUADRANGLE, (from the Latin *quadrantus*, quartered, and *angulus*, a corner) a quadrangular, or quadrilateral figure; or a figure which has four sides, or four angles.

To the class of quadrangles, or quadrangular figures, belong the square, parallelogram, trapezium, rhombus, and rhomboides.

A square, &c. is a regular quadrangle; a trapezium, an irregular one.

Quadrangular figures are not proper for fortifications; the flanks and flanked angles being too small.

QUADRANT, (from the Latin *quadrans*, a fourth part) an arc of a circle, containing 90 degrees, or one-fourth of the entire periphery.

Sometimes, also, the space, or area, included between this arc and two radii, drawn from the centre to each extremity thereof, is called a quadrant, or, more properly, *a quadrantal space;* as being a quarter of the entire circle.

QUADRATURE, (from the Latin, *quadratura*) literally, the finding of a square equal in area to any given figure; which was the method the ancients made use of, when they had in view the determination of the surface of any space; but the term, *quadrature*, has now a more indefinite signification; implying, in general, the determination of the area of a figure, without any reference to the geometrical exhibition of it, in a square or other rectilinear form.

QUADRELS, a kind of artificial stones, perfectly square; whence their name. They are made of a chalky, or whitish and pliable earth, &c., dried in the shade for at least two years.

They were formerly in great request among the Italian architects.

QUADRIFORES, folding-doors which are divided into two in the height, so making four flaps.

QUADRILATERAL, from the Latin, *quatuor*, four, and *latus*, a side) a figure whose perimeter consists of four right lines, making four angles; whence it is also called a quadrangular figure.

If the several angles be right, the figure is a rectangular quadrilateral. If oblique, an oblique-angular quadrilateral.

If the sides of a quadrilateral be equal, and the angles right, the figure is a square.

If the sides be equal, but the angles unequal, the figure is a rhombus.

If the angles be equal, and the sides unequal, the figure is a rectangle.

If only the opposite angles and sides be equal, the quadrilateral is a rhomboides.

If the opposite angles and sides be unequal, the quadrilateral is a trapezium.

If any side of a quadrilateral, inscribed in a circle, be produced out of the circle, the external angle will be equal to the opposite internal angle.

QUADRIPORTICUS, a quadrangle with porticos or ambulatories on each side.

QUARREL, a lozenge-shaped pane of glass; also a tile or other material of the same form; same as QUARRY.

QUARRY, (from the Irish, *carrig*, a stone mine, or place where stones are digged. The methods which are practised in searching for, and ascertaining the presence of different sorts of materials of this nature, are principally those of boring, by means of an auger or borer made for the purpose, into the earth, and digging into it in other ways. In searching for most sorts of mineral substances, coals, and some other matters, the use of the borer is constantly first had recourse to, and not that of sinking a shaft, however favourable the appearances of the place may be for the purpose, and the success of the undertaking. The ground is first tried by this means, and a certainty of success or failure gained, as well as that of the most proper situation for sinking the shaft, or making the opening, or pit, without much expense being incurred, in case of the former. In trying for ochres, marls, and other similar articles, the same implement is also in common use. But in raising and providing lime-stone, free-stone, flags, and slates, &c., in some cases, digging down into, and opening the ground, by spades and other tools, is the mode employed in the first instance, in consequence of such substances being obviously present in sufficient quantities to be wrought with advantage.

Lime-stone is a very general sort of stone, raised from quarries and pits, in many different parts of this country, as in Devonshire, Sussex, Kent, &c., towards the south, where it lies in vast beds, from which it is dug for use; in the more midland counties, as in Gloucestershire, Shropshire, Derbyshire, Staffordshire, and others, where it exists, and is employed to a still greater extent; but by far the most extensively in those farther to the north, as Lancashire, Westmoreland, Yorkshire, Cumberland, and some districts of Scotland. In many parts of the county of Lancaster, it is dug and raised from quarries, where it lies in a stratified manner at no great depth from the surface, being got up without much difficulty or trouble; while, in other places, it is forced from the solid rock with great labour and expense. This is likewise the case in many other districts. Wherever it is met with it is almost constantly a quarry material of great value, and affords much employment to labourers.

In the county of Kent, the banks of some of the large rivers are scooped out into stone quarries in a remarkable manner, some of them worn out and disused, others in the state of being wrought. It has been observed, that this is the nearest stone county into which water-carriage can penetrate from the metropolis; and that the original London was built, as well as the modern one chiefly paved, by materials from this district, such as the rag stone, and the large pebbles gathered on the sea-shores, before the Scottish granite came into use. In the neighbourhood of Maidstone, there are appearances of many abandoned and neglected quarries of this nature; but the most considerable, which were lately wrought in that vicinity, are those of Farleigh and Fant. In each of these, blocks of stones, of different kinds, and of every form and size, are met with, being separated by seams, and large irregular masses of earth of various qualities: among the rest, brick earth of the best quality. In some places, the stones are buried several feet under these earthy materials: in others, the rock rises to the surface. After this, the quarry-men worm their way; following it with irregular windings, leaving behind them refuse in greater quantity than the useful materials which they raise.

The stony surfaces which are principally met with in them are of two very distinct kinds: the one hard and of a strong contexture, provincially denominated *rag or Kentish rag;* the other of a soft crumbly nature, provincially termed *hassock.* The quarrymen are in the practice of dividing the first sort into two kinds; what they call the *common-rag* and the *cork-stone,* the latter being their principal object in these immense works. It has, in its general appearance, much resemblance to the strong gray limestones which are found in different parts of this country; but when minutely examined by means of a glass, its fracture and contexture have the characters of the Devonshire marbles: except that the grain of this sort of stone is somewhat coarser. In colour, too, it differs from those marbles, having a greater resemblance to the Yorkshire limestones. It is used for different purposes; much of it is sent to the neighbourhood of London, where it is burnt into lime for the use of the sugar-bakers; who for some reason or other chiefly employ lime burnt from this material, or stone, instead of that from chalk. It is likewise made use of as a building material; and particularly in pedestals, for the posts of cattle-sheds, and other farm-offices. It is hewn with stone-masons' axes, working with tolerable freedom.

It is very durable, as some part of the basement of Westminster Abbey appears to have been built with the stone from these quarries. In this case, it seems to have been dressed smooth: and the surface still remains with little alteration; having withstood the attacks of time with great firmness; it being, even now, difficult to detect a loosened splinter in the work.

The common rag-stone comprehends all the different kinds which are met with in these quarries, except that of the above, and that which is of the hassocky nature; though the true unmixed rag is a distinct sort, having characters different from any of the others. In colour, it inclines more to the red, or liver colour, than that of the cork-stone, but otherwise resembles it considerably. Viewed with a glass, its grain is finer, and the fracture flint-like.

It has of late years come into very extensive use. Its constituents are—carbonate of lime, with a little magnesia, 92.6; earthy matter, 6.5; oxide of iron, 0.5; and carbonaceous matter, 0.4 = 100.

The hassocky-stone appears, to the naked eye, to be of a soft, white, sandy quality; and its fracture is the same; but under the glass, its grain is fine, its contexture uniform, and so thickly interspersed with small seed like granules, of a dark or black colour, as to give it a gray appearance; sometimes bearing evident impressions of shells. Its texture is loose and brittle, crumbling easily between the fingers into a coarse, sand-like powder. It will not burn into good lime, although it is almost wholly calcareous.

Its principal use is that of forming a loose friable sort of rubbly sub-soil, in some places, where it is admirably suited to the growth of saintfoin, and some other crops of the plant as well as of the fruit-tree kinds.

The quarries in several other counties contain stony materials of all these different kinds, which are wrought and applied to a variety of uses.

Quarries of marble are wrought in several districts in different parts of the country, and afford great advantages in various ways. In Sussex they have a marble, which, when cut into slabs, is used for ornamenting chimney-pieces, and other purposes. It is equal in quality and beauty to most sorts, when highly polished. For square building and paving, it is also a material scarcely to be excelled. By burning, it likewise affords a very valuable manure, equal, and by some thought superior, to chalk, being cheaper to those who are near the places from which it is dug. It is found the most perfect about Kirdford, at the depth of from ten to twenty feet under ground, in flakes nine or ten inches in thickness, and is called *Petworth marble.* It was much employed in building the cathedral at Canterbury; the pillars, monuments, vaults, pavement, &c., being formed of it; and the archbishop's chair is one entire piece of it. Marble is got in some of the counties in the middle of the island, as Derbyshire, Nottinghamshire, &c.

At Beacon-hill, near Newark, a blue stone for hearths is obtained, which approaches to marble, and is capable of burning into lime. And, in the county of Derby, much good marble is raised in different places.—In Lancashire there are quarries of fine black marble, besides stones which approach to, and take on the polish of marbles. In many of the western and northern parts of Yorkshire, marble of various kinds is found, some much resembling, and others superior, in closeness of texture and distinctness of colours, to that which is wrought in Derbyshire. Also a stone, which greatly resembles the marble of that county, and which is capable of receiving much such a polish, and is nearly of the same colour, mixture, and appearance.

In the county of Inverness, likewise, marble of the greatest variety of colours, and of the most beautiful shades, has been met with in Ben-Nevis; and inexhaustible quarries of it lie untouched in the islands which belong to it.

Besides, this sort of material exists in immense quantities in quarries in many other parts of the kingdom.

Chalk is a material which is raised from quarries and pits, mostly in the southern parts of the country, as in Sussex, Surrey, Kent, Essex, Berkshire, Hertfordshire, &c. It exists in vast ranges and tracts in most of these districts, whence it is dug up from quarries, at different depths, according to circumstances, exposed in sheds to dry when wet, and then converted into lime for various uses, by means of fire: or it is employed in its broken and powdery state, without undergoing the above processes, by merely digging it out of such places. In some parts, as in Kent, and the neighbouring districts, it is often dug and raised from considerable depths, from beds of very great thicknesses. And near Reading, in Berkshire, there is a stratum of this substance, which is thirty feet in thickness. It is there used and dug out for manure, and occasionally as a building material; for the latter of which purposes it is very durable. The remains of the abbey of Hurley, and of the ancient chapel, now the parish church, built wholly of chalk, in the reign of William the Conqueror, are still as fresh and sound as if they had been the works of the last century. Chalk, when once indurated by the air, has a remarkable property of resisting the action of the weather.

Granite is a stony substance which is found to exist in some of the southern parts of the country, as well as in those of the north, but it abounds much more in the latter.

In the western parts of Cornwall, it is in great plenty in the districts of Penwith and Kirrier, presenting itself in large slabs on all the rocky hills or tors, as well as in the waste moors and valleys, and appearing in detached spots, even in the shelvy slaty tracts. It is of different colours and textures, being adapted to a great variety of uses and purposes, as those of building, and being wrought into columnar masses, eight or ten feet in length, for supporters to sheds, out-houses, &c., and as gate-posts, and bridges over brooks, rivulets, &c., as well as in the forming of rollers, and malting, salting, and pig-troughs. It is also an article of commerce to different parts. It is supposed to be exactly of the same nature with the original granite; and there are five sorts of it, which are distinguished by their colours, the white, the dusky or dove-coloured, the yellow, the red, and the black, most of which are charged with a brown and bright silvery matter.

The county of Inverness has a great deal of this sort of stone, and there are numerous quarries for raising and working it. The common granite abounds in all the different districts of it. In many places, the whole rocks are composed of this kind, which is uncommonly useful for all ordinary purposes. By natural fissures, which run in straight lines, and generally at right angles, it is formed into all-sized portions and shapes, having uniformly a plain surface; and, by means of cutters or transverse lines, these stones are easily quarried, and found in the greatest plenty everywhere. They are remarkably beautiful, being almost as smooth and regular as hewn stone, and, of course, well suited for various sorts of building-work. The best buildings of the county-town are of a dark kind of granite, which is very hard and durable, but which has few or no fissures. It is generally found in large blocks; and in many of these parts, there is no other material for building or adding ornament with. The manner of giving it the polish it admits of, at the quarries, is by means of small picks or pick-axes, which are, in fact, hammers with sharp points at each end, in the manner of those employed by millers in preparing their grinding-stones. It is a very heavy, compact stone. There is a mixed sort, denominated *peasy granite*, which consists of white, black, and gray spots, that sparkle beautifully in the sun, is very ornamental, and much used for different purposes, as stairs, doors, and windows. Though this is very solid, and almost without natural fissures, it splits very straight, by means of iron wedges, set in a line, and struck alternately with a hammer of great power.

A great deal of this kind of stone is imported into the metropolis, and other large towns, for paving the streets, &c. It is, on the whole, a very advantageous sort of quarry material in various parts of the kingdom.

Quarries of freestone are wrought in a great number of different places. In the more southern parts is found the Portland-stone, which is so famous and useful in building. A sort of this kind of stone, which much approaches to it in quality, is also met with in Cornwall. Some likewise exists in Devonshire and Gloucestershire. The Cotswold quarries, in the latter, afford freestone of an excellent quality, particularly those at Painswick, Lodbury, Lockhampton-hill, &c. It abounds more, however, in Cheshire, Lancashire, Westmoreland, Cumberland, and some of the still more northern districts. Several excellent quarries of freestone are carried on in the first of these, as those at Runcorn, Manley, &c., where much valuable stone of this nature is raised. The second county also affords equally valuable quarries in many different places, from which vast quantities of the stone are raised, and employed, or sent away to a distance. Those about Ormskirk, Up-Holland, and Wigan, as well as those on all the eastern side, are in general of a very good quality; and in the vicinity of Lancaster there are some excellent ones; that on the moor, or common, close to the town, is very extensive, and affords a freestone that admits of a fine polish. In this district, this sort of stone is met with, of a whitish-brown, yellowish and reddish cast, but the first is by much the most esteemed. In the eastern parts of Westmoreland, as about Hutton Roofe, and some other places, a good sort of freestone is dug up from pits and quarries formed for raising it. This sort of stone exists, and is quarried almost all over, the counties of Cumberland and Northumberland; and prevails occasionally in others, where it is wrought to advantage. A grit-stone, somewhat of this nature, is met with in some districts, as in Shropshire, &c., which is raised from quarries, and used as a building material. And a sandstone exists to considerable extent in others, as in Sussex, &c., that is sometimes dug up, and made use of for common buildings, &c. In Cheshire, on the hills near Macclesfield, about Kerridge, a sort of sandstone is met with, which is particularly well suited to the making of flags, and whetting tools, as well as sometimes to the forming of slates, for which it was formerly much employed. Near Pott-Shrigley, also, a fine sandstone is found, that admits of a good polish. The quarry has not, however, been wrought for some late years, as, from the extreme hardness of the stone, the expense of getting it is very considerable. There are several other quarries of excellent freestone wrought in the same neighbourhood.

There has been great abundance of freestone wrought, from time immemorial, in the low parts of the county of Perth, and quarries of a greater or smaller grained stone of this sort appear almost in every place, with the exception of the Carses. In the Lowlands, and near to the eastern sea, the pores and grain of it are coarser; but as the mountains are approached, the pores are less, and the grain finer, by which these stones admit of a smoother polish. The quarry of Tullyalan parish, called Long-annat, affords a stone of a very excellent quality. It is of a white colour, admits of a smooth polish, and resists the influence of the weather. Some of the principal houses in that part of the country, as well as some of the most magnificent public buildings in the capital of Edinburgh, as those of the Exchange, the University, and the Register-office, consist partly of this stone, and those found at hand. And farther, in some instances it has been carried to the continent. But the quarry of Kingoodie, in the Carse of Gowrie, is unquestionably the finest of this kind of any in the country. Astonishing blocks, in great numbers, are raised there, fifty feet in length, sixteen feet in breadth, and three feet in thickness. Such is the demand for this stone, both at home and abroad, that four vessels are employed in exporting it from this quarry.

Flag-stones and quarries for the working and preparing of all sorts of flags, are met with in all those situations where free-stone is found, and where it exists in rather thick strata, or layers, of some depth, which are capable of being separated by hammers, wedges, or other means. In many places in the southern parts of the island, the flags raised from such free-stone quarries are of an extremely good quality, being used in very large quantities for various purposes. Those of Cornwall and Devonshire also, in many cases, afford a good sort of flags. The sandstone quarries of Shropshire as, at Grinsell, near Shrewsbury, about Bridgenorth, and at Corndon-hill, near Bishop's-Castle, as well as in the Swinney mountain, &c., where alternate beds of fine white and red stone of this kind, of very superior quality and thickness, exist; that in the first of these situations, being twenty yards thick, affords flags likewise which are of a very useful nature. Freestone flags, too, of useful sorts, are met with in the quarries of some of the midland counties; and they abound much in many of the freestone quarries of Lancashire, Yorkshire, and some of the other more northern districts of the country.

The quarries of this kind become slate-stone, and furnish the white, gray, and brown slate, wherever the stone lies in thin layers, or strata, which are able to be raised and separated from each other with convenience and facility. They exist in most of the above tracts, and are plentiful in some of them, especially those toward the north. The Lancashire and Yorkshire quarries, in many places, supply the white and gray sorts in great abundance, and of good qualities. Those of Westmoreland, Cumberland, and Northumberland also afford them, in many instances, of a valuable nature; and they are equally good in the still more northern districts. There are numerous quarries of different colours of them in Clydesdale, Perthshire, Argyleshire, and the county of Inverness, from which vast supplies are constantly raised for home and other use. This sort of slate has, however, mostly the disadvantages of being very porous, heavy, less durable, and of requiring more and stronger timber to support it than some other kinds; being only fit for exposed climates and situations.

The quarries of the lighter and thinner kinds of slate, of the blue, green, purple, and other colours, formed from other sorts of stone, only exist in some particular districts, as those of Wales, and the northern part of Lancashire, and the adjoining counties, and in a few places in Scotland. The slate quarries of the Welch districts supply several kinds and colours in large quantities, and of good qualities; but the dark and lighter purples are the most prevalent sorts in most of them. In Lancashire, the quarries of this kind are very numerous in the part to the north of the Sands, as about Gothwaite-common, Kirby-moor, Conistone-hills, and Tilberthwaitefells, &c., and from which very large supplies of the blue, green, and the dark purple sorts of slate are raised, and sent away for exportation, or consumed at home for different purposes. They are wrought, and the slate prepared, in somewhat different manners in different places. The Gothwaite quarries have the slate dug out from the side of the hill, and carried away. But in some on Kirby-moor, a level is driven through the ground from below, the metal being conveyed away by small four-wheeled waggons, on iron railways. Those about Conistone are mostly worked into the hills, and the metal raised and carried out from them. Some of the Tilberthwaite quarries are wrought by blasting the slate-stone, and collecting and carrying it out of them on slanting roads, in small carts, or trucks, constructed for the purpose, of levels being below the hills, but not nearly so low as the bottoms of the quarries. Others are wrought by draught roads from the bottoms of them. One man will raise eighteen or twenty hundred-weight of slate in one day where the metal rises well, but less in other cases. In some, it is dug out by one set of men, split by another, and formed into slates by a third; for which purposes, flat crow-bars, slate-knives, and axes are employed. The slate is divided and distinguished into three sorts, as firsts, seconds, and thirds, or London, country, and toms. In the first, or Gothwaite quarries, the slate has a darkish purple or black cast. In the Conistone quarries, it has a fine blue and green appearance, and is much thinner and lighter than the other sort. The Tilberthwaite slate, in some instances, splits very fine, thin, and light, but does not cover so far as those of the Gothwaite and Kirby quarries. In some quarries a sort of rent is paid per ton, on the slate which is raised; while in others, a certain rent only is paid for the liberty of the royalty, and not a tonnage duty. These rents, or duties, on the workers of these quarries, are probably higher than they will bear, and have enabled the Welsh slate-dealers to undersell those of this county.

Westmoreland and Cumberland, in some instances, afford good blue and green slates. In the latter, some of an excellent quality are obtained in the quarries of Borrowdale, and inferior sorts in some of the neighbouring mountains.

The county of Argyle, in Scotland, in some parts, abounds with slate-quarries, as the tracts about Esdale, from which five millions of slates have for some time been annually sold. Quarries of the same kind are also wrought in many other parts, with great benefit to the inhabitants.

Slate-quarries are found in many parts of the highlands of the county of Perth, but none in the low. The slates in some are of a purple colour, in others of an azure blue, and in a few, of a muddy, sandy, brown complexion along the cutters. It is well known where the different sorts are quarried. The veins of slate-rock seem to run from Drumlane, in the parish of Aberfoil, in a north-east direction, to Dunkeld; and may be traced beyond the limits of the county both ways. The azure coloured are the best metal, and rise of a greater size than any of the other kinds. Many of the buildings in different places are slated with this beautiful covering. Into the lower districts of the county, slates are imported from Esdale, and the other quarries on the west coast of the county of Argyle.

Quarries of gray slate exist in many different parts of the county of Inverness, in which the quality is very good, and well suited to the climate. In some places these slates are much preferred to blue ones, as the latter are more expensive in procuring, and though nailed on the roofs ever so firmly, are apt to be loosened by high winds, unless bedded in lime, which circumstance renders repairs difficult.

Quarry, (from the French, *quarré*, square; or, according to some, a corruption of the English term, *quarrel*) a pane, or piece of glass, cut in a losenge or diamond form.

Quarries, or quarrels of glass, are of two kinds; viz. square and long, each of which is of different sizes, expressed by the number of pieces which make a foot of glass; viz., 8ths, 10ths, 12ths, 15ths, 18ths, and 20ths; but all the sizes are cut to the same angle, the acute angle being 77° 19′ in the square quarries, and 67° 22′ in the long ones.

Quarry-Cart, a name commonly given to that sort of cart which is principally employed in the work of quarries, and which is generally of a low, compact, strong kind, in its nature, form and manner of construction, in order to sustain heavy weights, and receive them without difficulty, or the danger of being destroyed. Carts for this purpose should always be made of well-seasoned wood, well put together, with sufficient strength of timber in those parts where the main stress of the load is placed.

Quarry-Waggon, or Truck, a small carriage of the low truck kind, which is much employed in the business of quarries, especially those of the slate kinds, for the purpose of holding and conveying the rough materials, which have been blown from the large massy rocks, or separated in other ways, out of or from the quarries and pits in which they are situate and contained, to the places where they are to receive their different preparations and shapes.

It is formed and constructed on a frame somewhat similar to that of the common barrow, and mounted on two low light iron-wheels on the fore part, having two feet behind, projecting from the frame, bent something in the manner of the letter S, and of sufficient length to let it stand or rest in a horizontal position while it is in the act of being loaded. These feet are usually made of iron, but they may be formed of other materials. A sort of inclined plane is formed from the bottoms of the quarries or pits, up which it is forced, with great ease and facility, by the workmen, or small animals of the horse kind, after being filled with these sorts of heavy materials.

QUARRYING, the business of directing and conducting the nature and management of sinking the different kinds of quarries, pits, and shafts, as well as of the different sorts of work which are necessary to be undertaken, carried on, and performed in the several different descriptions of them; such as those of separating, getting up, and preparing the various sorts of materials for use in the arts, or in other ways. It is a practice which requires considerable knowledge and experience, to be fully master of it in all its different bearings and intentions. *See* QUARRY, and QUARRYING SLATES AND STONES.

Almost every kind of quarrying-work requires a different kind of management, not only in the opening and sinking the quarries and pits in the ground at first, but afterwards in the methods and practices of working them, and getting up the various sorts of materials from them, as well as in the modes of preparing, trimming, and arranging them, after they have been raised. They are, however, mostly well known and familiar to the quarry-men and pit-men, who are usually engaged in works of the several kinds.

QUARRYING SLATES AND STONES, the methods of preparing them for their different uses and applications at the quarries and pits where they have been raised. The former of these articles, particularly those of the blue, green, and purple or blackish kinds, undergo several different sorts of preparation in the quarrying, according to the purposes to which they are to be afterwards applied. They are separated and divided into very thin pieces, or slates, where light neat coverings are required, or in much demand; but for more strong and heavy coverings, in exposed situations, or other places, they are split into much thicker sheets, layers, or slates, and are, of course, more clumsy in their appearance.

Each sort, in the business of quarrying, is wrought in a separate manner, and packed up by itself; the different sorts having appropriate names, as has been already seen.

The white or brown slates are never divided and prepared in so fine a way as the other kinds, but separated into much thicker flakes or laminæ, in this intention. The blue, green, and purple or darkish sorts, are, for the most part, found capable of being split into very thin laminæ, or sheets; but those of the white, or brownish freestone kinds, can seldom be separated or divided into any very thin slabs, as the layers of the large masses of the stones are of a much thicker nature, they consequently form heavy, strong, thick coverings, proper for buildings in exposed climates and situations, and of the more rough kinds, such as barns, stables, and other sorts of out-houses.

In the different operations and processes of this sort of quarrying, slate-knives, axes, bars, and wedges, are chiefly made use of for the different purposes of splitting and cleaning the slates, they being separated into proper thicknesses by the axe, bar, and wedge, and afterwards chipped into their proper forms and shapes by the knife. All the inequalities which may appear upon any of them, are removed by this last-named implement. In the quarrying of the latter sorts of materials, or those of stones, the work is usually performed in such a manner as to suit the different uses for which they are intended. Where flags are to be formed, they are split or riven into suitable thicknesses, and squared to different sizes, so as to be adapted to different applications. These operations are executed in rather a rough way, as they are afterwards to be finished by the stone-mason. When for steps, they have the proper breadths and depths given to them in a sort of squaring manner, being left to be completed as they may be wanted for particular uses and applications. Gate-posts are, for the most part, quarried so as to have from about a foot to a foot and a half or more in the square. Trough-stones have the quarrying performed so as to be formed into various proper-sized squares or other forms, in a rough manner, being left in these states to be afterwards hewn and hollowed out, in the intended parts, by the stone-masons.

Stones for building purposes are usually raised and quarried out roughly into something of the square shape, being left in that state for the builders, who afterwards fit them so as to suit their own purposes and intentions.

In the quarrying of stones, the quarrymen commonly make use of large hammers, with cutting ends on one side, the other being formed in a plain manner; strong, sharp, crow-bars, and broad, sharp, iron wedges; by which means these matters are, from the constant practice of the men, split and torn into such forms as are wanted, with great ease and facility.

QUARRYING TOOLS, the different sorts of implements made use of in the different works of the quarry. They are principally such as have been noticed in the former article; to which may be added different descriptions of picks, mattocks, and jumpers, or boring implements for the purpose of blasting the various kinds of stone, and other hard materials.

QUARRYINGS, the small pieces that are broken or chipped off from the different sorts of materials found and wrought in quarries while preparing for various uses. These substances where they are of the hard kind, such as those of the blue and lime stone, as well as some other sorts, are extremely well calculated for the purpose of forming and repairing roads, as they are nearly, if not quite, in a state fit for immediate application. Materials of these kinds ought, therefore, where they can be conveniently had, never to be neglected by those who have the care and management of roads, as they will save much expense and trouble, in a great number of instances.

QUARTERINGS, or QUARTERS, slight upright timber-posts framed together, and employed instead of walls for the separation of apartments &c.; they are lathed over in the same manner as ceilings, to receive plastering, but when used for external work they are usually boarded. They are of two kinds, single and double, the scantling of the former being 2 inches by 4 inches, and the latter 4 inches square; they are placed at about 12 or 14 inches apart. The term *quarterings* is especially applied to a series of quarters.

QUARTER-PARTITIONS, a partition composed of quarters.

QUARTER-ROUND, a term used by the workmen for any projecting moulding in general, whose contour is a perfect quadrant, or quarter of a circle, or which approaches near that figure. The architects usually call it *ovolo;* and Vitruvius, the *echinus;* but oval more properly applies to the quadrant of an ellipsis as used in Grecian architecture.

QUATRE-FOIL, (French, *quatre-feuille*), An ornament much used in Gothic architecture, formed by a moulding disposed in four segments of circles, forming four cusps or points at their intersection.

QUEEN-POST, a timber post employed in roofs, for the purpose of suspending the tie-beam. It performs the same office as a king-post, but the term is applied to such suspenders only when there is more than one in a single truss; when there is only one, it is termed a *king-post.*

QUICK-LIME, such lime as is in the caustic or most active state, and which possesses the greatest power of operating upon different substances with which it may come in contact. It is quite the opposite, in its qualities and properties, to that which has fallen down into a powdery state, in consequence of being saturated with water and carbonic acid gas, or fixed air, or which is slaked and become effete.

According to Dr. Anderson, lime is in the best and most fit state for the purpose of cement, when most perfectly caustic, or in the most crystallizing condition. It is remarked, that the powder of lime, when reduced by means of water into a fluid, or thin paste-like form, and then suffered to become dry, concretes into a coherent mass, which fixes to stones and other rough bodies in a very firm manner, and in this way becomes a proper cement for building any sort of walls. And that, after this pasty material has once become firmly dry, it is quite indissoluble in water, and incapable of ever being softened again by the moisture of the atmosphere or other similar causes. Hence it excels many other sorts of cements.

When composed for the purpose of building walls, &c.; it is usually denominated *mortar;* but when formed as an application in the way of a smooth coating upon any plain surface without intermixture with stony matters, it is commonly termed *plaster.*

When made from the lime of the purer sort of lime-stone, it is found to be more soft and crumbly, and to acquire a less degree of hardness, and to be broken with much less force, than where the lime-stone, from which it is made, contains a large proportion of sand; in which case it becomes much more hard, firm and durable.

It has, however, been discovered, that the purest lime may be rendered a firm cement by adding a proper proportion of clean hard sand to it; hence the practice of blending sand with lime, when intended for mortar, has become so universal. This is fully shown to have been very early the case, by the oldest lime-built walls which are now to be met with.

It nevertheless still remains a desideratum to ascertain the due proportion of sand necessary, as both writers and practical masons greatly disagree in opinion on this matter, as well as in their directions about the mode of mixing the materials, and of applying the cement; some of the more modern, especially ascribing extraordinary effects to a small variation in these particulars, while others deny that these circumstances have any sensible effect on the durability and firmness of the cement.

It is conceived that these different and contradictory opinions arise from the imperfect knowledge of the nature of quick-lime, and the variations it may admit of; for these variations are so very great, as to render it impossible to afford any general rules that can possibly apply in all cases. It is, therefore, conceived to behove those who are desirous of acquiring any consistent and satisfactory knowledge on this head, to endeavour to ascertain, in the first place, the circumstances which render calcareous substances *at all* capable of becoming a cement, and then to trace the several changes that may be produced upon it by extraneous causes.

Having explained the circumstances which cause the differences in limestone, and pointed out the different constituent principles of it, as well as various other peculiarities; it is known, that lime which has in any way absorbed its full quantity of air from the atmosphere, and become mild, is altogether unfit for becoming a cement, and that, of course, a great change may be produced upon the quality of any lime, by having allowed less or more of it to be in this state before it is worked up into mortar. And farther, that if a large quantity of water be put to fresh-slaked quick-lime, and beat up with it into a thin sort of paste, the water dissolves a small portion of the lime, which, as it gradually absorbs its air, is converted into crystals; between the particles of which crystals, that part of the lime which was not dissolved, and the other extraneous matters which may have been mixed with it, are entangled, so as to form a firm coherent mass of the whole. And that the pasty substance formed in this manner, is the well-known article mortar; and this heterogeneous, imperfectly semi-crystallized mass, constitutes the common cement employed in building ordinary walls, or other erections. These circumstances, therefore, being known, it is thought that it will not be difficult to comprehend what are the particulars necessary to form the most perfect cement of this nature. That since lime becomes a cement only in consequence of a certain degree of crystallization taking place in the whole mass, it is sufficiently obvious that the firmness and perfection of that cement must depend upon the perfection of the crystals, and the hardness of the matters that are entangled among them; for if the crystals are ever so perfect and hard of themselves, if they be separated from each other by any brittle incoherent medium, it is evident that the whole mass must remain in some degree brittle and incoherent. That as water can only dissolve a very small proportion of lime, even when in its most perfect saline or caustic state, or while it remains deprived of its carbonic acid gas, and, as happens in other similar cases, no more of the lime can be reduced to a crystalline mass than has been actually dissolved in the water; it follows, of course, that if mortar be made of pure lime and water alone, a very small proportion only can be dissolved by that small quantity of water that is added to it; and as this small proportion alone can afterwards be crystallized, all the remaining undissolved particles of the lime will be entangled among the few crystals that are formed. And as the undissolved lime in this mass will in time absorb its air, and be converted into *mild* calcareous earth, without having had a sufficiency of water to allow it to crystallize, it must concrete into a friable mass, exactly resembling chalk; this kind of mortar, therefore, when as dry as it can be made, and in its highest degree of perfection, will always be soft, and easily crumbled into powder. But if, instead of forming the mortar of pure lime alone, a large proportion of sand be added to it, the water will, in this case, dissolve as much of the lime as in the former; and the particles of hard sand, like sticks or threads, when making sugar-candy or other crystals, while surrounded by the watery solution, will help to forward the crystallization, and render it more perfect than it otherwise would have been, so as firmly to cement the particles of sand to each other. And as the granules of sand are perfectly hard of themselves, so as not to admit of being broken down like the particles of chalk, it necessarily follows, that the cement made of these materials must be much more perfect, in every respect, than the former.

After considering a variety of circumstances in regard to the solubility of lime in water, and its crystallization, it is remarked, that when a large quantity of sand is mixed in the mortar, that sand will of course bear a great proportion to the whole mass; so that the water that may be mixed with the mortar will be much greater in proportion to the quantity of lime contained in this mortar, than if the whole had consisted of pure calcareous matter. And that, as the sand absorbs none of that water, the water, now pure, is at liberty to act once more upon those few particles of caustic lime that may still remain in the mortar, which will be dissolved and converted into crystals in their turn. In this way, it may happen, in some circumstances, that a very large proportion of the lime may become crystallized; so that the mortar will consist almost entirely of sand enveloped in crystalline matter, and become in due time as hard as stone itself; whereas mortar, consisting of pure lime, without sand, can hardly ever be much harder than chalk. It is not, however, to be supposed, that in any case this dried mortar will assume that transparent crystalline form, or the compact firmness of some sorts of calcareous matters, such as marble and limestone. In mortar, in spite of the utmost care that can ever be taken, a very considerable quantity of the lime must remain undissolved; which undissolved lime, although it may be so much separated by the sand and crystalline limestone as not much to affect the hardness of the mortar, yet it must still retain its white chalk-like appearance. As marble and limestone are, however, always formed by those particles of lime that have been wholly dissolved in water, and from which they have been gradually separated by a more slow and more perfect mode of crystallization, they have nothing of that opaque calx-like appearance, but assume other colours, and appear more firm, uniform, and compact; the sand and other matters that may be enveloped in them being entirely surrounded with a pure crystalline matter.

But to obtain the most perfect kind of mortar, it is not, however, enough that a large proportion of sand should be employed, and that the sand should be intimately mixed with the lime; it is also of the utmost importance that a large proportion of water be added; for, without this, it is impossible that a large proportion of the lime can be crystallized: and the mortar, in that case, would consist only of a mixture of chalky matter and sand, which could hardly be made to unite at all, and would be little more coherent than sand by itself, and less so than pure chalk. In that case, pure lime alone must afford rather a firmer cement than lime with sand. It is also of very great importance that the water be retained as long in the mortar as possible: for if it be suddenly evaporated, it will not only be prevented from acting a second time upon the lime, after a part of what was first dissolved has been crystallized, but even the few crystals that would be formed when the water was suddenly evaporating, would be of themselves much more imperfect than they otherwise most certainly would have been. In proof of which, instances of the crystallization of common salt, lump-sugar, and sugar-candy, are adduced; after which it is noticed, that every one knows what a difference there is between the firmness of the different substances; and that as great must be the difference between the firmness of that cement which has been slowly dried, and that which has been hastily hardened by the powerful action of a warm air.

It is contended, that it is owing to this circumstance that the lime, which remains all winter in a mortar-tub filled with water, is always found to be much firmer and more coherent than the mortar that was taken from the same tub and used in any work of masonry, although in this case the materials were exactly the same. From the same cause, any work cemented with lime under water, if it has been allowed to remain undisturbed and uninjured until it has once become hard, is always much firmer than that which is above the surface of the water.

In order to render the force of the above reasoning more strong and convincing, lime-cement or mortar is compared to a mass of matter consisting of a congeries of stones closely compacted together, and united by a strong cementing matter, that had, while in a fluid state, pervaded all the interstices between the stones, and afterwards become a solid indissoluble substance. If the cementing matter be exceedingly hard and coherent, and if the stones bedded among it be also very hard and firm, the whole mass will become like a solid rock, without fissures, that can hardly be broken to pieces by the power of man. But, although the cement should be equally firm, if the stone, of which it consists, be of a soft and friable nature, suppose chalk or sand-stone, the whole mass will never be capable of attaining such a degree of firmness as in the former case; for, when any force is applied to break it in pieces, although the cement should keep its hold, the solid matter cemented by it would give way, and the whole would be easily broken to pieces. Whereas, in mortar, the sand that is added to it represents the stones of a solid matter, in the composition, the particles of which are united together by the lime which had been formerly dissolved, and now crystallized, which becomes an exceedingly solid and indissoluble concretion; and as the particles of sand are of themselves exceedingly hard, and the cement by which they are united equally so, it is plain that the whole concretion must be extremely firm, so as to require very great force to disunite any particle of it from the whole mass. But if, instead of employing sand, the only solid body that is entangled among the cementing matter should be chalk, (as in all cases where the mortar consists of pure lime alone,) or any other slightly coherent substance, let the cementing particles of that composition be ever so perfect, it is impossible that the whole can ever attain a great degree of firmness, as these chalky matters will be easily broken asunder.

It is remarked, in addition, that a variety of conjectures have been made about the nature of the lime-cement employed by the ancients. It has been thought that they possessed an art of making mortar which has been long since entirely lost; as the cement in the walls which have been built by them, appears to be, in many cases, much firmer than that which had been made in modern times. Yet, when the mortar of these old buildings is analyzed, it is found to consist of the same materials, and nearly in the same proportions, in which they are now made use of. And it is thought probable, that their only secret consisted in mixing the materials more perfectly than the rapidity or avarice of modern builders will permit; in employing their mortar in a much more fluid state than is done now; and in allowing it to dry more slowly, which the immoderate thickness of many of their walls would naturally produce, without any preconcerted design on their part. Tradition has even handed down to the present times the memory of the most essential of these particulars; as the lower class of people, in every part of the nation, at this moment, invariably suppose and believe that these old walls were composed of a mortar so very thin, as to admit of its being poured, like a fluid, between the stones, after they were laid in the wall: and the appearance of these old walls, when taken down, seems to favour this popular tradition. Nor is it doubted but that this may have been the case. The stones in the outer part of the wall, it is thought, were probably bedded in mortar, nearly as is practised at present; and the heart, after being packed well with irregular stones, might have the interstices between them entirely filled up with fluid mortar, which would insinuate itself into every cranny, and, in time, adhere as firmly as the stones themselves, or even more so, if the stones were of a sandy friable nature. And that, as these walls were usually of very great thickness, it might often happen, that the water in this mortar, by acting successively upon different particles of caustic lime, would at length be entirely absorbed by successive crystallizations, so as to become perfectly dry, without any evaporation at all; in which case, a very large proportion of the original lime must have been regularly crystallized in a slow and tolerably perfect manner, so as to attain a firmness little inferior to limestone, or marble itself.

It is supposed that, upon these principles, it is easy to account for the superior hardness of some old cements, when compared with that of modern times, in which a practice very different is usually followed, without having recourse to any wonderful *arcana* whatever.

There are likewise a few other circumstances that may influence the quality of common lime-mortar. If limestone be sufficiently calcined, it is deprived of all its moisture, and of all its carbonic acid gas, or fixed air. But experience shows, that limestone will fall to powder on the effusion of water upon it, when it is much less perfectly calcined, and while it still retains almost the whole of its fixed air. And that, as masons have hardly any other rule for judging whether limestone be sufficiently calcined, except this single circumstance of its falling to a powder when water is poured upon it, it may thus easily be perceived, that the same lime may be more or less fitted for making good mortar, according to a circumstance that, in a great measure, eludes the observation of operative masons; for if it should happen that all the pieces of lime drawn from a kiln at one time were just sufficiently calcined to make it fall to a powder with water, and no more, that powder would be altogether unfit for making mortar of any kind. This is a case that can seldom happen; but as there are a great many intermediate degrees between that state and perfect calcination, it must often happen that the stone will approach nearer to one of these extremes at one time than at another; so that the mortar may be much more perfect at one time than at another, owing to a variation in this particular.

All those who have written on the subject of lime as a cement, have endeavoured to ascertain what is the due proportion of sand for making the most perfect cement. But a little attention to the matter will show, that all rules which could be prescribed as to this particular, must be so vague and uncertain as to be of little utility to the practical mason; as, besides the variation which may arise from a more or less perfect degree of calcination as above, it is a certain fact, that some kinds of limestone are much more pure, and contain a much smaller proportion of sand, than others do; some being found almost perfectly pure, while others contain eleven-twelfths of sand, and all the intermediate proportions of it. Therefore, it would be absurd to say that pure lime would require as small a proportion of sand, when made into mortar, as that which originally contained in itself a much larger proportion of sand than any writer has ever ventured to propose for being put into mortar.

Besides, there are variations caused by the different nature of the calcination in the several sorts of limestone; from which it may, upon the whole, be concluded, that about one-tenth of *pure* limestone is not enough calcined to admit of being made into mortar; and that of the most impure sorts of limestone, not above one-fourth part of the lime contained in it is so much calcined as to be in a caustic state.

The variation that is produced by these means, in regard to the proportion of sand that will be required to the lime in the one or the other case, is found to be so extremely great as hardly to be conceived. It is, however, stated, that the best mortar that has been seen made was formed of lime which had been found to contain eleven parts of sand to one of lime; to this there was added between twice and thrice its whole bulk of sand by measure, which may be allowed to have been at least three times its quantity *by weight*. Therefore, supposing that every particle of that lime had been so perfectly calcined as to be in a caustic state, there could not be less than forty-seven parts of sand to one of lime. As much may, however, be allowed for the uncaustic part of the lime as is desired, and the calculation made accordingly. But it is hardly possible to suppose that above one-hundredth part of this mass, independent of the water, consisted of pure caustic calcareous earth.

On these considerations it is conceived, that it is impossible to prescribe any determinate proportion of sand to lime, as that must vary according to the nature of the lime, and other incidental circumstances, which would form an infinity of exceptions to any general rule. But it would seem that it might be safely inferred, that the moderns, in general, rather err in giving too little sand than in giving too much. It deserves, however, to be noticed, that the sand, when naturally in the limestone, is more intimately blended with the lime than can possibly be ever effected by any mechanical operation; so that it would be in vain to hope to make good mortar artificially from pure lime, with such a small proportion of caustic calcareous matter as may sometimes be effected when the lime naturally contains a very large proportion of sand. But there seems to be no doubt, that if a much larger proportion of sand were employed, and if that were more carefully blended and expeditiously worked than is common, the mortar would be much more perfect than is usual in modern times, as has been proved by actual trials.

Another circumstance that tends greatly to vary the quality of cement, and to make a greater or smaller proportion of sand necessary, is the mode of preparing lime before it is beaten up into mortar. When for plaster, it is of great importance to have every particle of the limestone slaked before it is worked up; for, as smoothness of the surface is the most material point, if any particles of lime should be beaten up in it, and employed in work before sufficiently fallen, the water still continuing to act on them after it was worked up, would infallibly slake such particles, which, forcibly expanding themselves, would produce those excrescences on the surface of the plaster commonly termed blisters. Consequently, in order to obtain a perfect kind of plaster, that will remain smooth on the surface, and free of blisters, there is an absolute necessity to allow the lime to lie for a considerable time macerating or *souring* in water, before it is worked up. And the same sort of process is necessary for the lime, when intended for use as mortar, though not so absolutely. Great care is, however, required in the management in this respect; the principal things being the getting of well-burnt lime, and the allowing it to macerate or *sour* with the water for only a *very short time* before it is used; but that which is the best burnt will require the maceration of some days in the water before it is sufficiently slaked in the whole mass for this purpose.

It has been almost universally admitted, that the hardest limestone affords a lime that will consolidate into the firmest cement; hence it is generally concluded, that lime made of chalk produces a much weaker cement than what is made of marble or limestone. It would seem, however, that if ever this be the case, it is only incidentally, and not necessarily so. As, from the nature of calcareous matter, every kind of lime is equally fit for becoming a firm cement, if it be first reduced to a proper degree of causticity, and has afterwards a due proportion of sand properly mixed with it, before it be employed in work. Different sorts of lime, without doubt, differ much from each other in the proportion of sand they naturally contain, and, of course, require very different proportions of sand to be added to them before they can be made equally perfect as a cement; which is an economical consideration of no small moment, in some cases, as it may make one sort of lime a great deal cheaper than another on some occasions, and, of course, deserves the attention of builders in general.

The excellencies and defects of other substances, that may be occasionally mixed with lime, in making cement, may be just noticed. Those commonly used as an addition to mortar, besides sand of various denominations, are powdered sandstone, brick-dust, and sea-shells. And, for forming plaster, where closeness rather than hardness is required, they use lime that has been slaked and kept long in a dry place till it has become nearly effete, powdered chalk, or whiting, and gypsum, in various proportions; besides hair and other materials of that nature. But some others have been more lately advised, such as earthy balls, slightly burnt and pounded, powdered and sifted old mortar rubbish, and others of a similar kind. All of which substances are found objectionable, in some respect or other, for this use, sand being the only perfectly suitable material that can be easily met with; on which account, it has been always justly preferred. Pure firm crystallized sand is the best; though all pure sands are not equally proper for this purpose.

It is stated by Sir Humphrey Davy, in his work on *Agricultural Chemistry*, that there are two modes in which lime acts as a cement; in its combination with water, and in its combination with carbonic acid. When quick-lime is rapidly made into a paste with water, it soon loses its softness, and the water and the lime form together a solid coherent mass, which consists of seventeen parts of water, to fifty-five parts of lime. When this hydrate of lime, while it is consolidating, is mixed with red oxyde of iron, alumina, or silica, the mixture becomes harder and more coherent than when lime alone is used; and it appears, that this is owing to a certain degree of chemical attraction between hydrate of lime and these bodies: and they render it less liable to decompose by the action of the carbonic acid in the air, and less soluble in water. It is thought that the basis of all cements that are used for works which are to be covered with water must be formed from hydrate of lime; and that the lime made from impure lime-stones answers this purpose very well. Puzzolana, it is said, is composed principally of silica, alumina, and oxyde of iron; and it is used mixed with lime, to form cements intended to be employed under water. It is stated that Mr. Smeaton, in the construction of the Eddystone lighthouse, used a cement composed of equal parts, by weight, of slaked lime and puzzolana. Puzzolana, it is said, is a decomposed lava. Tarras, which was formerly imported in considerable quantities from Holland, is found to be a mere decomposed basalt: two parts of slaked lime and one part of tarras form the principal part of the mortar used in the great dykes of Holland. It is supposed that substances which will answer all the ends of puzzolana and tarras, are abundant in the British islands. An excellent red tarras may be procured in any quantities from the Giant's Causeway, in the north of Ireland: and decomposing basalt is abundant in many parts of Scotland, and in the north of England where coal is found.

It is observed that Parker's cement, and cements of the same kind, are mixtures of calcined ferruginous, siliceous, and aluminous matter, with hydrate of lime.

It is noticed, that the cements which act by combining with carbonic acid, or the common mortars, are made by mixing together slaked lime and sand. These mortars at first solidify as hydrates, and are slowly converted into carbonate of lime by the action of the carbonic acid of the air. It was found by Mr. Tennant, that a mortar of this kind, in three years and a quarter, had regained sixty-three per cent. of the quantity of carbonic acid gas, which constitutes the definite proportion in carbonate of lime. The hardness of the mortar in very old buildings is also thought to depend upon the perfect conversion of all its parts into carbonate of lime. The purest lime-stones are the best adapted, it is said, for making this kind of mortar. The magnesian lime-stones make excellent water-cements, but act with too little energy upon carbonic acid gas, to make good common mortar. The Romans, on Pliny's authority, made their best mortar a year before it was used; so that it was partially combined with carbonic acid gas before it was employed, it is supposed. See more on this subject under the articles Cement, Lime, Mortar, and Plastering.

QUIRE, the same as Choir.

QUIRK, a piece of ground taken out of any regular ground-plat, or floor. Thus, if the ground-plat were square, or oblong, and a piece be taken out of a corner, to make a court, or yard, &c., the piece is called a *quirk*.

Quirk-Mouldings are the convex parts of Grecian mouldings, where they recede at the top, and form a re-entrant angle with the soffit, or level surface which covers the moulding.

Quirks, in moulding, belong to the ovolo and semi-reversa.

QUOIN, or Coin, (from the French, *coin*, of the Latin, *cuneus*), a wedge. *See* Coin.

Quoins, (from the French *coin*, a corner), the corners of brick or stone walls. The word is particularly used for the stones in the corners of brick buildings. When these stand out beyond the brick-work (their edges being chamfered off) they are called *rustic quoins*.

R.

RABBET, or Rebate, *see* Rebate.

Rabbet-Plane, *see* Plane.

RABBETING, or Rebating, the planing or cutting of channels, or grooves, in boards.

RACK, the case in a stable where the hay is placed for the horses.

RADIUS, in a circle, the right line drawn from the centre to the circumference.

RAFTERS, (Dutch), pieces of timber, which, standing by pairs on the reason-piece, or raising-piece, meet in an angle at the top, and form the roof of a building.

It is a rule in architecture, that rafters should not stand farther than twelve inches asunder.

For the sizes or scantlings of rafters, it is advisable that *principal* rafters from 12 feet 6 inches, to 14 feet 6 inches long, be 5 inches broad at the top, 8 inches at the bottom, and 6 inches thick. Those from 14 feet 6 inches, to 18 feet 6 inches long, to be 9 inches broad at the foot, 7 inches at the top, and 7 inches thick. And those from 18 feet 6 inches, to 21 feet 6 inches, to be 10 inches broad at the foot, 8 inches at the top, and 8 inches thick. Single rafters, 6 feet 6 inches long, must be 4 feet 3 inches in their square.

Rafters, the inclined timbers disposed in the sides of a roof, so that their edges may be in planes parallel to the covering which is supported by them. See the article Roof, Curb-roof; but more particularly Mechanical Carpentry.

RAG-STONE, a kind of limestone much used in building of late. *See* Quarry.

RAIL, (from the German, *riegel*), in *architecture*, is applied variously; particularly to those pieces of timber which lie horizontally between the panels of wainscot, and over and under them. The word is also applied to those pieces of timber which lie over and under balusters in balconies, staircases, &c. Also, to the pieces of timber that lie horizontally from post to post in fences, with pales or without.

Fig. 3.

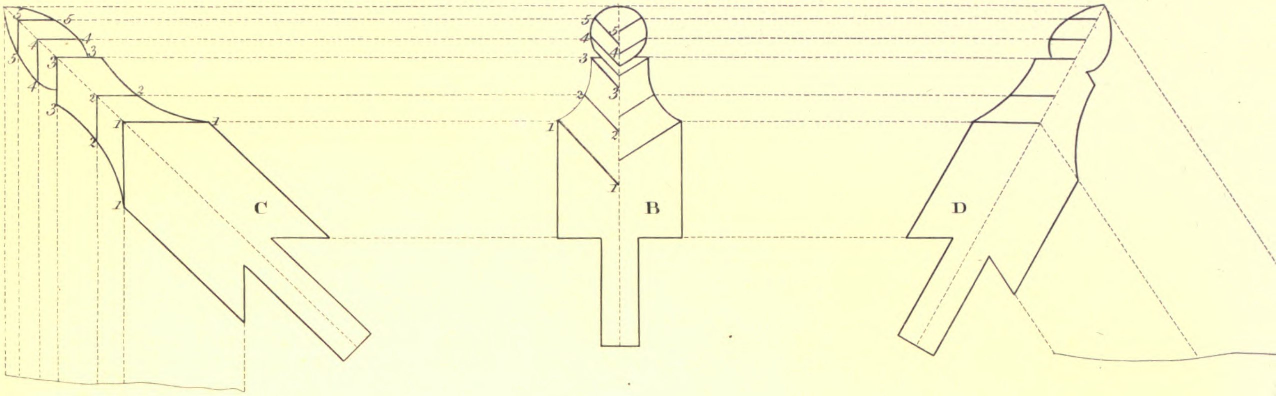


Fig. 2.

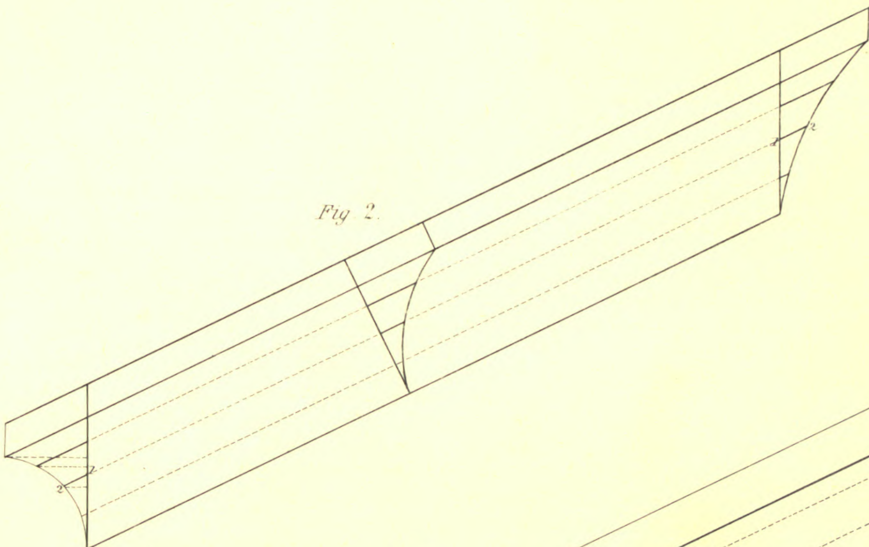
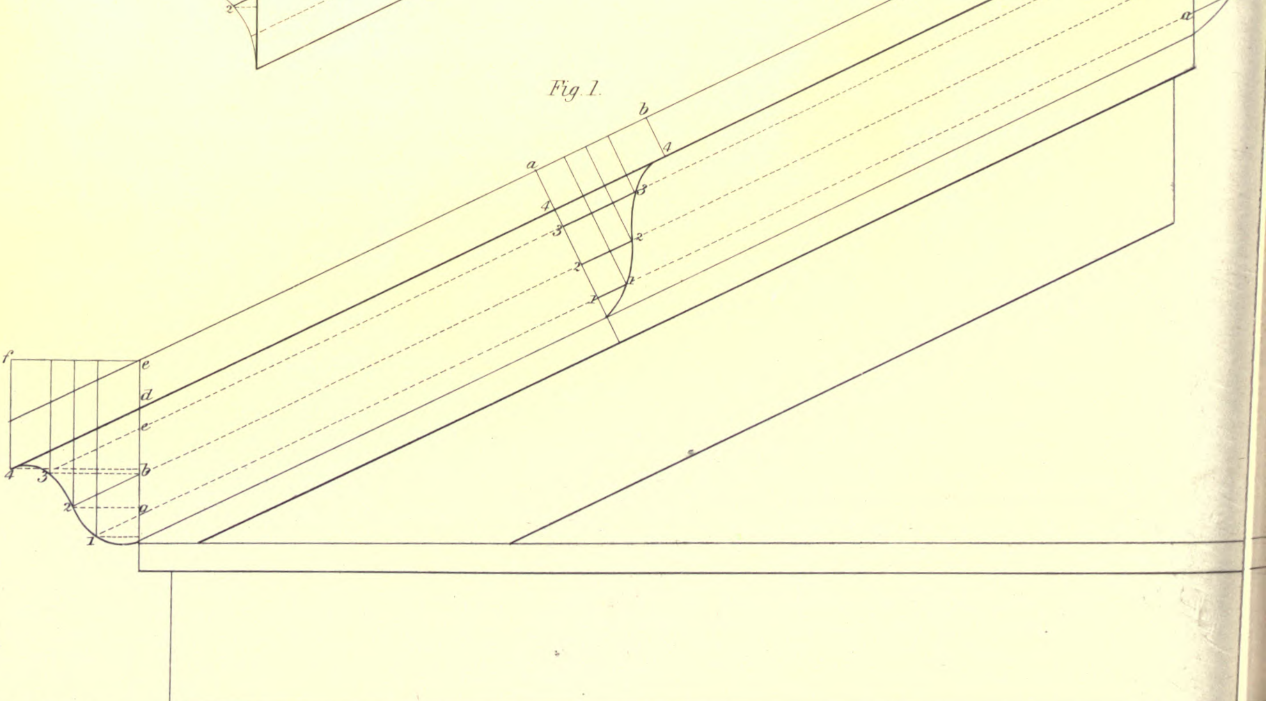


Fig. 1.



RAILING, in *Rural Economy*, a sort of fence constructed with posts and rails. It is often made use of in protecting young hedge-fences from the cropping of cattle or other animals. Any sort of coarse timber does very well for this last purpose, such as outside planks, and the boughs or loppings of timber plantations.

RAILWAY, or TRAM-ROAD, or DRAM-ROAD, or WAGGON-WAY, a track constructed of iron, stone, timber, or other material, upon the surface of an inclined plane, or other situation, for the purpose of diminishing friction, and thus serving for the easy conveyance of heavy loads of any kind of articles.

Railways were at first solely employed for transporting coals to a moderate distance from the pits, to the places where they could be shipped, and were universally made of wood. By degrees they were, however, carried to a farther extent; when the scarcity of wood, and the expense of their repairs, suggested the idea of employing iron for the purpose of improving these roads. At first, flat rods of bar-iron were nailed upon the original wooden rails, or, as they were technically called, *sleepers;* and this, though an expensive process, was found to be a great improvement.

They were next cast in the form of long narrow plates, with a vertical flanche on one side, so that the section presented the form of the letter L, and thus the wheels of the carriages were retained in the direction of the rails; the flanches on the wheels being dispensed with.

But the longitudinal timbers on which these plate-rails rested, being liable to rot and give way, were at last entirely discarded, and the rails were cast of sufficient depth to sustain the weight passing over them, and of length sufficient to reach from one cross sleeper to the next, to which they were secured by means of chairs; these rails were reduced in width, and the flanche transferred back again to the wheels.

About 1815, malleable bars were introduced, those of cast-iron having been found objectionable on account of their frangibility. The former were simply bars of iron, three or four feet long, and from one to two inches square, but they were found to destroy the wheels, on account of their narrowness: and a return to cast-iron appeared inevitable, until a new method of constructing the malleable rails was patented in 1820 by Mr. Birkinshaw. This improvement consisted in passing the bars, when red-hot, between rollers, which gave the required form to the rails, and by this means the bars were rolled in lengths of from 12 to 15 feet, and of any section required, the depth and breadth being increased in proportion to the distance from the bearings.

The rails are placed in chairs of cast-iron, which are spiked down to transverse timbers or sleepers, as they are termed, laid from 2 feet 6 inches to 3 feet apart. These sleepers are commonly of larch, about 9 feet in length, 9 inches in width, and 6 inches deep, and at either end at the distance apart of 4 feet 8½ inches, are placed the chairs or saddles to receive the ends of the rails, which run parallel to each other; they are generally about 5 inches deep at the centre, 2½ inches wide at the top and bottom, and ⅝ inch thick in the middle vertical rib.

The rails of the broad guage are placed 7 feet apart, and are spiked down to longitudinal timbers, which are kept equidistant by transverse sleepers.

The permanent way consists of a level roadway, properly ballasted with gravel or other suitable ballasting.

RAIN-WATER PIPE, a pipe fixed on the exterior of houses and other buildings, for the purpose of conveying rain-water from the roofs, &c., into a drain.

RAISER, a board set on edge under the foreside of a step, a stair, &c. *See* STAIRCASING.

RAISING-PIECES, or REASON-PIECES, in architecture, pieces that lie under the beams, and over the posts or puncheons.

The term is chiefly employed in buildings constructed of timber frame, where the interstices are filled with clay, or brickwork, called *panels.* In brick or stone buildings, the board or plank placed on the top of the wall is denominated the *wall-plate;* but, in some parts of the country, the wall-plates are denominated *platbands.*

RAKING, a term applied to such members of a building as slope or lie inclined to the horizon.

RAKING-MOULDING, in joinery, a moulding whose arrises are inclined to the horizon in any given angle.

If the raking-moulding has to meet with a horizontal moulding, at a given angle, on the plan; and if the section of the horizontal moulding be given; the following method will show how to find the section of the raking-moulding:

Figure 1.—Let the given moulding be a cima-recta; take any number of points in the curve, and through these points draw straight lines parallel to the rake; then the moulding shown in the middle of the rake, being pricked off from the level lines at the bottom, will give the section to work the raking-moulding.

If the moulding is required to be returned, as shown at the upper part, the inclined lines are continued; the proper projections are set at the top of the moulding, and vertical lines are drawn through the points of section to meet the respective inclined lines; then a curve, being drawn through the points of intersection, will give the horizontal return moulding at the top.

Figure 2.—An inclined cavetto, showing the section of the raking moulding, and also the section of the return level-moulding of the top.

Angle-bars, for shop-fronts, are also ranked among the class of raking mouldings. In *Figure* 3, let B be the common bar, of the same thickness with the angle-bar: take the raking projection, 1, 1, in C, and set the foot of the compasses in 1 at B, and cross the middle of the bar at the other 1; draw the lines 2, 2, 3, 3, &c. parallel to 1, 1, then prick the section at 1 C, from the ordinates so drawn at B, and thus the section of the angle-bar is obtained.

RAMMED-EARTH BUILDINGS, such as are raised with some sort of earthy material, hardened by being rammed into moulds or cases. This mode of building with earthy materials is supposed by some to have been known at a very early period, and has been long practised with success in the southern parts of France, especially about Lyons, though but little understood in any other part of Europe until comparatively lately. *See* PISE.

RAMP, in hand-railing, a concavity on the upper side, formed over risers, or over a half or quarter space, by a sudden rise of the steps above, which frequently occasions a knee above the ramp.

RAMPANT ARCH, one whose abutments spring from an inclined plane.

RAMPART, or RAMPIER, (from the Spanish, *amparo, defence*, or *covering,*) in fortification, a massy bank, or elevation of earth, about the body of a place, to cover it from the direct fire of the enemy, and of sufficient thickness to resist the efforts of the cannon for many days; and formed into bastions, curtains, &c.

Upon the rampart the soldiers continually keep guard, and pieces of artillery are planted there for the defence of the place. Hence, to shelter the guard from the enemy's shot, the outside of the rampart is built higher than the inside, *i. e.*

a parapet is raised upon it with a platform. Hence, also, earth not being capable to be raised perpendicularly, like stone, the rampart is built with a talus, or slope, both on the inner and outer side.

The rampart is sometimes lined, *i. e.* fortified with a stone wall withinside, otherwise it has a berme.

It is encompassed also with a moat, or ditch, out of which the earth that forms the rampart is dug.

The height of the rampart should not exceed three fathoms, this being sufficient to cover the houses from the battery of the cannon: neither ought its thickness to be above ten or twelve, unless more earth be taken out of the ditch than can be otherwise bestowed.

The ramparts of half-moons are the better for being low, that the small fire of the defendants may the better reach the bottom of the ditch; but yet they must be so high as not to be commanded by the covert-way.

Rampart, in civil architecture, is also used for the space left void between the wall of a city and the nearest houses. This is what the Romans call *pomœrium*, in which it was forbid to build, and where they planted rows of trees, for the people to walk and amuse themselves under.

RAMPS, in fortification, gentle slopes made for the cannon to be drawn up and down by, and also for the easy communication of the troops posted in a battery raised above the level of the ground. The rise of these slopes is about two inches, on twelve of base; or the length of the base is six times the height, and this is general for the draught of carriages; but footways need not be of so gentle a slope, as a rise of one foot in three may answer the purpose; or, instead of ramps, stairs may be, and commonly are, used for the passage of the foot. The breadth of a carriage ramp is usually about nine or ten feet; but those for foot-passage only need not be above three or four feet wide. Ramps may either rise on the side of an elevated work, or against a salient angle of that work, or on each side of an entering angle.

RANGE, or Ranging, (from the French, *ranger*, to place in ranks,) a term applied to the edges of a number of bodies, placed in a given surface: thus, if the edges of the ribs of a groin were placed in a cylindric surface, they would be said to *range*. It is also used in speaking of the side of a work that runs straight, without breaking into angles.

RASP, a rough file.

RATE, in architecture, the particular class of a building, under which it is arranged, as to the quantity of ground on which it stands, its height, or destination.

This classification is only used in the neighbourhood of London, in order to modify the construction according to the regulations of the building act. *See* House.

RAVELIN, in fortification, was anciently a flat bastion, placed in the middle of a curtain; but now it is a detached work, composed only of two faces, which make a salient angle, sometimes without, and sometimes with flanks; and raised before the curtain on the counterscarp of the place; serving to cover it and the adjoining flanks from the direct fire of an enemy.

A ravelin is a triangular work, resembling the point of a bastion with the flanks cut off. Its use before a curtain is, to cover the opposite flanks of the two next bastions. It is used also to cover a bridge, or a gate, and is always placed without the moat.

What the engineers call a *ravelin*, the soldiers generally call a *demi-lane*, or *half moon*.

There are also *double* ravelins, which serve to defend each other. They are said to be double when they are joined by a curtain.

READING-DESK, a raised desk in churches, from which the lessons and other parts of the services are read. It is more correctly termed Lettern, or Lectern, and consists usually of one or two sloping-desks of sufficient size to sustain the books raised upon a pedestal or standard; they are mostly made of wood, but frequently of brass or other metal, and is enriched with various degrees of ornamentation. In many cases, the stem or pedestal was surmounted by an eagle with outspread wings, on which the books rested.

REBATE, or Rabbet, (from the French, *rabbattre*, to abate,) a deep groove, or channel, cut longitudinally in a piece of timber, to receive the edge of a plank, or the ends of a number of planks, which are to be securely fastened into it. The depth of this channel is equal to the thickness of the plank, so that, when the end of the latter is let into the rebate, it will be level with the outside of the piece.

RECESS, (from the Latin, *recessus*,) a cavity in a wall, left either for ornament or use, or for both purposes united; for use, when it is to receive some piece of furniture, as a sideboard, or to add to the size of room; and for ornament when made in the form of a niche, to give beauty and variety to the building. When the construction of the edifice requires some of its walls to be of very great thickness, niches are frequently taken out of the wall, to lessen its thickness and give a greater quantity of floor-room; so that utility and ornament are united, and the expense of materials is saved.

RECIPIANGLE, or Recipient-Angle, a mathematical instrument, serving to take the quantity of angles; used especially in the drawing of plans of fortifications.

The recipiangle was formerly a popular instrument among the French, but little known among us; it is usually very simple, in form of a square, or rather a *bevel*; consisting of two arms, or branches, riveted together, but moveable, like a sector, on the centre or rivet.

To take an angle with it, the centre of a protractor is laid to the joint, and the degrees cut by the edge show the quantity of the angle; otherwise the angle made by the two rulers is drawn on paper, and then measured with a protractor.

Sometimes there is a circle divided into degrees added over the centre or rivet, with an index to show the degrees without a protractor. At other times the under branch is divided.

To measure a salient angle with any of the recipiangles, apply the insides to the lines that form the angle; for a re-entering angle, apply the outsides, &c.

RECTANGLE, (from the Latin, *rectangulus*,) called also *oblong*, and *long square*, a quadrilateral rectangular figure, whose opposite sides are equal. Or, a rectangle is a parallelogram, whose angles are right.

RECTANGULAR, a term applied to figures and solids which have one or more angles right. Such are squares, rectangles, and rectangled triangles, among plain figures; cubes, parallelopipeds, &c. among solids.

Solids are also said to be rectangular with respect to their situation: thus, if a cone, cylinder, &c. be perpendicular to the plane of the horizon, it is called a rectangular or right cone, cylinder, &c.

The ancients used the phrase *rectangular section of a cone*, to denote a parabola; that conic section, before Apollonius, being only considered in a cone, whose section by the axis would be a triangle, right-angled at the vertex.

Hence it was that Archimedes entitled his book of the quadrature of the parabola, by the name of *Rectanguli Coni Sectio*.

RECTANGULAR, or RIGHT-ANGLED TRIANGLE, a triangle, one of whose angles is right, or equal to 90 degrees. *See* TRIANGLE.

RECTIFICATION, in geometry, the finding of a right line equal to a proposed curve, or simply finding the length of a curve-line ; a problem which, even in the present advanced state of analysis, is attended, in many cases, with considerable difficulty ; and was, *in all*, totally beyond the reach of the ancient geometers, who were not able to assign the length of any curve-line whatever ; though they could, in a few instances, determine the area of a curvilinear space. The first rectification of a curve-line was effected by Mr. H. Neal, as we are informed by Dr. Wallis, at the conclusion of his *Treatise on the Cissoid.* This curve was the semi-cubical parabola, and Neal's rectification of it was published in July or August, 1657 ; and in 1659, the same was done by Van Haureat, in Holland.

It is, however, to the doctrine of fluxions and differential calculus that we owe the complete rectification of curve-lines, infinite terms, when they admit of it ; and in others, by means of infinite series, circular arcs, logarithms, &c.

RECTILINEAR, or RIGHT-LINED, a term applied to figures whose perimeter consists of right lines.

RECTORY, the official residence of a parish priest, usually in close proximity to the church.

REDANS (French) projections constructed at intervals in walls built on sloping or uneven ground, for the purpose of preserving the same height through its whole length.

REDOUBT, or REDOUBTE (from the Latin *reductus*) in fortification, a small square fort, without any defence but in front, used in trenches, lines of circumvallation, contravallation and approach ; as also for the lodging of corps de garde, and to defend passages. Redoubts are usually figures of three, four, five, or six sides, encompassed with a ditch, and a bank of earth, which consists of two parts called *rampart* and *parapet.* In marshy grounds, redoubts are often made of stone-work for the security of the neighbourhood ; their face consists of from ten to fifteen fathoms ; the ditch round them from eight to nine feet broad and deep : and their parapets, which are cut into embrasures and merlons, have the same thickness.

The inner sides of square redoubts are usually between the limits of twelve and thirty-two yards ; and when they are to be defended by musketry, the number of men necessary to the defence may be thus determined ; half the side squared, gives the number of troops ; and twice the square root of a given number of men, shows the length in yards of the side of a square redoubt proper to contain them.

REDUCTION of a Figure, Design, or Draught, the making a copy of it, either larger or smaller than the original, still preserving the form and proportion.

The great use of the proportional compasses is in the reduction of figures, &c., whence they are also called *compasses of reduction.*

REFECTORY, a dining-hall or refreshment room. The term is especially applied to the dining-halls of monastic or other religious establishments.

REFLEX, or REFLECT, in painting, is understood of those places in a picture which are supposed to be illuminated by a light reflected from some other body represented in the same piece.

Or, reflexes may be defined those places which, beside the general light that illumines the whole piece, receive some particular light from their situation with respect to some more illuminated polished body, that reflects part of the rays it receives upon them.

Reflexes are scarcely sensible, except in the shadowed parts. The management of the reflexes requires great accuracy and skill. All reflected light is supposed to carry with it part of the colour of the body which reflects it : so that those places which receive this light must have their colour mixed or tinged with that colour. But the same place may receive reflexes from different objects, differently coloured, and those, again, receive reflexes from others. The painter, therefore, must have a view to every circumstance of the colour, light, and position of each figure ; he must consider what effect each has on others, and pursue nature through all the variety of mixtures.

REGLET, or RIGLET, (from the French *reglette*), a flat narrow moulding, used chiefly in compartments and panels, to separate the parts, or members, from each other, and to form knots, frets, and other ornaments. The reglet, according to Daviler, differs from the *fillet* and *listel* in that it projects equally, like a ruler.

REGRATING, among masons, &c., taking off the outer surface of an old hewn stone, with the hammer and ripe, in order to whiten and make it look fresh again.

REGULA, a band below the tœnia in the Doric architrave.

REGULAR FIGURE, a figure that is both equilateral and equiangular; *i. e.*, whose sides, and consequently its angles, are all equal.

The equilateral triangle and square are regular figures. All other regular figures, consisting of more than four sides, are called regular *polygons.* Every regular figure may be inscribed in a circle.

REGULAR BODY, called also PLATONIC BODY, a solid terminated on all sides by regular and equal planes, and whose solid angles are all equal.

The regular bodies are five in number, viz., the *cube*, which consists of six equal squares ; the *tetrahedron*, or regular triangular pyramid, having four equal triangular faces ; the *octahedron*, having eight ; the *dodecahedron*, having twelve pentagonal faces ; and the *icosahedron*, having twenty triangular faces.

REGULAR ARCHITECTURE, such as has all its parts disposed in regular symmetry, or that has its parts disposed in counter-parts.

REINS OF A VAULT, *see* VAULT.

REJOINTING, the filling up of the joints of stones in old buildings, &c., when worn hollow by the course of time, or by weather. Rejointing is to be performed with the best mortar, as that of lime and cement ; sometimes also with plaster, as in the joints of vaults, &c.

RELATION, in architecture, between the several parts and members of an edifice, constitutes what is otherwise called *symmetry*.

RELIEVO, RELIEF, or EMBOSSMENT, a term applied to a figure which projects from the ground, or plane, on which it is formed, whether it be cut with the chisel, moulded, or cast. There are three kinds of relievo, viz. *alto*, *basso*, and *demi-relievo.*

Alto-relievo, *haut relief*, or *high relievo*, is when the figure is formed after nature, and projects as much as the life.

Basso-relievo, *bas relief*, or *low relievo*, is when the work is raised but a little from its ground, as in medals, and the frontispieces of buildings, particularly the histories, festoons, foliages, and other ornaments, in friezes. *See* BASSO-RELIEVO.

Demi-relievo is when one half of the figure rises from the plane, *i. e.*, when the body of a figure seems cut in two, and one-half is clapped on a ground. When, in a basso-relievo, some parts stand clear out, detached from the rest, the work is called a *demi-bosse.*

Relievo also denotes the sally, or projecture of any architectural ornament.

This, Daviler observes, is always to be proportioned to the magnitude of the building it adorns, and the distance at which it is to be viewed. If the work be insulate, and terminated on all sides, it is called a *figure in relievo*, or a *round embossment*. Such are statues, acroters, &c.

Relievo, in painting, denotes the degree of force, or boldness, by which a figure seems, at a due distance, to stand out from the ground of the painting, as if really embossed.

The relievo depends much on the depth of the shadow, and the strength of the light; or on the light of the different colours bordering on each other; and particularly on the difference of the colour of the figure from that of the ground.

When the light is well chosen, to make the nearest parts of figures advance; and well diffused on the masses, still diminishing insensibly, and terminating in a large spacious shadow, brought off insensibly; the relievo is said to be *bold*, and the claire obscure *well understood*.

RENAISSANCE, that style which arose in the arts in general, and also in architecture, by the attempt made to revive classic taste upon the decline of the Gothic system. This revival was commenced in Italy in the latter part of the fourteenth century, by Brunelleschi, and still further developed by his successors, amongst whom may be mentioned Alberti, Bramante, Michael Angelo Buonarotti, Palladio, &c. The Gothic style had never been fully developed, nor obtained a secure footing, in Italy; and hence the classic styles were revived without difficulty, and with greater success than in those countries where the Gothic had been fully established; and although even in Italy the latter style does not seem to have disappeared immediately—for we see in many buildings an admixture of the two—still the struggle for pre-eminence was not so great, or of so long continuance, as in other countries. In Italy, the classic principles were at once introduced in the constructive and essential parts of the building, and the Gothic only retained in matters of detail; whereas in other places the contrary practice occurred—that is to say, the change took place gradually by the introduction or substitution of classic details upon buildings essentially Gothic, until at last the classic predominated both in essentials and accessories. *See* Italian and Tudor Architecture.

RELIQUARY, a casket of wood, metal, or stone, frequently enriched with precious stones, &c., for the purpose of preserving reliques.

RENDERING, in building, *see* Pargeting and Plastering.

REPAIRING of large walls, doors, ceilings, coverings, &c., belongs to the proprietor, or landlord: the tenant is only charged with small repairs, or glass windows, locks, &c., by the French called *locative* repairs.

REREDOS, the ornamental screen, or other decorative work, of whatever kind, employed to enrich the wall at the back of the altar.

RESERVOIR (French), a large pond or pen of water, artificially made, in order to retain and collect it for the use of canals, rivers, mills, &c.

In a building, the reservoir is a large bason, usually of wood, lined with lead, where water is kept to supply the occasions of the house. Large reservoirs are frequently constructed of cast-iron.

The reservoir is sometimes, also, a large bason of strong masonry, clayed or paved at the bottom, where the water is reserved to feed *jets d'eau*, or spouting fountains.

RESISTANCE, or Resisting Force, any power that acts in opposition to another, so as to destroy or diminish its effect.

Of resistance there are several kinds, arising from the various natures and properties of the resisting bodies, and governed by various laws: as the resistance of solids, the resistance of fluids, the resistance of the air, &c.

Resistance of Solids, the force with which the quiescent parts of solid bodies oppose the motion of others contiguous to them.

Of this there are two kinds. The first, where the resisting and resisted parts, *i. e.* the moving and quiescent bodies, are only contiguous, and do not cohere; i. e. where they constitute separate bodies or masses.

This is what M. Leibnitz calls *resistance of the surface*; but which is now more commonly denominated *friction*.

The second case of resistance is where the resisting and resisted parts are not only contiguous, but cohere; i. e. are parts of the same continued body or mass.

To which we may also add, the resistance which takes place between surfaces of solids, when completely in contact, though not forming one and the same body; or the resistance they offer to separation.

Resistance of the Fibres of Solid Bodies, *Theory of the.* To form an idea of this resistance or renitency of the parts, suppose a cylindrical body suspended vertically by one end. Here all its parts, being heavy, tend downwards, and endeavour to separate the two contiguous planes, where the body is the weakest; but all the parts resist this separation by the force with which they cohere, or are bound together. Here, then, are two opposite powers; viz., the weight of the cylinder, which tends to break it; and the force of cohesion of the parts, which resists the fracture. If the base of the cylinder be increased, without increasing its length, it is evident the resistance will be increased in the same ratio as the base; but the weight also increases in the same ratio: whence it is evident, that all cylinders of the same matter and length, whatever their bases may be, have an equal resistance, when vertically suspended.

But if the length of the cylinder be increased, without increasing its base, its weight is increased, while the resistance, or strength, remains the same: consequently, it is weakened by its additional length, and has a greater tendency to break.

Hence, to find the greatest length a cylinder of any matter may have to break with its own weight, it is only necessary to know what weight is just sufficient to break another cylinder of the same base and matter: for the length of the required cylinder must be such, that its weight may be equal to the weight of the first cylinder, together with the additional weight that was employed in producing the separation.

If one end of the cylinder were fixed horizontally into a wall, and the rest suspended thence, its weight and resistance would then act in a different manner; and if it be broke by the action of its weight, the rupture would be at the end fixed into the wall. A circle, or plane, contiguous to the wall, and parallel to the base, and consequently vertical, would be detached from the contiguous circle within the plane of the wall, and would descend. All the motion is performed on the lowest extremity of the diameter, which remains immovable, while the upper extremity describes a quadrant of a circle, and till the circle, which before was vertical, become horizontal, *i. e.* till the cylinder be entirely broken.

In the fracture of the cylinder, it is visible, two forces have acted, and the one has overcome the other: the weight of the cylinder, which arose from its whole mass, has overcome the resistance which arose from the largeness of the base; and, as the centres of gravity are points in which all the forces, arising from the weight of the several parts of the same bodies, are conceived to be united, one may conceive the weight of the whole cylinder applied in the centre of gravity of its mass, *i. e.* in a point in the middle of its axis: and the resistance of the cylinder applied in the centre of gravity of its base *i. e.* in the centre of the base; it being the base which resists the fracture.

When the cylinder breaks by its own weight, all the motion is on an immovable extremity of a diameter of the base. This extremity, therefore, is the fixed point of a lever, whose two arms are the radius of the base, and half the axis; and, of consequence, the two opposite forces do not only act of themselves, and by their absolute force, but also by the relative force they derive from their distance with regard to the fixed point of the lever.

Hence it evidently follows, that a cylinder, *e. gr.* of copper, which, vertically suspended, will not break by its own weight, if less than four hundred and eighty fathoms long, will break with a less length in an horizontal situation; because the length, in this latter case, contributes two ways to the fracture; both as it makes it of such a weight, and as it is an arm of a lever to which the weight is applied. Hence, also, the smaller the base is, the less length or weight will suffice to break it; both because the resistance is really less, and because it acts by a less arm of a lever.

If two cylinders of the same matter, having their bases and lengths in the same proportion, be suspended horizontally; it is evident, that the greater has more weight than the lesser, both on account of its length, and of its base. But it has less resistance on account of its length, considered as a longer arm of a lever, and has only more resistance on account of its base; therefore it exceeds the lesser in its bulk and weight more than in resistance, and, consequently, it must break more easily.

Hence we see why, upon making models and machines in small, people are apt to be mistaken as to the resistance and strength of certain horizontal pieces, when they come to execute their designs in large, by observing the same proportion as in the small. Galileo's doctrine of resistance, therefore, is no idle speculation, but becomes applicable in architecture, and other arts.

The weight required to break a body placed horizontally, being always less than that required to break it in a vertical situation; and this weight being greater or less, according to the ratio of the two arms of the lever, the whole theory is always reducible to this: viz. to find what part of the absolute weight the relative weight is to be, supposing the figure of the body known; which indeed is necessary, because it is the figure that determines the two centres of gravity, or the two arms of the lever. For if the body, *e. gr.* were a cone, its centre of gravity would not be in the middle of its axis, as in the cylinder; and, if it were a semi-parabolical solid, neither would its centre of gravity be in the middle of its length or axis, nor the centre of gravity of its base in the middle of the axis of its base. But still, wheresoever these centres fall in the several figures, the two arms of the lever are estimated accordingly.

It may be here observed, that if the base, by which the body is fastened into the wall, be not circular, but, *e. gr.* parabolical, and the vertex of the parabola be at the top, the motion of the fracture will not be on an immovable point, but on a whole immovable line; which may be called the *axis of equilibrium;* and it is with regard to this, that the distances of the centres of gravity are to be determined.

Now, a body horizontally suspended, being supposed such that the smallest addition of weight would break it, there is an equilibrium between its positive and relative weight; and, of consequence, those two opposite powers are to each other reciprocally as the arms of the lever to which they are applied. On the other hand, the resistance of a body is always equal to the greatest weight which it will sustain in a vertical situation without breaking, *i. e.* is equal to its absolute weight. Therefore, substituting the absolute weight for the resistance, it appears that the absolute weight of a body, suspended horizontally, is to its relative weight as the distance of the centre of gravity from the axis of equilibrium is to the distance of the centre of gravity of its base from the same axis.

The discovery of this important truth, at least an equivalent to it, and to which this is reducible, we owe to Galileo. From this fundamental proposition are easily deduced several consequences; as, for instance, that if the distance of the centre of gravity of the base from the axis of equilibrium be half the distance of the centre of gravity of the body, the relative weight will only be half the absolute weight; and that a cylinder of copper, horizontally suspended, whose length is double the diameter, will break, provided it weigh half what a cylinder of the same base, 4801 fathoms long, weighs.

On this theory of resistance, which we owe to Galileo, M. Mariotte made a very ingenious remark, which gave birth to a new system. Galileo supposes, that where the body breaks, all the fibres break at once; so that the body always resists with its whole absolute force, or with the whole force that all its fibres have in the place where it is to be broken. But M. Mariotte, finding that all bodies, even glass itself, bend before they break, shows that fibres are to be considered as so many little bent springs, which never exert their whole force till stretched to a certain point, and never break till entirely unbent. Hence, those nearest the axis of equilibrium, which is an immovable line, are stretched less than those farther off; and, of consequence, employ a less part of their force.

This consideration only takes place in the horizontal situation of the body; in the vertical, the fibres of the base all break at once; so that the absolute weight of the body must exceed the united resistance of all its fibres: a greater weight is therefore required here than in the horizontal situation; that is, a greater weight is required to overcome their united resistance than to overcome their several resistances one after another. The difference between the two situations arises hence, that in the horizontal there is an immoveable point, or line, as a centre of motion, which is not in the vertical.

Varignon has improved on the system of M. Mariotte, and shown, that to Galileo's system it adds the consideration of the centre of percussion. The comparison of the centres of gravity with the centres of percussion afford a fine view, and set the whole doctrine in a most agreeable light.

In each system, the base, by which the body breaks, moves on the axis of equilibrium, which is an immoveable line in the same base; but in the second, the fibres of this base are continually stretching more and more, and that in the same ratio as they recede farther and farther from the axis of equilibrium; and of consequence, are still exerting a greater and greater part of their whole force.

These unequal extensions, like all other forces, must have some common centre where they all meet, and, with regard to which, they make equal efforts on each side; and, as they are precisely in the same proportion as the velocities which the several points of a rod moved circularly would have to each other, the centre of extension of the base, by which the body breaks or tends to break, must be the same with the centre of percussion. Galileo's hypothesis, according to which the fibres are supposed to stretch equally, and break all at once, corresponds to the case of a rod moving parallel to itself, where the centre of extension or percussion does not appear, as being confounded with the centre of gravity.

The base of fraction being a surface, whose particular nature determines its centre of percussion, it is necessary that this should be first known, to find on what point of the vertical axis of that base it is placed, and how far it is from the axis of equilibrium. Indeed, we know in the general, that it always acts with so much the more advantage as it is farther from it; because it acts by a longer arm of a lever; and, of consequence, it is the unequal consistency of the fibres in M. Mariotte's hypothesis which produces the centre of percussion; but this unequal resistance is greater or less, according as the centre of percussion is placed more or less high on the vertical axis of the base, in the different surfaces of the base of the fracture.

To express this unequal resistance, accompanied with all the variation it is capable of, regard must be had to the ratio between the distance of the centre of percussion from the axis of equilibrium, and the length of the vertical axis of the base; in which ratio, the first term, or the numerator, is always less than the second, or the denominator; so that the ratio is always a fraction less than unity; and the unequal resistance of the fibres in M. Mariotte's hypothesis is so much the greater, or, which amounts to the same, approaches so much nearer to the equal resistance in Galileo's hypothesis, as the two terms of the ratio are nearer to an equality.

Hence it follows, that the resistance of bodies in M. Mariotte's system is to that in Galileo's, as the least of the terms in the ratio is to the greatest. Hence, also, the resistance being less than what Galileo imagined, the relative weight must also be less; so that the proportion already mentioned, between the absolute and relative weight, cannot subsist in the new system, without an augmentation of the relative weight, or a diminution of the absolute weight; which diminution is had by multiplying the weight by the ratio, which is always less than unity. This done, we find that the absolute weight, multiplied by the ratio, is to the relative weight as the distance of the centre of gravity of the body from the axis of equilibrium, is to the distance of the centre of gravity of the base of the fracture from the same axis; which is precisely the same thing with the general formula given by M. Varignon for the system of M. Mariotte. In effect, after conceiving the relative weight of a body, and its resistance equal to its absolute weight, as two contrary powers applied to the two arms of a lever, in the hypothesis of Galileo, there needs nothing to convert it into that of M. Mariotte, but to imagine that the resistance, or the absolute weight, is become less, everything else remaining the same. One of the most curious, and perhaps the most useful questions in this research, is to find what figure a body must have, that its resistance may be equal in all its parts, whether it be loaded with an additional weight, or as only sustaining its own weight.

To this end, it is necessary that some part of it should be conceived to be cut off by a plane parallel to the fracture, so that the momentum of the part retrenched be to its resistance in the same ratio as the momentum of the whole is to its resistance. These four powers act by arms of levers peculiar to themselves, and are proportional in the whole, and in each part, of a solid of equal resistance. From this proportion, Varignon deduces two solids, which shall resist equally in all their parts, or be no more liable to break in one part than in another. Galileo had previously found one of these, which is that in which the sides are parabolical: the other, found by Varignon, is in the form of a trumpet, which is to be fixed into the wall by its greater end; so that its magnitude, or weight, is always diminished in proportion as its length, or the arm of the lever by which it acts, is increased. It is remarkable, that, however different the two systems may be, the solids of equal resistance are the same in both.

The following is a general synopsis of the most important results which have been drawn by different writers on this subject, both practical and theoretical.

1. The resistance of a beam or bar, to a fracture, by a force acting laterally, is as the solid made by a section of the beam in the place where the force is applied, into the distance of its centre of gravity from the point or line where the breach will end.

2. In square beams, the lateral strengths are as the cubes of their breadths or depths.

3. In cylindric beams the resistances or strengths are as the cubes of the diameters.

4. In rectangular beams, the lateral strengths are conjointly as the breadths and squares of the depths.

5. The lateral resistance of any beams, whose sections are similar figures and alike placed, are as the cubes of the like dimensions of those figures.

6. The lateral strength of a beam, with its narrower face upwards, is to its strength with the broader face upwards, as the breadth of the broader face to the breadth of the narrower.

7. The lateral strengths of prismatic beams of the same materials, are as the areas of the sections, and the distance of their centre of gravity, directly, and as their lengths and weights reciprocally.

8. When the beam is fixed at both ends, the same property has place, except that, in this case, we must consider the beam as only half the length of the former.

9. Cylinders and square prisms have their lateral strengths proportional to the cubes of their diameters, or depths, directly, and their lengths and weights inversely.

10. Similar prisms and cylinders have their strength inversely proportional to their linear dimensions.

The following results are wholly drawn from experiments on different substances, by Emerson and other writers, by means of which the propositions stated in the preceding part of this article may be submitted to computations.

The relative Resistances or Strengths of Wood and other Bodies.

	Proportional Resistance.
Box, yew, plum-tree, oak	11
Elm, ash	8½
Walnut, thorn	7½
Red fir, holly, elder, plane crab-tree, apple-tree	7
Beech, cherry-tree, hazel	6⅝
Alder, asp, birch, white fir, willow	6
Iron	107
Brass	50
Bone	22
Lead	6½
Fine free-stone	1

A cylindric rod of good clean fir, of an inch circumference, drawn in length, will bear at its extremity 400lb.; and a spear of fir, of two inches diameter, will bear about seven ton weight. A rod of good iron, of an inch circumference, will bear nearly three ton weight. A good hempen rope of an inch circumference, will bear 1,000lb. at its extremity. Hence Emerson concludes, that if a rod of fir, or a rope, or a rod of iron, of d inches diameter, were to lift a quarter of the extreme weight that they would support, then

The fir would bear . . $8\frac{4}{5} d^2$ hundred weight.
The rope . . . . $22\ d^2$ ditto.
The iron . . . . $6\frac{3}{4} d^2$ tons.

To these results we may add, from the experiments and investigations of Professor Robison, that a prism of white marble, an inch square and a foot long, bears about 500 lb. And that, from the various authors he has collected, the cohesive force of a square inch of gold, when cast, is about 20,000 lb; of silver, 40,000 lb.; cast-iron from 40,000 to 60,000 lb.; wrought iron from 60,000 to 90,000; soft steel, 12,000 lb.; razor steel, 15,000 lb.; oak and beech, in the direction of their fibres, from 8,000 to 17,000 lb.; willow, 12,000; cedar, 5,000 lb.; fir, 8,000 lb.; ivory, 16,000 lb.; bone, 5,000 lb; rope, 20,000 lb. And a cylinder, an inch in diameter, loaded to one-fourth, will carry, if of iron, 135 cwt.; of rope, 22 cwt.; oak, 14 cwt.; and fir, 9 cwt.

The resistance of some metals is doubled, or tripled, by the operation of forging and wire-drawing; and the cohesive, as well as the repulsive force of wood, is often increased by moderate compression. Oak will *suspend* much more than fir; but fir will *support* twice as much as oak; which difference is supposed to arise from the curvature of the fibres of oak; yet oak has been known to support, with safety, more than two tons for every square inch. Stone will support from 250 to 850,000 pounds, on a foot square; brick, 300 lb.; and sometimes they are practically made to support one-sixth as much. Stone is said to be capable of bearing a much greater weight in that position in which it is found in the quarry, than in any other position.

RESOLUTION OF FORCES, the division of a force into two separate forces, acting in different directions, which shall have an equivalent effect to the original force. *See* FORCES.

RESPOND, a half pillar or pier attached to or abutting against a wall.

RESSAULT, (French) the effect of a body, which either projects, or falls back, *i. e.* stands either more out or in than another; so as to be out of the line, or range, with it.

The term is little used in English; though the want of a word of equal import pleads for its naturalization.

RETAINING WALL, a wall erected for the purpose of retaining earth, or other loose or shifting material, and preventing slips and similar accidents; such are the wing-walls of bridges, &c.

RETICULATED, a term applied to any plane surface, formed into squares by chequered lines. The use of reticulation is to make a drawing similar to a given original, in the easiest manner: for this purpose, the original is divided into squares, and the size of the drawing, required to be copied, is divided into the same number of squares; then tracing the lines through all the squares as they appear in the respective squares of the original will give the outline of the design.

RETICULATED WORK, a kind of masonry or brick-work, formed of small square stones or bricks, set lozenge-wise, and presenting the appearance of net-work on the face.

RETRENCHMENT, (from the French, *retranchment*, formed of *re*, and *trancher*, to cut) in architecture, carpentry, &c., is used not only for what is cut off from a piece when too large, in order to better proportioning it, or some other convenience, but also for the projectures taken out of streets, public ways, &c., to render them more even, and in a line.

RETRENCHMENT, in war, denotes any kind of work cast up to strengthen or defend a post against the enemy. Such are ditches, with parapets, gabions, facines, &c. for a covering, &c.

RETRENCHMENT, (in fortification) is more particularly used for a simple ritirade made on a hornwork, or bastion, when it is intended to dispute the ground inch by inch.

RETURN, in building, denotes a side, or part that falls away from the front of any straight work.

RETURN BEAD, a bead which appears on the face and edge of a piece of stuff in the same manner, forming a double quirk.

REVELS (pronounced *reveals*, from the Latin, *revello*, to retract or draw back) the vertical retreating surface of an aperture, or, the two vertical sides of the aperture, between the front of the wall and the windows or door-frame, most commonly posited at right angles to the upright surface.

The revels of windows, in common brick buildings, are generally $4\frac{1}{2}$ inches in breadth, receding from the face of the wall to the sash-frame; but, in massy stone buildings, they ought to be of greater thickness, according to the magnitude or dimensions of the aperture.

REVOLUTION, (from the Latin, *revolvo*) in geometry, the motion of any figure quite round a fixed line as an axis. Thus, a right-angled triangle, revolving round one of its legs as an axis, generates by that revolution, a *cone*. *See* CONE.

RHOMB. *See* RHOMBUS.

RHOMBOIDES, (Greek) a quadrilateral figure, whose opposite sides and angles are equal, but which is neither equilateral nor equiangular; or, it is an oblique-angled parallelogram.

RHOMBUS, or RHOMB, (from the Greek, ῥεμβω, *to encompass*, or *turn round*) an equilateral rhomboid; or a quadrilateral figure, whose sides are equal and parallel, but the angles unequal; two of the opposite ones being obtuse, and the other two acute.

RIB, (Saxon) an arch-formed piece of timber. Also the projecting moulding on the soffit of a vaulted roof, which divides the vault into severies or compartments; and serves to conduct the thrust of the vault to the pier erected for its support.

RIBBING, the whole of the timber-work for sustaining a vaulted or coved ceiling.

RIBET, a term used in Scotland for the recess made in the sides of apertures of stone or brick work, to admit of door or window-frames.

RIBS, arch-formed timbers for sustaining the plaster-work of a vault, or coved ceiling.

RIDGE, (from the Saxon, *hrigg*) the highest part of the roof, or covering of a house. The term is particularly used for a piece of wood in which the rafters meet.

RIDGE-TILE. *See* TILE.

RIGGEN, a provincial term for the ridge of a roof.

RIGHT ANGLE, an angle which subtends a quadrant or quarter of a circle, containing 90 out of the 360 degrees into which the circumference is divided.

ROADS, as regards the history of road-making, the first steps towards the construction of permanent and durable roadways are said to have been taken by the Greeks, and also that this people expended considerable care and labour in their construction. But more noted than the Greeks in this matter, were the Carthaginians, from whom the Romans are by some reported to have derived their success in similar works. The first Roman road was constructed during the censorship of Appius Claudius, about 309, B.C.; it was first carried to Capua, and afterwards extended to Brundusium, a length of 350 miles; its breadth is about 14 feet, and its thickness, 3 feet; the paving being laid upon a foundation of rough stones cemented with mortar, and that again upon a bed of gravel. This road is still entire; it was called the Via Appia in honour of the consul, as was the second, the Via Aurelia, and the third the Via Flaminia. In the time of Julius Cæsar, the number of roads had greatly increased, so that all the principal cities of Italy were connected with Rome by paved roads, and from that period such means of communication began to be extended into the provinces, their principal object being to provide a ready mode of access into distant provinces, for the passage of troops and similar purposes.

Augustus, when emperor, paid more attention to the great roads than he had done during his consulate. He conducted roads into the Alps; his plan was to continue them to the eastern and western extremities of Europe. He gave orders for making an infinite number in Spain; he enlarged and extended the Via Medina to Gades. At the same time, and through the same mountains, there were opened two roads to Lyons, one of them traversed the Tarentaise, and the other was made to the Alphenin.

Agrippa seconded Augustus ably in this part of his government. It was at Lyons he began the extension of roads throughout all Gaul. There are four of them particularly remarkable for their length, and the difficulty of the country through which they passed. One traversed the mountains of Auvergne, and penetrated to the bottom of Aquetaine. Another was extended to the Rhine at the mouth of the Meuse, and followed the course of the river to the German Ocean; the third crossed Burgundy, Champagne, and Picardy, and ended at Boulogne-sur-mer; the fourth extended along the Rhone, entered the bottom of Languedoe, and terminated at Marseilles. From these principal roads, there were an infinite number of branch roads, namely, to Treves, Strasburg, Belgrade, &c. There were also great roads from the eastern provinces of Europe to Constantinople, and into Croatia, Hungary, Macedonia, and to the north of the Danube at Torres.

The seas were able to cut across the roads undertaken by the Romans, but not to stop them. Witness Sicily, Corsica, Sardinia, England, Asia, and Africa, the roads of which countries communicated with the roads of Europe by the nearest ports. What labours! when we embrace in one point of view, the extent and the difficulties which opposed themselves—the forests opened, the mountains cut through, the hills lowered, the valleys filled up, the marshes drained, and the bridges that were built.

"The Roman roads," says Mr. Tredgold, "ran nearly in direct lines; natural obstructions were removed or overcome by the effort of labour or art, whether they consisted of marshes, lakes, rivers, or mountains. In flat districts, the middle part of the road was raised into a terrace.

"In mountainous districts, the roads were alternately cut through mountains, and raised above the valleys, so as to preserve either a level line or a uniform inclination. They founded the road on piles, where the ground was not solid; and raised it by strong side-walls, or by arches and piers, where it was necessary to gain elevation. The paved part of the great military road was sixteen Roman feet wide, with two side-ways, each eight feet wide, separated from the middle way by two raised paths of two feet each."

Even to such a remote province as Britain were such means of communication opened, good evidence of which still exists in the present day. In this country, a grand trunk, as it may be called, passed from the south to the north, and another to the west, with branches in almost every direction that general convenience and expedition could require. What is called the Watling street, led from Richborough, in Kent, the ancient Ruterpiæ, north-east through London to Chester. The Ermine street passed from London to Lincoln, thence to Carlisle and into Scotland.

The fossway is supposed to have led from Bath and the western regions north-east, till it joined the Ermine street. The last celebrated road was Ikeneld or Ikneld, supposed to have extended from near Norwich southward into Dorsetshire.

If we carefully trace the distance from the wall of Antoninus in (Britain) to Rome, and from thence to Jerusalem, it will be found that the great chain of communication from the north-west to the south-east part of the empire, was drawn out to a length of 4,080 Roman miles, or 3,740 English miles; the public roads were accurately divided by milestones and ran in a direct line from one city to another, with very little respect for the obstacles either of nature or private property; mountains were passed, and bold arches thrown over the broadest and most rapid streams. The middle part of the road was raised into a terrace, which commanded the adjacent country, and consisted of several strata of sand, gravel, and cement, and was paved with large stones, which in some places near the capital were of granite. It is estimated that the Romans constructed, in all, not less than 14,000 miles of paved roadway.

Since the Romans, no country seems to have surpassed or even equalled them in the hardness and durability of their roads; in England we may presume that this branch of engineering has been carried on with greater succes of late years than in any other country of modern times; we say of late years, for it was not until the latter half of the eighteenth century, that any considerable improvement was effected; the roads previous to that period having been of a most rude and unsatisfactory description. The greatest share of praise for improvement in the construction of roads, is due to Mr. Telford, the eminent engineer, who reduced the practice into a system conformable to the laws and requirements of science.

Practice of road-making.—The first object to be attended to in the formation of a road, is the preparing of a good solid foundation; for on this, more than on anything else, depends the durability and convenience of the road. This premiss has been denied by some persons, and the contrary assertion put forward by Mr. McAdam, a name which has become intimately associated with road-making, from the circumstance of that gentleman having introduced into England that system which has been named after him, and is known under the title, "Macadamized." This gentleman we believe was the first publicly to maintain the opinion, that an elastic road was equally good as one with a firm unyielding surface, and not only so, but even preferable. In a publication on this subject, he says—

"That a foundation or bottoming of large stones is unnecessary and injurious on any kind of subsoil.

"That the maximum strength, or depth of metal, requisite for any road, is only ten inches.

"That the duration only, and not the condition of a road, depends upon the quality and nature of the material used.

"That freestone will make as good a road as any other kind of stone.

"That it is no matter whether the substratum be soft or hard."

In contradiction to such assertions as these, we have the universal experience of practical men, and the testimony of both practical and scientific men, such as Telford and Lardner.

To comprehend thoroughly the great importance of making a regular and strong foundation, it should be borne in mind that roads are structures that have to sustain great weights, and violent percussion; the same rules, therefore, ought to be followed with them as are followed with regard to other structures. A road will never be of long duration, nor at any time in a satisfactory condition, which has not a firm and substantial foundation. But not only is its durability affected under such circumstances, it has disadvantages in other points equally important and essential to a good roadway. Besides the durability of a structure, we have to consider its economy, and its adaptation to the special purpose for which it is intended. Now, the object to be attained by a good road is the conveyance or transport of goods in the readiest and most economical manner, so that the constantly-occurring expense of transit ought to be taken into even more careful consideration than the original outlay upon the road itself; we want goods to be conveyed at as small an expense as possible. Now, the largest item in the expenditure for the conveyance of goods consists in the expense of the power employed; and as much as we can reduce the amount of this power, by so much do we reduce the expense likewise. According to all experience, as well as science, the power required to draw a carriage, or any body, over a yielding or elastic surface, is much greater than that required to draw the same over a hard unyielding surface; and the reason is plain—there is not so much friction in the latter case as in the former, and the surface in contact with the wheels of the conveyance is not so great as on a yielding roadway. "The resistance," says Professor Leslie, "which friction occasions, partakes of the nature of the resistance of fluids; it consists of the consumption of the moving-force, or of the horse's labour, occasioned by the soft surface of the road, and the continually depressing of the spongy and elastic substrata of the road. In fact, on a yielding roadway, the carriage or waggon has to be drawn over a series of hillocks, for, as the load passes over it depresses that portion of the road immediately beneath it, and has before it, to be passed over in its turn, a portion which has not yet undergone this process: the comparison between the tractive power employed on roads of different elasticities, has been well illustrated—thus:—An ivory ball set in motion with a certain velocity over a turkey carpet, will suffer a visible relaxation of its course; but with the same impelling force it will advance farther, if rolled over a superfine cloth; still farther over smooth oaken planks; and it will scarcely seem to abate its velocity over a sheet of fine ice."

The fact of greater tractive power being required in elastic than in hard roads has been proved beyond a doubt, by the experiments made by Sir John Macneil, by his machine invented for this purpose.

These experiments uniformly show, that the force of traction is in every case in an exact proportion to the strength and hardness of a road. The following are the results on a well-made pavement:—The power required to draw a waggon is 34 lbs.; on a road made with 6 inches of broken stones of great hardness, laid on a foundation of large stones set in the form of a pavement, the power required is 46 lbs.; on a road made with a thick coating of broken stone, laid on earth, the power required is 65 lbs.; and on a road made with a thick coating of gravel, the power required is 147 lbs.: thus it appears that the results of actual experiments fully correspond with those deduced from the laws of science.

Sir John, in his examination before a Commitee of the House of Commons in 1836, says, "The great advantage of the roads appearing by the machine is certainly in proportion to their solidity and their strength, and their want of yielding. If it could be a perfectly solid mass of stone or metal, the least resistance would be presented; that is shown both on stone tramways and on metal tramways, and metal rails."

This foundation should be composed either of a rough paving of large stones, or of a sufficient bed of concrete, the former being the practice of Mr. Telford, and the latter of many engineers of the present day; the selection of either of these materials will depend upon their economy in various places; whichever is most accessible, may be safely used; but whatever material be used, it is necessary that the substratum should be of uniform strength and solidity over the entire surface, otherwise, after the pavement has been laid, the weaker parts will give way, while the stronger maintain their position, and so the surface of the road becomes broken and uneven, rugged, and full of hollows; for this reason we prefer the use of concrete, which offers greater security against this defect than foundations made of large stones or rubble, though in many roads even concrete is not sufficient entirely to prevent it. We are inclined to think that the value of concrete for this purpose has not been fairly tested, for the work, especially in London roads, is usually got through in so hurried a manner as not to allow a sufficient time for setting: we imagine, that with a somewhat thicker bed of concrete, the materials of which have been properly mixed, and allowed a sufficient time to set before the metalling is put on, we should be enabled to construct roads sufficiently firm to bear the extraordinary wear and tear of London traffic, and that, too, at a less cost than is expended on the present roadways. We are aware that there are many disadvantages to contend with in London roads; that they are continually being pulled up, and thereby destroyed, for works connected with water, gas, or sewers, and that this acts as a great discouragement to the construction of good roads. That any necessity of this nature should be allowed to exist is much to be lamented, but we feel confident that such practices might be restricted to a very considerable extent, without doing any injury to the public convenience. The concrete foundation should be slightly curved, falling from the centre towards both sides, which form will assist to drain it, and also to give the proper form to the surface of the roadway. It is necessary that this lower surface should be properly drained, otherwise the water will lie there, and destroy the road. If the concrete were laid 18 inches thick, we should not deem the extra expense ill laid out for a good road. With respect to the other kind of foundations, Mr. Parnell says—"In streets where the traffic is not very great, the foundation should be made in the following manner:—A bed should be formed, with a convexity of 2 inches to 10 feet, so as to admit of 12 inches of broken stone being laid upon it: these should be put on in layers of four inches at a time. After the first layer is put on, the street should be kept open for carriages to pass over it. When the first layer has become firm and consolidated, then another layer of 4 inches should be laid on, and worked in as before, care being taken to rake the ruts and tracks of the wheels of carriages, so that the surface may become smooth and consolidated. The same process should be repeated with the third layer of stones, by which means a solid and firm foundation will be established, of 12 inches in thickness, for the dressed paving-stones to lie upon." Such directions deserve greater attention than we fear they usually receive; in all cases, let your foundation be secure before you lay your roadway.

Various kinds of materials are used for the purpose of forming the upper coat of the road, and amongst those most frequently employed may be mentioned broken Guernsey granite, flints, gravel, and cubes of granite of various sizes. Of these the broken granite and granite cubes are most useful, the one for general purposes, the other for roads which are subject to great wear and tear, such as those in the principal thoroughfares of London, for although both descriptions of material are used for this purpose, yet we are inclined to think that the broken stone is scarcely durable enough for such work: and there is this further objection to it, that it is constantly requiring repairs, which must, to a certain extent, inconvenience public business. Besides this, as usually managed, they occasion a great deal of dust and dirt, while the draught of vehicles upon them is very heavy, and their maintenance expensive. It would be scarcely fair, however, to attribute the faults of management to the quality of the material, and we believe that many of the above objections may be removed by skilful management.

In the first place, as regards durability, the objection would be removed to a considerable extent by employing a good foundation, and laying the metal carefully upon it, providing for the proper drainage of surface and substratum as mentioned above, for the lodgment of water either above or below such roads is very injurious, and tends, perhaps more than anything else, to their destruction. Having obtained a good foundation, the next point is to cover it with a hard compact crust impervious to water, and laid to a proper cross section, so that it may be speedily drained and no water be allowed to remain on the surface, which, besides its inconvenience to passengers, is very destructive to the surface of the road. A practice has come into vogue of late, of covering the road when made, with a binding composed of the grit collected off the road in wet weather, and by the operation of water-sweeping. The binding is laid on regularly and watered until the new material is firmly set, which it does very quickly, and when the binding is of good quality and properly laid on, it assists its formation very considerably, and altogether improves the condition of the road and economizes the material, for it saves the wear and attrition of the new stone. Some road-makers object to this binding on the ground, that it destroys or rots the road, and that when the road is set it has to be carted away again; but this is only the case where improper binding is used, such as is swept from streets which are not properly cleansed, and therefore consists principally of mud, and not of grit, or rather of grit so mixed with dirt as to be for the most part useless for binding. This method of binding a road removes in part the objection which is made against the resistance occasioned by the loose stones of a newly-laid broken road.

We alluded just now to the cleansing of roads, and it is a matter which deserves considerable attention, and is applicable to every variety of road; a dirty road is a constant source, only not of inconvenience, but of expense, for scarcely any thing destroys a road more readily than dirt. And not only is this the case, but the tractive power also required on a dirty road is twice as great as that required on a clean one: when we come to add to this the damage done to property by the mud in wet weather, and the dust in dry, we shall be able to form some notion of the waste occasioned by dirty roads.

The best method of cleansing roads is by water-sweeping: a method of watering and sweeping combined, the roads being first watered and then swept, by which means the road is thoroughly washed from its impurities. The watering is usually carried on by means of a water-cart, but a more effectual means, as far as the cleansing of the road is concerned, is afforded by the hose and jet. The sweeping is mostly effected by hand, and in some places this method is carried on systematically, which is an improvement upon the old practice; but of all methods offered to the public, that of Whitworth's sweeping-machine, is the most effective, and in the end, we believe, the most economical, By this machine an endless chain of brooms is made to revolve by the motion of the wheels, and to sweep the dirt immediately from the roads up an inclined plane into the cart, without fear of splashing, or any other annoyance to the public, which is a vast improvement on the old practice of stacking the mud or dust up in heaps, and letting it remain in that state until the carts come round, during which period a considerable portion of it had probably been spattered about by the traffic, or blown in all directions by the wind, and even then passengers must expect to be bespattered by the negligent manner in which the refuse was carted away. This machine, too, presents other advantages, in the width of the brooms, and the uniform pressure exerted throughout, a pressure which can also be regulated as occasion demands. Water-sweeping by this machine is, we venture to assert, one of the best, if not the best method of cleansing roads, and our assertion is supported by facts. It has been objected that water-sweeping removes the material of the road, but the contrary has been proved to be the case. Mr. Smith, the eminent surveyor of Birmingham, says, "I have found that the use of sweeping-machines, with the proper employment of water, has reduced the amount of material required for the repair of roads in Birmingham one-third, viz., from 20,000 to 13,000 cubic yards; the first named amount is the average of seven years preceding the introduction of the machines, the latter of the three years subsequent." On the 22nd of March, 1848, some experiments were made upon the subject in the Quadrant, Regent-street, the road being then covered with a thick coating of dust, which was causing great annoyance as well as injury to the road, but could not be removed by scraping without removing also much of the new stone to which it adhered. It was determined to sweep half of it dry, and half after proper watering. This was done, and the sweepings removed were washed, to separate the refuse from the stony matter mixed with it; one third part of that which was taken dry consisted of coarse grit which would have been useful on the road; one-twelfth part only of that which was removed in the form of slop was stony matter, and that was so completely pulverized as to be of scarcely any use—it had done its work. After the two portions of the road had been cleansed, the difference between them was very striking. That which was swept dry was still covered with adhesive matter, which, together with the stones to which it adhered, was lifted by the wheels, the whole road being rough and uneven. The portion which had been swept with water was perfectly even and smooth. On the 24th both portions were swept, but only one quarter as much dirt was taken from that which had been water-swept as from the other. On the 26th it rained, and three times as much slop was taken off the part of the road which had not been water-swept on the 22nd. The preservative effect of water-sweeping by machine was most striking, by the decidedly better condition of that portion of the road cleansed in this effective manner.

The granite-cube roads are preferable to macadamized in point of durability, and therefore are more eligible in this respect for places where there is great traffic, but nevertheless there are objections which partly outweigh these advantages, one of which, of considerable importance, arises from the circumstance of the wear and tear of vehicles being very great on such roads on account of the frequency and violence of the concussions to which they are subject; and although the draught upon macadamized roads is, generally speaking, heavier than upon pavement, yet this advantage is probably more than neutralized by the concussions alluded to, which form a great impediment and injury to vehicles travelling quickly.

Another objection is, that a horse has not nearly so secure a footing upon paving as upon a broken-granite road.

A system of tram-roads has been adopted for special traffic on some roads with great advantage, as in the Commercial and East India Dock roads, where two parallel lines or tramways of masonry are laid for the wheels to run upon, the space between being paved with the ordinary paving. These trams were made of large blocks of granite 5 or 6 feet in length, 16 inches wide, and 12 inches deep, and have been found to stand the heavy traffic much better than ordinary pavement would have done.

Roads paved with blocks of wood are of comparatively recent invention, and offer many advantages over common roads, in the evenness of the surface, but more especially by the prevention of noise, which is a great inconvenience on paved roads. It is to be regretted, however, that with such advantages it has defects, which, until removed, will put an effectual bar to its general employment; we allude to its want of durability, and consequent expense, but more especially to its slipperiness in wet and damp weather. The former objection we feel confident may be removed by employing greater care in the construction and drainage of the substructure; and the latter has been remedied, in some degree, by spreading broken granite on the surface.

In concluding this article, we beg to recapitulate the principal points to be attended to in the construction and management of roads:—viz.; a good solid foundation, proper drainage, and efficient cleansing. We subjoin a table of the comparative costs of various kinds of Roads with some cursory observations on their peculiarities.

A Table showing the comparative First Cost, Annual Expense, and Durability, of different descriptions of Carriage-Roads, as for example, in a road 42 feet wide, with ordinary substratum.

Material used.	First Cost for square yard.	Cost for square yrd. per annum for repairs.	Value of materials at end of			Observations on durability and condition the road would be in at the end of 20 years.	Cleanliness.
			10 yrs.	20 yrs.	30 yrs.		
Guernsey Granite, or Macadamized road.[a]	4s. 6d.	1s. 6d.	3d.	3d.	3d.	The price in each case is taken for London wear; as in the principal thoroughfares at the West End, the road being always renewed at the expense stated, the value of materials would be the same at each period.	The mud in wet and the dust in dry weather, are the chief objections to these roads; they are very expensive to keep clean.
Grueby & Whinstone.	about the same	see 2d column					Grueby stone turns to a light mud in bad weather, and roads made with it, cost more to keep clean than granite roads.
Ightam stone, a small quantity of this stone is sometimes sent into the London market.	3s. 6d.	2s.	nil.	nil.	nil.	This material will not bear the traffic granite will; it has been used in streets of secondary traffic, but grinds to powder in dry, and goes off to light mud in wet weather.—The same remarks as above as to value at 20 years.	Same remarks as made upon Grueby stone, apply to this in reference to cleansing the roads.
Flints............	3s.	2s. 3d.	nil.	nil.	nil.	The same observations which have been made in reference to Ightam stone, apply in a still stronger degree to flint roads, as they are much inferior in durability, though well suited to some localities.	Very difficult to keep clean.
Aberdeen Granite, 3-inch cubes, concrete foundations.[b]	17s. 6d.	For the first 3 yrs. nil, afterwards 3d. per annum.	7s.	4s.	2s. 6d.	The price named as value of a certain number of years' wear, is what the materials would sell for if removed. They would be worth more, if removed to other streets.	This is the best and cleanest of pavements, as it offers the greatest facilities for washing.
CUBES. 9 inch deep by 5 wide[c]	14s.	do.	6s. 6d.	4s.	3s.	Do.	Good pavement, but not so clean.
WOOD. Metropolitan Wood-paving Comp.; Concrete foundation included.[d]	12s. 6d.	1s. 6d.	The value of material when relaid at the end of every eight years, 1s. per square yard.			The price named as for annual repairs, is sufficient to lay with new when required, and it is presumed this would be necessary at the end of every eight years.	Wood offers great facilities for cleansing; it is swept easier, and at less cost, and the sweepings are valuable for manure, while the sweepings of broken-stone roads are not. It can be easily washed also, but should not be kept wet, if possible to avoid.
There are other forms of Wood Pavement, but none equal to the above.							

Remarks.

[a] The Guernsey granite is the only material which has been found to stand the extraordinary wear and tear of London traffic, all other stone has failed, or has not been procurable at a reasonable price.

[b] The annual cost of repairs depends not only on the traffic over the road, but on its good or bad formation originally. Some part of the New Road, for instance, is made on so bad a bottom, that in wet weather, the substratum works up, and destroys the new material. An eminent contractor, some time since, sent in an estimate, to take out the substratum to a certain depth, fill in with good hard stuff, and make them a good road over it. This done, he would have undertaken to keep the road in repair at 1s. per yard per annum.

A road made with the centre of granite, and sides of flints, has been found to answer well in the neighbourhood of London; also flints in the centre, and the sides paved with granite stones, (cubes.)

[c] This is not equal to the 3-inch cubes described above.

[d] The first cost of this description of road, has alone prevented its becoming more general; but there seems little reason to doubt, that it will be found almost the only pavement suited to London wear.

The contract price for keeping in repair Regent-street, is 6d. per square yard per annum for 7, 14, or 21 years.

This piece of wood has been strewed with clear Guernsey Granite, broken in small pieces, which has been found in a great degree to prevent the slipperiness so much complained of. The expense of the experiment, borne by the Commissioners, was £125, or about 2d. per yard.

ROD, a linear measure of $16\frac{1}{2}$ feet. Also a superficial measure of $272\frac{1}{4}$ square feet, by which brickwork is usually calculated; the rod contains $272\frac{1}{4}$ square feet of brickwork, a brick and half thick, or 306 cubic feet.

ROE-STONE, or OOLITE, a variety of limestone, composed of small round globules, resembling the roes of fishes, imbedded in a calcareous cement. These globules are composed of concentric lamellæ, and are evidently the result of crystallization. They vary in size from a grain of mustard-seed to that of a pea: when they are as large as the latter, it is called *pea-stone.* Roe-stone is one of the secondary limestones, which may be considered as belonging to the chalk-formation. It lies under chalk in various parts of England, being separated from it by beds of sand and clay. It is found also in many parts of Europe; but, according to Humboldt, is not met with in South America. Some of the strata of this stone are extensively used for purposes of architecture: the most distinguished are the Ketten stone, in Northamptonshire; the Bath firestone, in Somersetshire; and Portland stone, in the island of Portland. Portland stone is of a yellowish-white colour: the more compact varieties, when closely inspected, show a tendency to crystalline arrangement; it is composed of carbonate of lime, with a small admixture of silex and alumina.

ROLL-MOULDING, a moulding in Gothic architecture of a circular section, though frequently interrupted or broken by a fillet.

ROLLS or ROLLERS, among carpenters, masons, &c., plain cylinders of wood, seven or eight inches in diameter, and three or four feet long; used for the removing of beams, huge stones, and similar burdens, which are cumbersome, but not exceedingly heavy. These rollers are placed, successively, under the fore part of the masses to be removed; which, at the same time, are pushed forward by levers, &c., applied behind.

When blocks of marble, or other excessively heavy loads, are to be removed, they use what they call *endless rolls.* These, to give them the greater force, and prevent their bursting, are made of wood joined together by cross-quarters; they are about double the length and thickness of the common roller, and, besides, are girt with several large iron hoops at each end. At a foot distance from the ends are four mortices, or rather only two, but pierced through and through, into which are put the ends of long levers, which the workmen draw by ropes fastened to the ends, still changing the mortise, as the roll has made a quarter of a turn.

ROMAN ARCHITECTURE. The early Romans can scarcely be said to have possessed any style of architecture of their own, but borrowed their ideas of building first from the Etruscans, and, at a later period, from the Greeks. In the time of Romulus, their buildings would seem to have been of the most rude description, their dwelling-houses being composed chiefly of straw, and thence termed culmina; and at a somewhat later period, even their temples were only small square erections scarcely large enough to contain the statue of the deity.

Ancus Martius was the first king who commenced works of a larger class requiring skill in their construction, and his first attempt was the construction of the city and port of Ostia, at the mouth of the Tiber. Tarquin the Elder brought with him the skill and enterprise of the Etruscans, and set about improving the city with energy and perseverance; his first work was to erect the grand circus; he also constructed the walls of the city with large hewn stones, and commenced the great cloaca, or public sewer, as well as the temple of Jupiter Capitolinus, which was continued by Servius Tullius, who also enlarged the city. Tarquinius Superbus yielded to none of his predecessors in the decoration and improvement of the city. During his reign the circus was completed, as was also the cloaca maxima, which was considered one of the wonders of the world, and still remains as a monument of the enterprising spirit of the Tarquins. It was constructed of wrought stone, and was of such dimensions, that a wagon loaded with hay could pass through it; and was carried through rocks and under hills, and many were the engineering difficulties overcome in its construction. The temple of Jupiter Capitolinus was not completed till after the expulsion of the kings, but was considerably advanced by this king.

After this period, some of the principal works were—the completion of the Capitol, commenced by Tarquinius, the formation of the Campus Martius, and the outlet for the relief of the lake Alba. In the year 389, B. C., the city was burned by Brennus, which afforded an opportunity for rebuilding it in a more convenient and sumptuous manner; but unfortunately, the opportunity was not taken advantage of, and the houses were erected after a more irregular plan than they had previously been; for whereas, in the old city, the public sewers ran under the roadway; in its re-edification, the streets were laid out without any reference to this arrangement—a want of consideration, the effects of which were greatly felt at a subsequent period.

During the censorship of Appius Claudius, 309 B.C., the first paved road was laid by the Romans; it extended from Rome to Capua, and afterwards to Brundusium, a length of 350 miles, and is to be seen at the present day. It was 14 feet in width, and about 3 feet deep, being composed of three thicknesses, the lower one consisting of rough stones grouted together, the second of gravel, and the third of stones of various dimensions, but so accurately pointed, as to have the appearance of a single stone. The credit of constructing the first aqueduct also belongs to this censor, by which a supply of water was conveyed from Præneste to Rome, by means of a deep subterraneous channel upwards of 11 miles in length. During the two first Punic wars, many temples were erected, but they do not appear to have been of great magnificence. Cato adorned the city with a basilica, which he named Portia, and Sempronius erected a second, which was called after his own name.

The censors Fulvius Flaccus and A. Postumius Albinus, contributed much to the embellishment of the city; they paved it, adorned it with porticos, enlarged the circus, and made public ways and bridges on the outside. At this period, the more wealthy Romans began to live out of the city, and build country-residences, which were, in many cases, of considerable extent and luxurious decoration. To such an extent was the magnificence of these villas carried at last, that we find Cicero in the habit of employing no less than two architects.

All this time but little taste had been exhibited in the decoration of their buildings, which were mostly of brick, or, at best, of stone obtained in the neighbourhood; but as their conquests extended, and they became intimate with the more costly buildings of their enemies, they began to entertain more expanded ideas of magnificence in art. Metellus Macedonicus, the contemporary of Mummius, the victor of Corinth, was the first to build at Rome a temple of marble; but from this time most of the larger edifices were constructed of this material. At this period also, Grecian art and architects were introduced, and many works of art brought thence to decorate Rome; Sulla carried away the columns, &c., from the temple of Jupiter Olympius at Athens, to embellish that of Jupiter Capitolinus at Rome.

The first permanent theatre was erected by Pompey; previous to his time, such erections were not allowed to remain

Ruins of Ancient Rome

after the shows, and therefore only temporary buildings were erected for the purpose. Of these, however, some were of great size and magnificence; M. Æmilius Scaurus, when ædile, erected one capable of containing 80,000 persons, which is reported to have been sumptuously decorated. Another theatre was erected by Curio, one of Cæsar's partisans, which exhibited great mechanical skill. Two large theatres of timber were constructed back to back, and on one side so connected with hinges and machinery for the purpose, that when the theatrical exhibition had closed, they were wheeled or slung round, so as to form an amphitheatre, wherein, in the afternoon, shows of gladiators were exhibited. Pompey's theatre was built of stone, and was made capable of accommodating 40,000 persons; it was surrounded by a portico for shelter in case of unseasonable weather, and had attached to it a curia provided with a basilica, or hall of justice, as also a temple dedicated to Venus.

Under the auspices of Julius Cæsar, many new and magnificent buildings were erected. On his return from Utica, after his threefold victory, he brought into the treasury no less than 65,000 talents, and 2,822 crowns of gold, which afforded him every facility for carrying out his magnificent projects, amongst which may be mentioned the extension of the circus, and formation of a lake for the exhibition of Egyptian and Tyrian galleys, a new forum, two temples to Venus, one of which was on an exceedingly grand scale, and a third to Clemency. Besides these, he commenced a vast theatre, the drainage of the Pontine marshes, the improvement of the navigation of the Tiber, by forming a new bed from Rome to the sea, a canal through the Isthmus of Corinth, the formation of a port at Ostia, and of a causeway across the Apennines, from the Adriatic to Rome; add to this, the re-building of Corinth and Carthage, and we shall be enabled to form a conception of the vast ideas and ready execution of this great man.

Such an introduction as this was worthy the golden age which followed in the next reign, an age which the peace purchased by the victorious arms of Cæsar had yielded to the cultivation of civil arts, and that excessive refinement which led the way to luxury and consequent ruin. In this reign most of the finest buildings were erected, and architects flocked from all quarters, and especially from Greece to assist in beautifying the city, the latter being highly esteemed and eagerly employed; in short, Greece at this time had become the standard of taste amongst the Romans, not only in the arts, but in customs and manners. Augustus had conceived the project of making Rome the most splendid city in the world; and not only set about embellishing it himself with the greatest ardour, but also incited his friends, and the principal personages of the empire to follow his example, which indeed they were not slow in following; and amongst the buildings erected by them may be mentioned, a temple of Hercules Musagetes, by Marcius Philippus; a temple of Diana, by L. Corfidius; of Saturn, by M. Plaucus; of Concord, and of Castor and Pollux, by Tiberius; the Atrium Libertatis, by Asinius Pollio; a theatre, by Cornelius Balbus; and an amphitheatre, by Statilius Taurus. His friend Agrippa was highly distinguished in this respect; he erected many magnificent buildings, aqueducts, baths, fountains, &c., but he stands pre-eminent above all his countrymen, by the erection of that monument of Roman skill and enterprise, the Pantheon. The principal edifices erected by Augustus himself were—the forum and temple of Mars Ultor; the temple of Apollo Palatine, with portico and library; the temple of Jupiter Tonans, on the Capitol; the porticos of Livia and Octavia; the basilica of Caius and Lucius; the theatre of Marcellus; and a mausoleum for himself and family. After such an enumeration, the boast of Augustus will not appear a vain one, "that he found Rome built of brick, and left it of marble."

During the reigns of the immediate successors of Augustus, architecture fell into decline, and the only building of any importance which we hear of before Nero's time, is the Aqua Claudia, a large aqueduct, which was completed by Claudius. Its length was 46 miles, and for more than 10 it was carried on arches more than 100 feet above the level of the ground. Nero's edifices were gorgeous in the extreme, but more remarkable for expensive decoration than intrinsic merit of design; his Domus Aurea is a remarkable specimen of his prodigality in such matters; it was erected by two architects, Severus and Celar, and was most lavishly embellished, so that it would be difficult to form an idea of its expense.

Under Vespasian, and his successors, architecture again flourished, to which the remains of the Coliseum abundantly testify. This building was commenced by Vespasian, and completed by his son Titus, and its erection is said to have occupied no greater space of time than two years and nine months; it covers nearly six acres of ground, and was reported capable of containing 100,000 spectators. The reign of Titus is also remarkable for the erection of the baths and triumphal arch which bear his name. Trajan is the next name worthy of record, as a liberal patron of architecture, and amongst his works may be mentioned the forum, triumphal arch, and column which has never yet been surpassed. His bridge over the Danube, which was destroyed by Hadrian, was a bold undertaking; it is reported to have consisted of 20 stone piers, 60 feet wide, and 150 in height, the arches between being not less than 170 feet in span; his architect was Apollodorus, who fell a victim to his master's jealousy, for blaming his architectural plans. Few princes erected a great number of edifices than did Hadrian, amongst which were the Maison Carreé at Nismes, his villa and mausoleum, the amphitheatres at Capua and Verona, and the bridge over the Tagus at Alcantara. Besides these, he re-built Jerusalem, which he styled Ælia Capitolina, also part of the temple of Jupiter Olympius at Athens. In this reign also an aqueduct was constructed by Herodes Atticus to supply Troas with water, and, by the same man, a stadium at Athens 600 feet long, a stadium at Delphi, a theatre at Corinth, and baths at Thermopylæ.

Under the Antonines were erected the temple of Antoninus and Faustina, the Antonine column, and that of Marcus Aurelius, besides many other temples and works in the provinces, amongst which may be enumerated the re-building of Smyrna, Laodicea, and other Asiatic cities. After this period architecture gradually declined; a little improvement may be seen in the reigns of Septimius and Alexander Severus, but taste had greatly deteriorated, and art had fallen to too low an ebb to be restored. Antoninus Pius is reported to have erected the vast edifices of Balbec and Palmyra, but the subject admits of a doubt. Dioclesian made a bold effort to restore architecture to its original position, but it was beyond his power, and although his buildings, his baths, and his palace at Spalatro were magnificent in point of extent, and a certain kind of grandeur, yet they bear evident tokens of the state into which architecture had fallen. The palace at Spalatro covered between nine and ten acres, one of the sides being 600, and the other 700 feet in length; attached to it was a portico 500 feet long, embellished with painting and sculpture. Constantine was a great builder, but he transferred the seat of empire to Byzantium, and thus Roman architecture was superseded by the new style which he introduced in his new capital. This change, however, is to be the less regretted, inasmuch as Roman art had already degenrated beyond hope of restoration, and new edifices of barbarous design had begun to be erected at the expense of those of better design already in existence.

In comparing the relative merits of Greek and Roman architecture, there can be no question but that the former by far excels in matter of taste; and this, by many writers, seems to be the only question considered. But this is not fairly the whole point at issue between them; there are other matters to be brought under consideration; and such are—variety, as well in use as in design; the capability of being adapted to different purposes of life; as well as excellency and facility of construction. Now, although the Greeks far exceed their rivals in simple grandeur, chasteness of decoration, and correctness of detail, still it must be remembered that their structures are chargeable with sameness and monotony: their plans scarcely ever varied from the oft-repeated rectangle; the only change consisting in the different arrangement of the columns, and in the applications of the few orders of architecture which they possessed; the only variation in plan which occurs, is to be found in the Erechtheum at Athens, and some smaller monuments, as the Temple of the Winds, the Choragic Monument of Lysicrates, and such like. Grecian architecture was almost entirely devoid of composition; and no attempt was made in them of grouping their several parts, so as to produce a varied, yet effective, outline.

Now, on the other hand, the Romans were not so much a sentimental as a practical people; and this fact, we think, will account in a great measure for their different appreciation of the art under consideration. During the earlier period of their history, it will be found that they constructed only works of public utility and convenience, and whose only claim to beauty consisted in their magnitude, their grand conception, the mechanical skill employed in their construction, and their perfect adaptation to the purposes for which they were intended. The effect produced by them is rather surprise and admiration than pleasure; they awe by their grandeur, rather than satisfy by their display of taste. Such works would not be classed in the present day under the term architecture at all, but under that of engineering—two terms which are perfectly distinct in this application, although both applied to works of construction, to buildings, or artificial erections, the one, however, applies more especially to the science, the other to the art, of building; not that science is absent in either case, but that art—that is, fine art—in the one case stands pre-eminent, as scientific skill does in the other. Under the term engineering we should include the roads, bridges, aqueducts, and sewers, for which the early Romans are so noted, and whose mode of construction was probably learned from the Etruscans, who seem to have been a people of similar character, though of improved civilization, to the Romans. This practical character to which we allude, the Romans never entirely lost, even after they had become acquainted with the voluptuousness of Greece, and during the luxury of the court of Augustus and the succeeding emperors; for although at this period they began to cultivate architecture simply as one of the fine arts, still not even then did they lose sight of utility in their buildings.

With the Greeks, religion was almost the sole purpose for which architecture seemed to exist; with few exceptions, we have no other examples but temples: on the other hand, the temples of the Romans were neither so extensive nor so numerous as their works of public utility or convenience; and this also arises from their national peculiarities; for they were neither so religious, nor so philosophical and contemplative, as the Greeks. Amongst Roman remains, besides the engineering works which we have above alluded to, we have fora, baths, palaces, circi, theatres, amphitheatres, libraries, halls of justice, triumphal arches, commemorative columns, mausolea, and such like. The requirements which were necessary for such buildings as these, led, no doubt, to the practice of composition and grouping, for it is very certain that one uniform plan of building would not have been suitable for such a variety of purposes; but this was not the only cause of variety in their buildings, although, perhaps, the principal one. Another may be observed in the employment of the arch, which allowed much greater latitude of construction than the entablature of the Greeks; with the latter the intercolumniations were fixed to a certain gauge, or at least limited within a determinate range; whereas, with the former, every facility was afforded for increasing or diminishing the space between the piers to almost an unlimited degree. It is not improbable, too, that the semicircular form of the arch, which was in such constant use, assisted in the development and frequent employment of circular plans, or of plans in which circular and curved lines were introduced; for it is not unlikely that the existence of a form or figure in the elevation should suggest its application to the plan likewise. This employment of the circle in the plans of their buildings led inevitably to that which was quite a new feature in architectural design, the dome—a feature, too, which gave a totally distinct character to the buildings in which it was employed, and introduced an important element of variety into architectural design. Of this arrangement the Pantheon is the most remarkable example; and it requires none other, to attest to the importance of the change then introduced. The effect of the interior is strikingly different from anything which had before appeared; a vast area, such as that of the Pantheon, covered over by a single hemispherical dome, must, at the time of its erection, have produced a most wonderful and novel effect. Nor is the exterior devoid of novelty or character—a fact which is especially observable in the rectangular portico—projecting from a larger circular building. Such a combination forms a striking contrast to the uniformity of Grecian edifices. In the instance of the Pantheon, the exterior is destitute of columns, except in the portico. But there are many buildings in which the circular plan was carried out with an external peristyle: such, for instance, is the temples of the Sibyl; or, as it is otherwise named, that of Vesta at Tivoli. Buildings of this class were roofed with hemispherical domes, or with lesser segments of a sphere; but these were not visible on the exterior, being concealed by the projecting colonnade. Even in the Pantheon, where the dome is hemispherical, and of so great diameter, it does not form a conspicuous object on the outside, for its springing line is situated at about the level of the lower cornice; and its external height is still further reduced, by the base of the outer portion of the dome being formed into several courses of steps. Had the entire height of the dome been visible from the exterior, it would have borne by far too great a proportion to its base. In the time of Constantine, the circular plan was employed with an internal colonnade, as in the church of San Stephano Rotundo, and that of Sta Costanga; in both which cases, the circular portion within the colonnade is of greater elevation than that portion embraced between the colonnade and external walls, and is covered with a dome; but in Sta Costanga there is a further peculiarity, for the columns are not only coupled, but are arranged in an unusual manner, in pairs, one behind the other: the columns serve to support in arcade. Both these edifices have been claimed as heathen temples, (the one as dedicated to Faunus, and the other to Bacchus,) but seemingly without any other foundation than conjecture, and the existence of some decorations which a[illegible] applicable to the Christian religion, as well as to the heathen mythology. A more notable example of the circular form is the Church of the Holy Sepulchre at Jerusalem, built by the empress Helena, mother of Constantine.

The circular form was also a favourite one for tombs and mausolea, amongst the more remarkable of which are those of Augustus and Hadrian. The former consisted of four cylindrical stories, the diameter of each being somewhat smaller than that below it, and the uppermost crowned by a colossal statue of the emperor. The latter is now the well-known castle of St. Angelo, and originally consisted of a cylindrical building, placed upon a square base, the height of which was about half that of the superstructure. No remains are now left of the uppermost stage of the building, which was also circular, and was surmounted with a peristyle of 34 Corinthian columns; its diameter being about one-third that of the larger cylinder. Of a similar form is the tomb of Cecilia Metella, but devoid of the upper story. A more curious example is the sepulchral monument at St. Renie, which consists of three stories, the lowest a square base, raised on gradini, and covered on each side with sculptures in relief; the next square, with an attached fluted Corinthian pillar at the angles, and an open arch on each side; and the uppermost a Corinthian rotunda, forming an open or monopteral temple, in which are two statues. The tomb of Virgil consists of a square base, surmounted by a conical structure; and a cenotaph at Constantina, in Africa, has the lower story cylindrical, surrounded by a peristyle; while the upper is a lofty cone, formed in receding courses or steps. Edifices erected on polygonal plans were not uncommon, of which the octagonal were most frequent; the latter form was commonly employed in saloons to public baths; and there is an octagonal temple in Dioclesian's palace at Spalatro. Buildings of six sides were not common; but there is one at Balbec of peculiar form, two of the sides measuring 110 feet each, and the four remaining only 88 feet. There is also a curious circular temple at Balbec, of curious design; it is placed upon an octagonal base, the sides of which are curved inwardly, presenting a concave face; and at the angles of which are placed columns bearing an entablature, which is curved in a similar manner to the base.

We have alluded to the previous examples, for the purpose of showing how infinitely varied Roman edifices were in the arrangement of the main parts, and how readily a different distribution of the same or similar parts were made to exhibit a dissimilar effect. Many examples in proof of the same might be offered, were it within our limits to do so, and these on a more extensive scale, as witness the baths, fora, &c., with their many courts, saloons, galleries, and porticos, each of which might present some different method of distribution. It will thus be seen, how, in point of practical utility, the Romans took precedence of the Greeks, and how they were enabled to erect buildings suitable for any purposes which might be required. In such matters, they undoubtedly have the pre-eminence, but in matters of pure taste, they must be content to yield priority to the Greeks; for although in many cases they have shown proof of excellency of design, of which we need no other illustration than the Corinthian order, which was fairly their own; yet at the same time, the generality of their designs do not exhibit that purity and simplicity which is the mark of true excellence. But besides this, many violations of true taste are constantly occurring even in their best works, indeed they seem to have been inherent in the system; amongst these, we may mention the inconsistent employment of the arch and entablature in the same design; and it is to be lamented, that instead of endeavouring vainly to unite the two systems, they had not struck out in a bolder course by themselves, and worked out a consistent style of building. It is true that they employed the arch very freely, and sometimes probably more so than correct taste would warrant; yet at the same time they did not take that advantage of the possession of such means of construction as they might have done in a scientific point of view; they piled arch over arch, and seemed to be pleased with their acquisition, and content to make use of it, but not to apply it with any idea of improvement. But there are still one or two other points which merit reprehension, for instance, the employment of columns merely for the purpose of decoration, as where they are half inserted in the walls, or where pilasters supply their place. Now, columns are evidently intended for support, and they should always manifest such intention; and where they are used in positions where such support is not required, their employment is certainly objectionable, and would not be admitted in accordance with strict taste: the construction of ornament merely as ornament, and especially when its employment is liable to deceive, is to be condemned. A forcible illustration of the above kind is to be observed in triumphal arches, in which, although the columns be entirely isolated, and standing in front of the wall, they serve no practical purpose, their only use being to support a projecting portion of the entablature; and if it be asked for what purpose this projection is made, the most ready reply will be to give an useless column something to do. The fact is, that they are both added for the sake of effect, probably for variety in outline and for the sake of the deep shadow which such a projection would cast: but as far as construction goes, the whole thing is a sham, and deceptions in buildings indicate a low ebb of taste and science in architecture. Another characteristic of Roman art, and one which entered very largely into the system, is the employment of order above order in the same building, which illustrates at once its virtues and faults; for while on the one hand, such an arrangement is incompatible with the requirements of the highest standards of taste, yet still at the same time it proves their aptness of invention, and versatility of design.

We have now endeavoured to show in as fair a light as possible, the comparative merit of the two styles; and while, as a question of taste, we must without doubt yield the palm to Greece, we are inclined to think with Mr. Freeman, that architecture would have flourished more successfully at Rome, had she remained unacquainted with that of her rival.

Descriptions of some of the principal Roman buildings will be found in the body of this work; we may refer especially to the articles under the following heads:—PANTHEON, AMPHITHEATRE, BALBEC, PALMYRA, &c. The adaptation of the orders will be found noticed under CORINTHIAN, DORIC, IONIC, ROMAN, and TUSCAN ORDERS.

ROMAN ORDER, an ordinance of architecture, invented by the Romans from the Ionic and Corinthian orders; and hence, it has also obtained the name of the COMPOSITE ORDER. *See* ORDER.

Vitruvius, the most ancient writer on architecture, after describing the three Grecian orders, mentions several fanciful compositions, without giving them any particular denomination. The name of *Composite order* is of modern application, and has been applied in consequence of the numerous examples to be found at Rome, and other parts of the ancient Roman territory, of an order compounded of the Ionic and Corinthian, which is of a very uniform character.

The capital of the Roman order is compounded of the Ionic and Corinthian, the upper part being the Ionic, and the lower the Corinthian. The entablature, as found in the ancient remains of Roman architecture, is Corinthian, and not one example is to be found in the Roman antiquities as published by Desgodetz, but what have Corinthian entablatures.

The Composite order, as is to be found in several of the works of the principal Italian architects, has been compounded from the remains of the frontispiece of Nero, which is entirely Corinthian, and from the temple of Concord at Rome : the cornice is imitated from that of the frontispiece of Nero, which is the boldest, and one of the most beautiful remains of Roman grandeur. The upper part of the capital is taken from the temple of Concord, where the sides, or flanks, are the same as on the fronts, and project at every angle, the face of the abacus being concave ; and the two lower rows of leaves are what is usually found in any example of the Corinthian order ; but there is some little difference between the caulicoles, or stalks, that spring up between the leaves, which, though suitable to the composition, are not so elegant as in the Corinthian order.

It does not appear quite satisfactory to us why the examples included under this description, should be especially entitled to the term Roman, for the Corinthian has quite an equal claim ; they both owe their existence to the Romans. Why, indeed, any such marked distinction should be set up between the two, is not quite clear, for they are evidently but different modifications of the same idea ; and we think there can be discovered as much diversity in examples included under the term Corinthian, as between them and the Composite.

We subjoin a list, extracted from one of Mr. Weale's works, showing the proportions of the order in various examples.

	Base.	Column.	Capital.	Architrave.	Frieze.	Cornice.	Entablature.	Diam. of Column.
	Diam. Mod. Ht.	Diam. Mod. Ht.	Diam. Mod. Ht.	Diam. Mod. Ht.	Diam. Mod. Ht.	Diam. Mod. Ht.	Diam. Mod. Ht.	Ft. Inch.
Arch of Titus	0 0 23	10 0 6	1 0 $14\frac{1}{4}$	0 1 16	0 1 14	1 0 2	2 1 2	2 $10\frac{0}{10}$
Arch of Septimius Severus	0 0 20	9 1 10	1 0 $5\frac{1}{2}$	0 1 15	0 0 $25\frac{1}{2}$	1 0 $8\frac{1}{2}$	2 0 19	2 $0\frac{2}{10}$
Baths of Diocletian	0 0 20	10 0 $29\frac{3}{4}$	1 0 11	0 1 $14\frac{1}{2}$	0 1 14	0 1 21	2 0 $19\frac{1}{2}$	—
Palladio	0 1 $1\frac{1}{2}$	10 0 0	1 0 0	0 1 10	0 1 4	0 1 20	2 0 0	—
Scamozzi	0 1 0	9 1 15	1 0 0	0 1 9	0 1 $1\frac{1}{4}$	0 1 $16\frac{3}{4}$	1 1 27	—
Vignola	0 1 0	10 0 0	1 0 0	0 1 15	0 1 15	1 0 0	2 1 0	—
Caryatides of the Temple of Pandrosus	—	5 0 0	0 0 27	0 1 $25\frac{1}{2}$	0 1 0	1 0 0	1 1 $25\frac{1}{2}$	—

The example of the Roman order which we have given, is from that exquisite remain of antiquity, the arch of Titus, at Rome.

ROMANESQUE ARCHITECTURE, a term applied to different purposes by various writers ; but the most useful and consistent application seems to include all the various kinds of building which originated from the Roman, and which appeared after the decline of art in that country, but with this limitation, that they still retain the semicircular arch. Under this general title, then, will be embraced the debased Roman, the Byzantine, Lombardic, Saxon, Norman, and the several varieties of the same class. For further information, *see* the above articles.

ROOD, a crucifix more especially applied to those which were placed in an elevated situation at the east end of churches between the nave and chancel. They were of large dimensions, and usually of wood, with figures of the Virgin and St. John placed on either side, and at the foot of the upright arm of the cross.

Rood Beam, a beam carried over the entrance to the chancel, for the purpose of supporting the rood.

Rood Loft, an elevated loft or gallery occupying a similar position to the rood-beam, but resting or appearing to rest on a screen below. It was usually spread out from the top of the screen on both sides of it, so as to give a landing at top of sufficient space for the rood-screen, and for the passage of persons to and fro. It was from this place that a part of the Romish service was performed. The soffit of the loft on either side of the screen, was either coved, or in the form of a semi-vault, with groining and ribs. The loft was approached by a staircase in the chancel-pier or main walls of the church, and these are frequently the only evidence of the existence of the loft.

Rood-Screen, the screen of open work which in most churches separated the nave and chancel ; the lower portion being panelled, and the upper perforated with rich tracery-work in the head. In the centre was a door, or pair of gates giving admission to the chancel. Such screens were usually of wood, but sometimes of stone, especially in cathedrals and larger churches ; they are also sometimes double ; as at St. David's Cathedral, and Gilden Morden, Cambridgeshire. Rood-screens, as well as the loft, and rood itself, were often of most elaborate workmanship, highly decorated with gilding and colour.

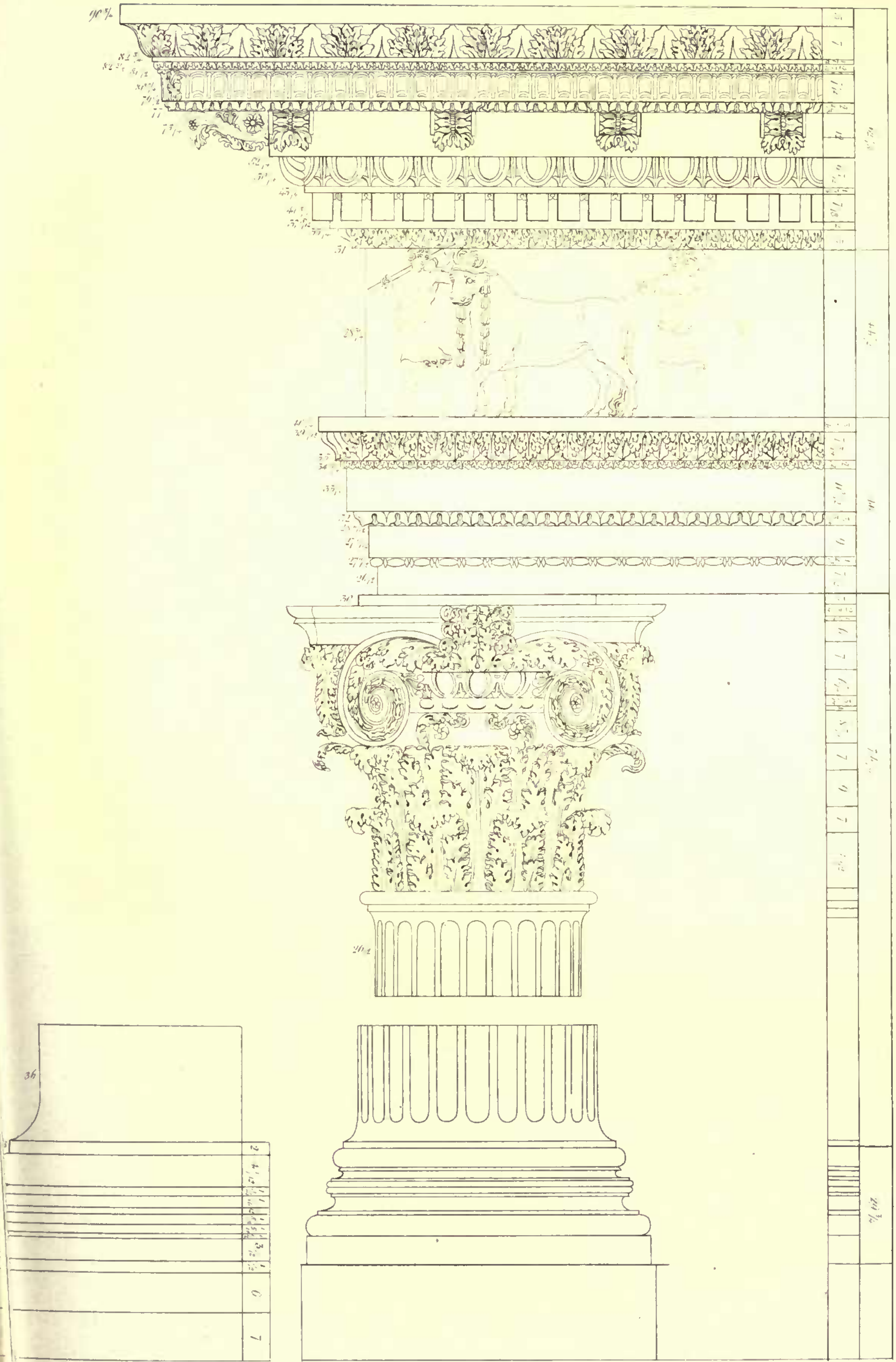
Rood Tower, the tower at the intersection of nave and transepts.

ROOF, (from the Saxon, *hrof,*) the cover, or top of a building, generally consisting of two sloping sides, though occasionally of other figures.

The ancient Egyptians, Babylonians, Persians, as well as other Eastern nations, had their roofs quite flat. The Greeks appear to have been the first who made roofs with a declination each way from the middle to the edges ; this was very gentle, the height from the ridge to the level of the walls not exceeding one-ninth or one-eighth part of the span, as may be seen by many ancient temples now remaining. In northern climates, subject to heavy rains and falls of snow, the ridge must be very considerably elevated. In most old buildings in Britain, the equilateral triangle seems to have been considered as the standard, both in private and public edifices ; and this pitch continued for several centuries, till the disuse of what is called Gothic architecture. The ridge was then made somewhat lower, the rafters being *three-fourths* of the breadth of the building. This was called *true pitch ;* but, subsequently, the *square* seems to have been considered as the true pitch. The heights of roofs were gradually depressed from the square to *one-third* of the width, and from that to *a fourth*, which is now a very general standard ; though they have even been executed much lower. There are some advantages in high-pitched roofs, as they discharge the rain with greater facility ; the snow continues a much shorter time on the surface, and they are less liable to be stripped by heavy winds. Low roofs require large slates, and the utmost care in execution ; but they have the advantage of bein

ROMAN ORDER

PLATE I.



much cheaper, since they require shorter timbers, and of a much less scantling. When executed with judgment, the roof is one of the principal ties to a building; as it binds the exterior walls to the interior, and to the partitions, which act like strong counterforts against them.

Roofs are of various forms, according to the nature of the plan, and the law of the horizontal and vertical sections. The most simple form of a roof is that which has only one row of timbers, arranged in an inclined plane, which throws the roof entirely to one side. This is called *a shed-roof*, or *lean-to.* The most elegant roof for a rectangular building, consists of two rectangular planes, of equal breadth, equally inclined, and terminating in a line parallel to the horizon; consequently, its form is that of a triangular prism, each side being equally inclined to the plane of the wall-head. This is sometimes called a *pent-roof.*

When the plan is a trapezium, and the wall-heads properly levelled, the roof cannot be executed in plane surfaces, so as to terminate in a level ridge. The sides, therefore, instead of being planes, are made to wind, in order to have the summit parallel to the horizon; but the most eligible method is to make the sides of the roof planes, enclosing a level space, or flat, in the form of a triangle, or trapezium, at the summit of the roof. Roofs flat on the top are said to be *truncated:* these are chiefly employed with a view to diminish the height, so as not to predominate over that of the walls.

When all the four sides of the roof are formed by inclined planes, it is said to be *hipped*, and is, therefore, called a *hipped-roof;* and the inclined ridges springing from the angles of the walls are called *hips.* Roofs of this description are frequently truncated; and when the plan of the walls is in the form of a trapezium, the truncation of the roof becomes necessary.

Roofs upon circular bases, with all their horizontal sections circular, the centres of the circles being in a straight line drawn from the centre of the base perpendicular to the horizon, are called *revolved-roofs*, or *roofs of revolution.*

When the plan of the roof is a regular polygon, or a circle, or an ellipsis, the horizontal sections being all similar to the base, and the vertical section a portion of any curve convex on the outside, the roof is called *a dome.*

To save the expense of lead in the roofs of rectangular buildings, instead of the flat, a valley is sometimes used, which makes the vertical section in the form of the letter M, or rather an inverted W; and hence it has obtained the name of *an M roof.*

Definitions.—In order to be understood by the reader, it will be necessary to explain such terms as are used in the subsequent part of the article, by way of definitions.

Wall-plates, pieces of timber laid on the wall, in order to distribute the pressure of the roof equally, and to bind the walls together. They are sometimes called *raising-plates.*

Trusses, strong frames of carpentry, generally of a triangular form, supporting the covering. They are disposed at equal distances, and are used when the expansion of the walls is too great to admit of common rafters alone, which would be in danger of being bent or broken by the weight of the covering, for the want of some intermediate support. They are variously constructed, according to the width of the building, the contour of the roof, and the circumstances of walling below, &c.

Tie, any piece of timber connected at its extremities to two others, acted upon by opposite pressures, which have a tendency from each other; or, to extend the tie, as a rope or chain.

Straining-piece, a piece of timber, connected at its extremities to two others, acted upon by opposite pressures, which have a tendency towards each other.

Hence, a tie acts contrary to a straining-piece. A chain, rope, or small bar of iron, may be used for the former; but the latter must always be inflexible, being in a state of compression.

Principal rafters, two pieces of timber in the sides of a truss, supporting a grated frame of timber-work over them, on which the slating or covering rests.

Purlins, horizontal pieces of timber fixed upon the principal rafters.

Tie-beam, a horizontal piece of timber, connected to two opposite principal rafters. It answers a twofold purpose, viz., that of preventing the walls from being pushed outwards by the weight of the covering, and of supporting the ceiling of the rooms below. When placed above the bottom of the rafters, it is called *a collar-beam.*

Common rafters, pieces of timber of a small section, placed equidistantly upon the purlins, and parallel to the principal rafters: they support the boarding to which the slating is fixed.

Pole-plates, pieces of timber resting on the ends of the tie-beams, and supporting the lower ends of the common rafters.

King-posts, an upright piece of timber in the middle of a truss, framed at the upper end into the principal rafters, and at the lower end into the tie-beam: this prevents the tie-beam from sinking in the middle.

Queen-posts, two upright pieces of timber framed below into the tie-beam, and above into the principal rafters, placed equidistantly from the middle of the trruss, or its extremities.

Struts, oblique straining-pieces, framed below into the king-posts or queen-posts, and above into the principal rafters, which are supported by them; or sometimes they have their upper ends framed into beams, which are too long to support themselves without bending. They are often called *braces.*

Puncheons, short transverse pieces of timber fixed between two others for supporting them equally, so that when any force operates on the one, the other resists it equally; and if one break, the other will also break. These are sometimes called *studs.*

Straining-beam, a piece of timber placed between two queen-posts at the upper ends, in order to withstand the thrust of the principal rafters.

Straining-sill, a piece of timber placed at the bottom of two queen-posts, upon the tie-beam, in order to withstand the force of the braces, which are acted upon by the weight of the covering.

Camber-beams, horizontal pieces of timber, made on the upper edge, sloping from the middle towards each end, in an obtuse angle, for discharging the water. They are placed above the straining-beam in a truncated roof, for fixing the boarding on which the lead is laid; their ends run three or four inches above the sloping plain of the common rafters, in order to form a roll for fixing the lead.

Auxiliary rafters, pieces of timber framed in the same vertical plane with the principal rafters, under and parallel to them, for giving additional support, when the extent of the building requires their introduction. They are sometimes called *principal braces* and sometimes *cushion-rafters.*

Joggles, the joints at the meeting of struts with king-posts, queen-posts, or principal rafters; or, at the meeting of principal rafters with king and queen-posts: the best form is that which is at right angles to the struts.

Cocking, or *cogging*, the particular manner of fixing the tie-beams to the wall-plates: one method is by dove-tailing, the other is by notching the under side of the tie-beam, and cutting the wall-plate in a reverse form to fit it. This method is far preferable to the other, as it is not liable to be drawn, which the other is very subject to when the timber shrinks.

Ridge-tree, a piece of timber fixed in the vertex of a roof, where the common rafters meet on each side of it; the upper edge of it is higher than the rafters, for the purpose of fixing the lead which goes over it to cover the ends of the slates in the upper course.

Straps, thin pieces of iron running across the junction of two or more parts of a truss, or frame of carpentry, branching out from the intersection in the direction of the several pieces, for the purpose of securing them to each other. They ought always to be double, viz., one strap on each side, and their ends strongly bolted to each of the pieces.

The uses of these various parts will be illustrated in what follows; and here, it may be proper to observe, that though every one of the parts above defined *may* be found in the same roof, it is not necessary that a complete roof should have them all; the introduction of many of them depends on the distance of the walls, the contour of the roof, the partitions below, the quantity of head room wanted in the garrets, &c.

Other names of timbers will be fully illustrated in the descriptions of other roofs, in due order of succession.

Before we proceed to the construction of roofing, it will be necessary to show upon what principles a body, or piece of timber, may be supported in various positions.

Proposition I. *Plate* I. (*of Mechanical Carpentry*) *Figure* 1.—*If a heavy body*, A B C D, *be suspended by any two inclined strings*, D E *and* C F, *in a vertical plane, a right line drawn through the intersection, perpendicular to the horizon, will pass through the centre of gravity of the body.*

It is shown by the writers on mechanics, that if any three forces act upon a point, or a body, their directions will tend to the same point, or be parallel to each other. It is well known that every body acts with its full force in one point only, viz., its centre of gravity, and in a direction perpendicular to the horizon: therefore, if a body be sustained at E and F, it will revolve round these points, till the line, G H, passing through the intersection, H, of the two strings, D E and C F, and the centre of gravity, G, becomes perpendicular to the horizon.

Corollary 1.—Hence, if any body be supported by two strings, it may also be supported by two planes perpendicular to those strings, provided the two points of the body supported be in the direction of the strings; for every body acting upon a plane acts in a line perpendicular to that plane.

Corollary 2.—Hence, also, a body may be supported by two props in any two directions that it may be supported by strings, provided the surface of the body, at the points of contact, or the ends of the props, be planes, at right angles to the strings.

Corollary 3.—Hence, all the properties that have been demonstrated of three forces acting upon a body supposed to be void of weight, will equally flow from a heavy body supported by two strings, by substituting the weight of the body for the middle force; and hence, if the direction of any force supporting a heavy body be given, the other may easily be found.

Proposition II.—*Given the position in which a body should be placed, and the position of a plane supporting the body at one end; to find the position of another plane to support it at another given point, and to find the pressure on the planes, the weight of the body being given.*

Through the centre of gravity of the body draw a vertical line, and through any point on which the body rests on the given plane, draw a line perpendicular to that plane, meeting the vertical line: from the intersection draw a line to the other point, which is to be supported; from that point draw a plane at right angles to this line, which will be the direction of the plane required.

To find the intensity of the forces, take any distance on the vertical line, to represent the weight of the beam, from the intersection; on that line, as a diagonal, complete a parallelogram, whose sides are in the directions of the lines perpendicular to the supporting planes; and the side of the parallelogram, perpendicular to either plane, will represent the force on that plane.

Example 1. *Figure* 2.—Let the body, A B C D, lie upon the top of the wall, K C at C, so as to touch the lower edge, B C, of the body, at that point, C; it is required to find the direction of a plane that will support the lower end at B, and to find the pressure of the body on the wall and on the plane.

Through the centre of gravity, G, of the body, draw the vertical line G F; draw C F perpendicular to C B; join F B, and draw B I perpendicular to F B; and B I will be the direction of the plane required. On the vertical line, G F, make F M to represent the weight of the body, and complete the parallelogram L M N F; then F N will represent the force on the wall-head, in the direction F C; and F L the force acting perpendicular to the plane, or in the direction B F. But if the vertical and horizontal thrusts on the wall at C be required, draw N P perpendicular to F G, meeting it in P; then the force, F N, will be resolved into two forces, F P and P N. P N will represent the horizontal part of the force, viz., that which pushes the wall in a direction parallel to the horizon; and F P the other part, which tends to press it downwards in a direction perpendicular to the horizon.

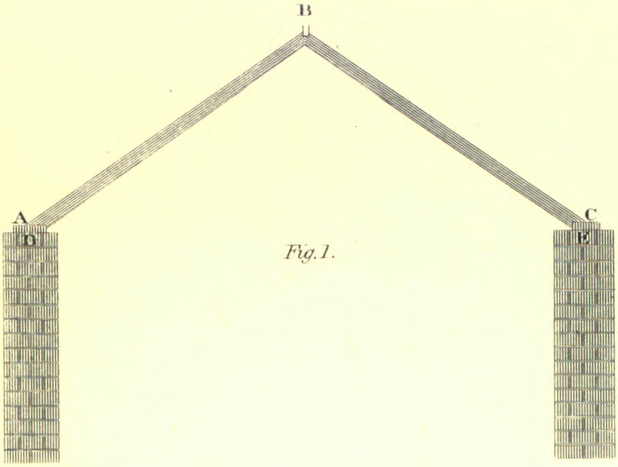
Example 2. *Figure* 3.—Let the sloping body, A B C D, be supported by a wall at its lower end, D, which coincides with the surface of the body, and let G be the centre of gravity; it is required to cut a notch out of the body, at the upper end, C, so that it may rest upon the top of a wall, which is made to fit the notch, and to find the pressure on the walls.

Draw the vertical line, G E; from D draw D E perpendicular to D C; join E C, and make C F at right angles to it; then, the notch H C F being cut, the body, A B C D, will be at rest. To find the pressure on the walls, complete the parallelogram, E I K L, having a given angle, D E C, and its diagonal on the given line, E O; then, if K E represent the weight of the body, I E will represent the pressure in the direction D E, upon the wall at D, and L D the pressure in the direction C E, The horizontal and perpendicular pressures upon each wall may be found, as in the preceding example, by resolving each of the forces I E and L E, into two; one of which is perpendicular to the horizon, and the other parallel to it.

Scholium.—It must be observed in this example, that the notch, which is cut out at C, will remove the centre of gravity nearer to the lower end, D, and consequently alter the slope, C F; but as this can only be in a very small degree, the equilibrium will hardly be affected by it, when the notch is very small.

Example 3. *Figure* 4.—Let one of the corners of a sloping body, A B C D, rest upon the top of a wall at D, which is quite level: it is required to find the position of a notch, cut out of the upper end, C, so that the body may rest upon a wall made to fit the notch.

Let the small part, F C H, be so cut that C H may be parallel to the horizon, then the body will be supported by the two walls at C and D. For, draw D I, O K, and C L perpendicular



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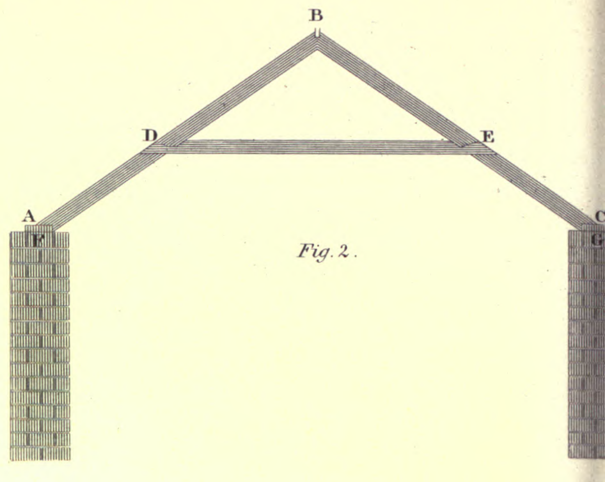

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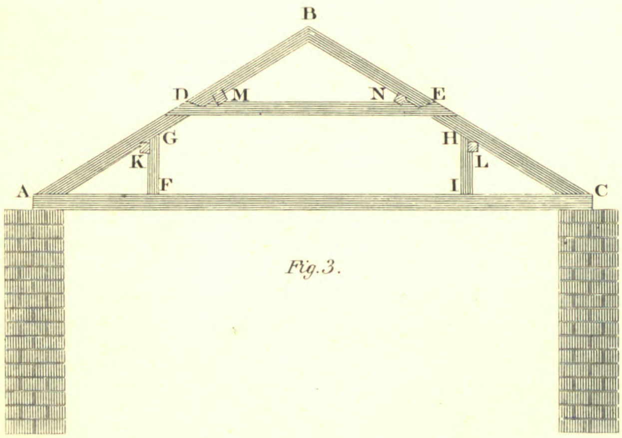

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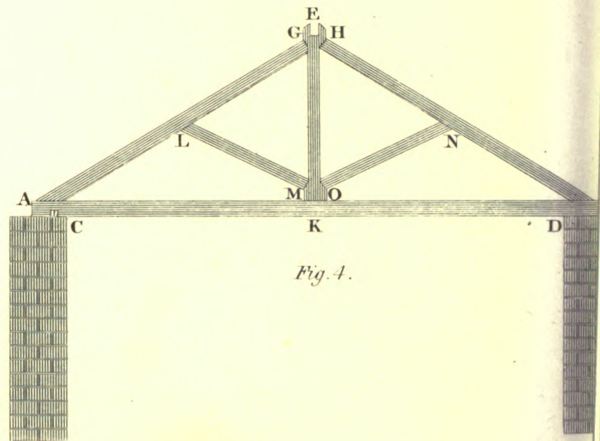

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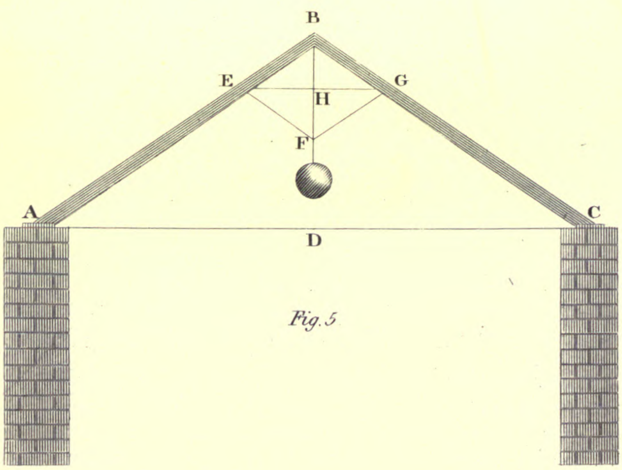

Fig. 5

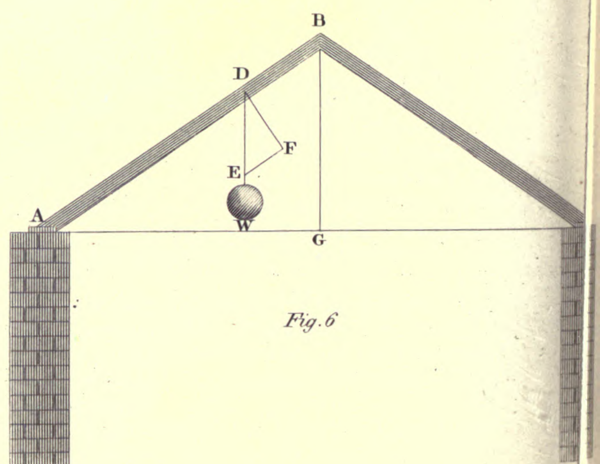

Fig. 6

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to the horizon, these lines being produced, they may be supposed to meet at an infinite distance. To find the pressure on the walls: join D C, and produce the vertical line, K G, to meet it in E; then, if G be supposed to be the weight of the body, the pressure on D will be $\frac{EC \times G}{DC}$, and the pressure on C $= \frac{DE \times G}{DC}$.

Example 4. *Figure* 5.—Let the body, A B C D, lie with its upper end against the vertical face of a wall at C; it is required to find the position of a plane supporting the lower end, D, so that the body may be at rest.

Draw the vertical line G E; also C E perpendicular to the face of the wall, C L; join E D, and draw D F perpendicular to E D; then D F will be the position of the plane required. Complete the parallelogram, E H I K; then the pressure on D and on C, and the weight of the body, will be to each other as E H, E K, E I.

Example 5. *Figure* 6.—To support a body, A B C D, by two props at two given points, E and I, the direction of one of the props, E F, being given:

Draw the vertical line, G K; produce F E to K; draw K I H; and I H will be the prop required. On the vertical line, G K, take K M to represent the weight of the body; and on K M, as a diagonal, describe the parallelogram, K L M N; then K L will be the compression of the prop E F, and K N the compression of the prop I H.

CONSTRUCTION.—*Plate* II. *Figure* 1.—Of common roofs, the simplest construction is that which consists of two rafters, as A B and B C; D and E are wall-plates, on which the feet, A and C, of the rafters rest; the bottoms of the rafters are cut in the form of a right angle (called by the workmen *a bird's mouth*) reversed to the wall-plate, and are fixed to it with nails; but this form can only be applied to buildings that have their walls at no great distance from each other.

Figure 2.—The next form is that of having two rafters, as A B, B C, a collar-beam, D E, with two wall-plates, F and G, below. This form will admit of a greater distance between the walls than the other: the beam is placed in the situation D E, in order to give head-room within; but when the span, F G, of the walls is considerable, the parts A D and C E being considered as levers, and acted upon by the reaction of the walls, the rafters are either liable to be broken at the points D and E, or curved with a concavity on the upper edges.

Figure 3.—The third form of common roofs consists of two rafters, A B, B C; a tie-beam, A C, for preventing the rafters from pushing out the walls; a collar, or straining-beam, D E, and two puncheons, or studs, F G and H I, for keeping the rafters straight; this construction is used for cheapness, and may be executed with safety in houses not exceeding 45 feet wide; but it is necessary to have partitions immediately below, or at no great distance from the studs. Instead of supporting every opposite pair of rafters, as in this example, it happens, in many roofs of this construction, that the rafters take the place of principals, and are fixed at 7, 8, 9 or 10 feet from each other; while purlins run over the heads of the puncheons at K and L; and, at the ends of the collar-beams, at M and N, between every two rafters, smaller rafters are fixed to the purlins, the wall-plates at bottom, and the ridge-tree at the top.

Figure 4.—The most simple construction of a truss consists of the following parts:—A B the tie-beam, cocked upon the wall-plates, C and D; E K the king-post; A G and B H principal rafters, fixed to the king-post at the joggles, G and H; M and N O struts, mortised into the rafters at L and N, and joggled to the king-post at M and O.

PROPOSITION III.—*In any roof constructed with two equal rafters only; as the height of the roof is to half the breadth of the building, so is half the weight of the roof to the horizontal thrust, or lateral pressure.*

Figure 5.—Let A B C be a roof, having the two equal rafters, A B, B C; join the bottom of the rafters, A C; draw B D perpendicular to it; complete the parallelogram B E F G, and draw E G, cutting B D in H. Then, because the triangles, B H E and B D A are similar,

B D : D A : : B H : H E.

Corollary 1.—Hence, in a roof with two rafters and a tie-beam at the bottom, the tension, H E, of the tie-beam is $= \frac{DA \times BH}{BD}$.

Corollary 2.—Hence, also, B D : B A : : B H : B E; that is, as the height of the roof is to the length of the rafter, so is half the weight of the roof, represented by B H, to the compression of the rafters $= \frac{BA \times BH}{BD}$.

Corollary 3.—Half the weight of the roof, the tension of the tie-beam, and the compression of the rafters, are to each other as the height of the roof, half the breadth of the span, and the length of the rafters; for the triangle B H E is similar to the triangle B D A.

PROPOSITION IV.—*If a rafter bear any weight, or have a weight uniformly diffused over it, the force tending to break it is equal to the cosine of elevation multiplied into the weight, divided by radius.*

Figure 6.—Let A B, B C, be two equal rafters; join A C, draw B G perpendicular to it meeting it in G; and let the weight W be suspended by the string D E. Draw D F perpendicular to A B, and E F parallel to it; then, if D E represent the weight, D F will represent the force tending to break the rafter; and E E its tendency to push it from B towards A.

Now because E F is parallel to A B, the alternate angles A D E and D E F are equal, and the angles D F E and A G B are right angles; the triangles E D F and B A G are similar; therefore A B : A G : : D E : D F $= \frac{AG \times DE}{AB}$; but if A G be made the radius, then D E will be the cosine of elevation; therefore R : cos' elevation : : D E : D F $= \frac{\text{cos' elevation} \times DE}{R}$

Corollary 1.—Hence the weight employed, the pressure in a direction of the length of a rafter at A, the tendency to break it, are as radius, the sine, and cosine of elevation.

Corollary 2.—Because D F $= \frac{\text{cos' elevation} \times DE}{R}$, and because the stress is as the length, when the weight is given, the stress is as the cosine of elevation multiplied into the weight, and this product multiplied into the length of the rafter; the radius being a constant quantity.

PROPOSITION V.—*To prevent the rafters of a roof, with a tie-beam, from bending in the middle; and to remove lateral pressure from the walls, when there is no beam.*

A variety of methods may be used for this purpose; but the best are those in which the shortest and least quantity of timber are employed, without producing a transverse strain upon any part. When a roof consists of two rafters only, no part of the rafters can be loaded between their extremities; nor indeed will they bear their own weight without producing a concavity on the upper side, which will be greater as the length of the rafter and weight applied to it are greater. Now, because the shorter the rafters are at the same elevation, the greater weight they will bear, and be more able to support their own weight; the object is to support them by a sufficient number of fixed points, either from the roof itself, or from other immoveable places. There are three points for this purpose; if the rafters have a tie-beam below, that is, at the vertex, and at the two extremities of the rafters, the triangle being immoveable at the angles, every force applied there tends either to compress or extend the sides of the frame, without a transverse strain.

Examples.—Let it be required to divide each of the rafters into three equal lengths, in order to support two purlins on each side; this may be done, as in *Plate* III. *Figure* 1, by pieces, C E, C D, A G, A F, reaching from the two lower angles, C and A, and to the opposite sides of the rafters, A B and B C, intersecting each other at H and I, and halved upon each other at these intersections: this mode prevents the rafters from sagging, but does not afford any support to the tie-beam. The meeting of so many braces at the same point, too, gives little opportunity of making the ends entirely secure, even though assisted by iron straps.

Another mode may be by introducing a king-post. B K, *Figure* 2, to which the struts, D H, E I, F M, G L, may be firmly joggled at H, I, M, L, and mortised to the rafters at D, E, F, G: this method keeps up the middle of the beam; but when the roof is low, and the span great, the struts, D H and F M, require themselves to be supported, and are much too oblique to prevent a change of figure.

Another method may be, as in *Figure* 3, with the king-post in the middle, as before, two queen-posts under the rafters at E and F, two struts, H E and I F, joggled to the bottom of the king-post at H and I, and to the top of the queen-posts at E and F; and in order to secure the points N and P, two other braces, N Q, P R, are joggled to the bottom of the queen-posts at Q and R, and mortised into the rafters at the upper end. This construction supports the tie-beam in three different points, and each of the rafters in two. The timbers are much shorter than those of the preceding; but so many joggles are certainly an objection to this method, as the shrinking of the timber must be very considerable in three breadths, which would allow the roof to descend.

When the span is great, and the points to be supported many, an excellent method may be as in *Figure* 4, where there are two arches of cast-iron, or good English oak, introduced, which abut on the king-post, and at the other extremity at the ends of the beam. The rafters and the beam, by this mode, may be supported by as many equidistant points as we please.

When the tie-beam is removed from the bottom, as in *Figure* 5, and no fixed points are to be found from below, a longitudinal truss may be constructed, the end of which is shown at A B, and the manner of framing it in *Figure* 6, the two ends being supposed to be firmly fixed into the gables; but where the length is great, the form of *Figure* 7, with a parabolic arch, would be much better: by this method, the rafters will be kept nearly in the same plane, and all lateral pressure from the walls will be removed; for it is evident that if the ridge-tree is supported, there can be no motion downwards in the direction of the rafters, the whole roof being hung to this longitudinal frame.

Proposition VI.—*Figure* 8.—If a roof be constructed with two equal rafters, A M, C M, with a tie extending from the bottom of each to an intermediate point in the opposite rafter, and the ties halved together at their intersection, B, so as to form with the rafters a quadrilateral, M D B E, at the vertex, and two triangles, A D B and C E B; then, if M D be equal to M E, and C P represent the direction and quantity of force on the wall at C, the force tending to break the rafters at D and E is $\frac{\text{S. PCK} \times \text{S. DME} \times \text{LK} \times \text{DM}}{\text{S. LCK} \times \text{R}}$.

For completing the parallelogram P C L K; making [...] equal to C L; and N O parallel, and M O perpendicular to A M, [...] triangles C B E and A B D may be looked upon as solid lev[...] (at least with regard to forces applied to the angles) movea[...] round B. Then the force C P will communicate the force [...] to the rafter, and C L is the power acting obliquely at M u[...] the rafter A M: then because N O is parallel, and O M perp[...]dicular to A M, O M is the force tending to break the raf[...] at D, and O N that pushing it towards A: therefore, let M[...] be considered radius, and O M will be the sine of the an[...] D M N, or D M E; for produce A M to Q, and the angle N M[...] will be the supplement of the vertical angle D M E; theref[...] the sine of N M Q, equal to the sine of the angle M N O, is [...] same with the sine of N M A; then by trigonometry,

LK : LC :: S. LCK : S. CKL or S. PCK

NM or LC : MO :: R : S. DME = S. MNO;

therefore, LK : MO :: S. LCK × R : S. PCK × S. DME.

Hence $\text{MO} = \frac{\text{S. PCK} \times \text{S. DME} \times \text{LK}}{\text{S. LCK} \times \text{R}}$ = the force acti[...] perpendicular to A M at M; but the force tending to bre[...] the rafter at D is as the lever D M multiplied into this forc[...] that is $= \frac{\text{S. PCK} \times \text{S. DME} \times \text{LK} \times \text{DM}}{\text{S. LCK} \times \text{R}}$.

Corollary 1.—Hence, if the angle D M E is a rig[...] angle, the force tending to break the rafter at D will [...] $\frac{\text{S. PCK} \times \text{LK} \times \text{DM}}{\text{S. LCK}}$.

Corollary 2.—Hence the rafters of every roof of this co[...]struction must sag in a greater or less degree, by the acti[...] of the rafters against each other at the point M; that is, th[...] will be bent into curves concave on the upper edges; but [...] a diagonal connect the two vertical points M and B, th[...] change of figure will be prevented.

Proposition VII.—*To remove the lateral pressure of [...] roof without any intermediate beam, brace, or strut.*

Plate IV. *Figure* 1. No. 2.—Let A B, B C, be two rafte[...] and let there be constructed a strong wall-plate, D E F G, No. [...] firmly bolted together at the angles; then if the roof [...] to be gable ended, after having fixed the rafters to a comm[...] ridge-tree, let two curves be made of cast-iron or go[...] English oak, of a parabolic form, and let into the rafters, eith[...] on the upper or under surface, and firmly secured to them b[...] bolts or nails, and at their lower extremities to the angles [...] the wall-plates, the vertex of each curve meeting the ridg[...] piece on each side of it or nearly so, as may be convenien[...] One half of the plan, No. 1, exhibits the form for th[...] execution of a gable-ended roof, and the other for a hippe[...] roof. The two sides, laid in plano for each form, are show[...] in No. 3 and No. 4; at H I K L and M N O P, H L and D[...] represent the same wall-plate; D G, N O, and E F anoth[...] wall-plate, I K and M P meeting the ridge on each side of i[...] but it must be observed when the roof is to be hipped, th[...] the ridge-tree must be very strong, as the compressure wi[...] be very great, the hip-rafters acting like powerful braces [...] its extremities. Hence it is evident that the wall-plates ac[...] as the tie-beams of a common roof, and the curves as th[...] rafters; or, more naturally, like an arch of a bridge in equ[...]librio. It has already been shown that equal weights acting in equidistant lines, require an arch of a paraboli[...] form to keep them in equilibrio. In this it is to b[...] considered, that as the arches are placed with their crow[...] upwards, they are in a state of compression, and may be go[...] out very conveniently in several lengths; but if the arche[...] were inverted, they would be in a state of tension; each arc[...] must then be in one piece, as the ridge would be compresse[...]

ROOF.

Fig. 1.

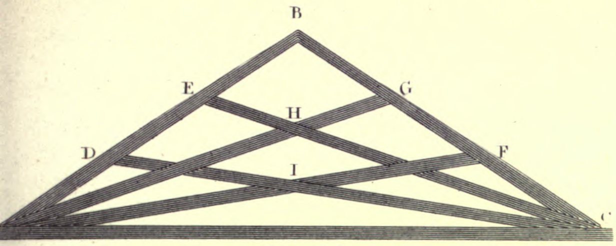
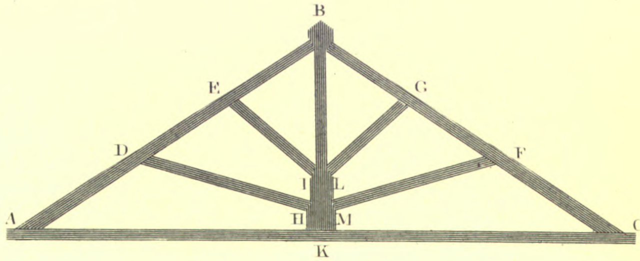


Fig. 2.



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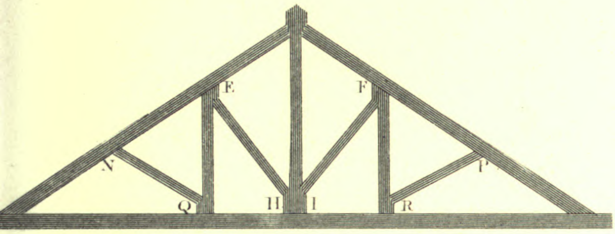

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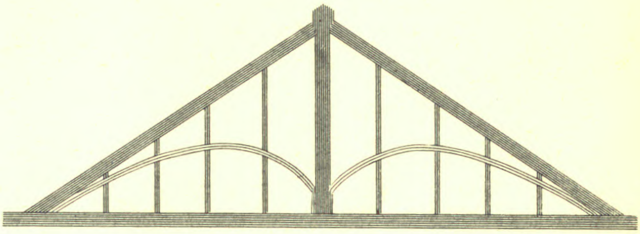

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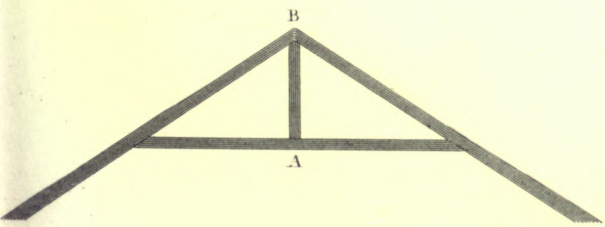


Fig. 8

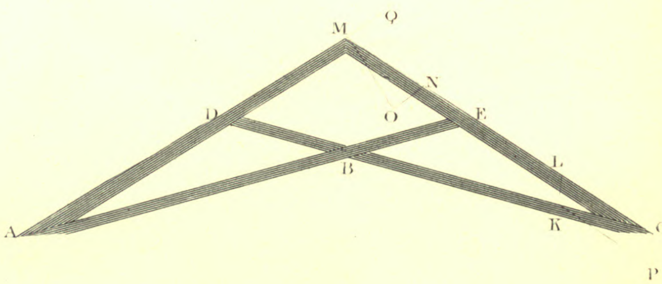
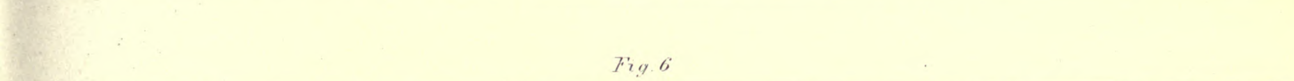


Fig. 7.

Fig. 6



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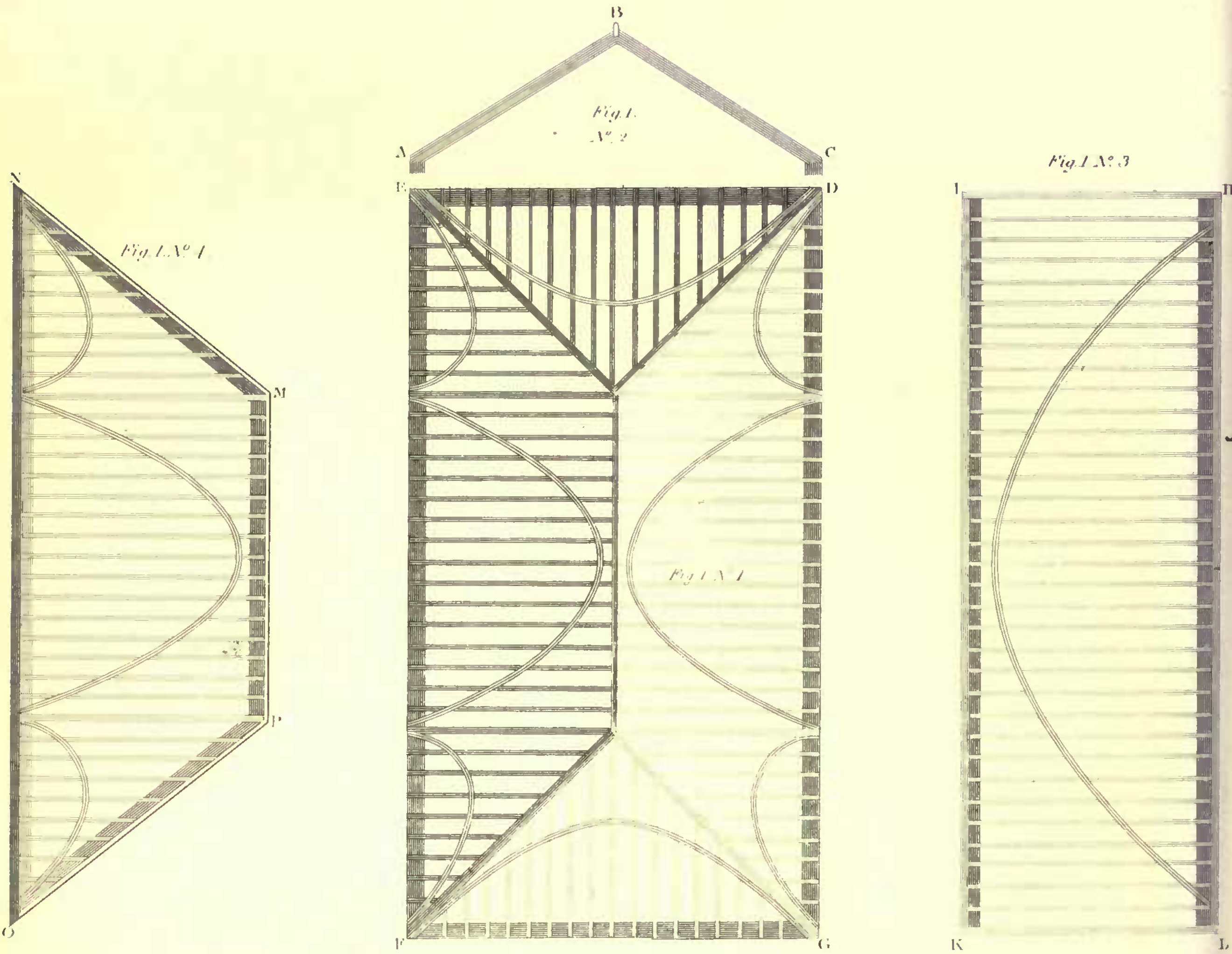

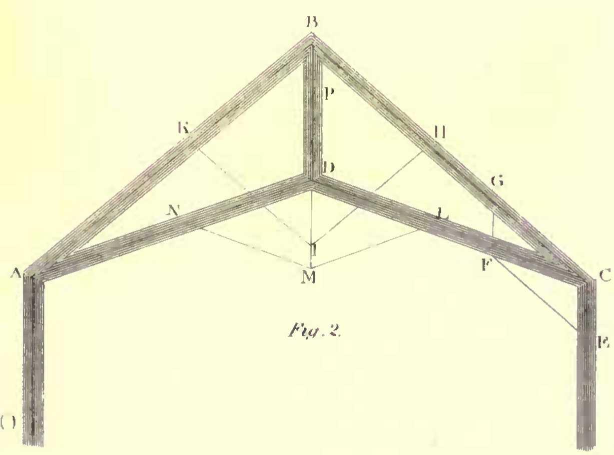

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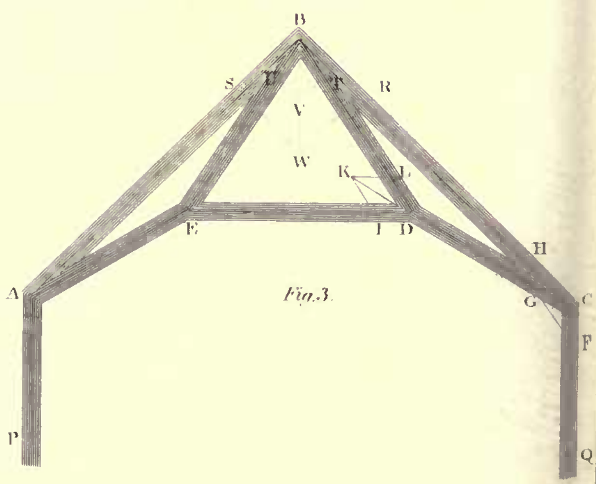

Fig. 3.

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by the tension of the two curves. This inverted disposition of equilibration is not so secure as when the crown of the arches either meets the ridge or lies towards it.

Though the above construction will prevent lateral pressure, it will not hinder the rafters from sagging; but the addition of a collar-beam will effectually answer this purpose in all moderate spans.

PROPOSITION VIII.—*Given the construction of a roof, of which not more than three timbers meet at the same junction, and a force in the direction of any one of the timbers; to find the forces communicated to the other timbers, so that the roof shall be in equilibrio.*

Begin with the given force, and take a part of the line of its direction from the junction to represent it; then, with the other two directions, complete a parallelogram, and apply them from the next junctions on the same straight line from which they were taken, and complete parallelograms, as before. Proceed in this manner, from one junction to another, until parallelograms have been made at every one. Then the parts of these parallelograms, in the directions of the timbers, are the forces in these directions; and to ascertain the state of tension or compression of any timber, observe that when two of the angles formed by three directions are less than two right angles, the middle force acts always contrary to the two extreme ones, as has already been explained; and that when any two of the angles of direction are greater than two right angles, then the forces will act towards or from the same point.

Example 1.—*Figure* 2.—Let A B C D A be a roof, consisting of two rafters, A B, B C, two beams, C D, D A, and a king-post, D B, supported by the walls A O and C E. Let C E represent half the weight of the roof, or the reaction of the wall, C E; complete the parallelogram C E F G; make D L equal to F C, and complete the parallelogram L M N D; then C F, or D L, is the force in the direction of the beam C D, or A D, and D M is the force in the direction of the post D B; now, because the angles E F C and F C G are less than two right angles, and because the point C is pressed by the reaction of the wall E C, it will also be pressed by the force G C, and drawn by the force C F; therefore the beam C D is in a state of tension, and the rafter B C in a state of compression. Again, because C D B and B D A are greater than the two right angles, and because C D is in a state of tension, B D and D A are also in a state of tension.

If B H be made equal to G C, and the parallelogram B H I K completed, and if B P be made equal to D M, then will P I be equal to twice C E, the pressure on the walls.

Example 2.—*Figure* 3.—Let A B C D E A be a roof, supported by walls in the directions P A and Q C, and let there be two pieces of timber, B D and B E, connecting the angular points, D and E, to the ridge at B.

Take C F to represent half the weight of the roof, or the reaction of the wall Q C: complete the parallelogram C F G H; produce C D to K; make D K equal to G C, and complete the parallelogram D I K L; then G C, or D K, is the force in the direction of the timber C D or A E, and is in a state of tension, because the angles F C G and G C H are less than two right angles, and because C F is in a state of compression; C H, the force in a direction of the rafter B C, is also in a state of compression; and because any two of the three angles, G D B, G D E, E D B, are greater than two right angles, and D C is in a state of tension, the two pieces, D B and D E, are also in a state of tension; that is, E A, E D, E D, D D, D C, are all ties. The force in D B or E B is D L, that in D E is D I.

If D R and B S be made equal to C H, and the parallelogram B R W S completed; and if B T and B U be made equal to L D, and the parallelogram B T V U completed, then will V W be equal to twice C F; that is, by reducing the force in the direction of the pieces B E and B D to an equivalent one.

PROPOSITION IX.—*Given the lengths* A B, B C, C D, D E, *of the rafters of a roof and their angles of position, to find those angles that require ties, and those which require struts.*

Plate V. *Figure* 1.—Let A B be to B C as 3 to 4, that is, as 6 to 8, the proportion of the weight of the rafters; then if 8 be taken for the weight of each of the upper rafters, $\frac{8+8}{2} = 8$ will be the weight on the vertical angle C, and $\frac{6+8}{2} = 7$, will be the stress on each of the vertical angles B and D, so that the weight on the vertical angle is to that on each of the lower angles, as 8 to 7. Draw the vertical line D G F, and draw A G, A F, parallel to the rafters B C, C D; then if F G be to G B as 8 to 7, the rafters will be in equilibrio, and require no ties. But suppose it should be found that F G is to G B as 1 to 2; as that will keep it in equilibrio, it would require a very considerable addition laid on the angle, D, to keep it from springing outward, so that if two braces, F G and K L, No 2, were fixed to the rafters, A B, B C, C D, D E, these would be in a state of compression; and if the brace, H I, were fixed at the top, it would be in a state of tension: F G and K L only require firm butments, but H I to be well bolted. It may here be observed, that if the vertical angle only be braced and secured to the two rafters, the whole frame will then be immoveable.

PROPOSITION X.—*To discover the effect of bracing the angles of a roof flat on the top, supported by puncheons at the bottom of the rafters, to accommodate a semicircular ceiling within.*

Figure 2. No. 1.—Let A B C D E F be the truss, divested of its braces, the bottoms of the puncheons resting firmly on the walls at A and F, and the joints at B, C, D, E, to be quite moveable, like rule-joints. Now, as this disposition of timbers would fall, and in falling, would assume the form of No. 2, the angles at C and D would become more and more obtuse, while those at A and E would, in the same proportion, become acute; the latter would, therefore, require straining-pieces, and the former ties; the straining-pieces must have good abutments, and the ties must be well bolted at their extremities.

Let No. 3 be the truss, with braces disposed in the lower angles; this disposition will bend the rafters B C, D E, and the puncheons, B A, E F, convex towards the outside, which is entirely occasioned by the braces, G H, N O: the camber-beam, C D, is no otherwise affected than by its own weight. Let it now be supposed, that the angles C and D, No. 4, are braced at I K, L M. In this disposition, the puncheons, B A, E F, are not affected in respect of transverse strains; the rafters C B, D E, and the beam C D, would all become concave on the outside; and the points B and E, at the bottom of the rafters and top of the puncheons, would be pushed out beyond the perpendicular of A and F, at the bottom: here it is necessary to observe that the effect produced in this case on the rafters C B and D E is contrary to the effect produced in No. 3, by the braces being disposed in the lower angles. Lastly, suppose that all the angles are braced, as in No. 5, it is evident, since the braces, H G, N O, produce a contrary effect to the braces K I, L M, these bending the rafters downwards, and those upwards, that the rafters C B and D E will become nearly straight, or assume an undulated line: the puncheons B A and E F, receiving the force of the braces H G and N O at the points G and O, must still be bent, so long as the under ends, G and O, of the braces do not coincide with the under ends, A and E, of the puncheons: in this case, there is no other remedy than by giving the puncheons a scantling sufficient to withstand this transverse strain, or horizontal thrust, at the points G and O; however, the shape of the contour may be pretty well secured by introducing two abutments, H I and M N, No. 6; these by being bolted through the two ends, will add greatly to the stiffness of the rafters B C and D E; the bolts that go through the upper ends may also serve for the braces I K and L M: the shape of the horizontal beam, C D, will likewise be very much preserved by the piece K L, bolted in three places, one at each end, into the braces I K and L M, and another in the middle: the contour of a roof, thus supported, would be quite unchangeable, if the rafters were inflexible; but, as this is not the case, and as they are acted upon transversely by the braces, the truss will therefore, in some degree, be expanded at B and E, and consequently occasion lateral pressure on the walls; it will, therefore, be unfit for an oblong building, without other precautions for this purpose. By inserting parabolic curves in the sides B C and D E, as in *Plate* IV. *Figure* 1, it will be effectually prevented.

In roofs of this description, joggle-pieces of wood should never be used, as their shrinking would tend greatly to alter the outline of the rafters.

Having laid down such principles as will enable the workman to judge of the strength and strain of timbers in the framings of carpentry, it will now be necessary to proceed to show the mode of constructing roofs to answer various purposes; to give some practical observations relative to their strength, and to show the various modes of joining timbers, the forms of traps, &c.

As we have above stated, the simplest form of a perfect trussed roof, consists of two principal rafters inclined to each other, and meeting at the apex, the lower ends being tied together by a horizontal tie-beam, to prevent their spreading and thrusting out the walls upon which they are supported. As, however, the gravity of this tie-beam, especially if of any considerable length, is apt to cause it to sag in the centre, between the bearings, it is necessary to provide another bearing for it between the walls, and this is effected by suspending it in the centre by means of what is termed a *king-post*, which, in its turn, is held up between the principal rafters at the apex of the roof. To assist in effecting the same object, the tie-beam is sometimes cambered or arched, but this plan can scarcely be recommended, for if the timbers settle, as in all probability they will do, the cambered beam being extended into a straight one is liable to push out the walls, and cause the mischief which it was intended to prevent. The better plan is, to camber the beam only on the upper side, the lower side being horizontal, so as to have the greater scantling in the centre; this plan, however, is not without objection, for by it you have the greater weight at the centre, where it is most effective to cause the beam to sag. To afford the same assistance to the principals, and to prevent their sagging by their own weight and that of the covering which they have to support, short struts are carried from their centre to the foot of the king-post on either side of it, and on this they have their support. In a truss of this kind we have the tie-beam and king-post in a state of tension, while the principals and struts are subject to compression. Roofs of this class are very common, and are adapted for buildings where the span is not above 30 or 35 feet.

When the span gets beyond this, it is necessary to suspend the tie-beam at more points, and first of all, at two where the extreme bearings are not much more distant. In this case two suspenders, termed *queen-posts*, are employed, holding up the tie-beam at two points equidistant from each other and from the walls of the building; the principals are not extended to meet each other at the apex, but terminate at the queen-posts against which they abut, and the queen-posts are retained at the required distance from each other by means of a *straining beam*, which also abuts against the head of the queen-posts, and by this means they are suspended. This description of truss is something like the first, if we suppose the king-post separated into two halves, with a horizontal strut placed between them, to prevent the principals from being pressed together; struts are also placed at the foot of the queen-posts, to support the principals.

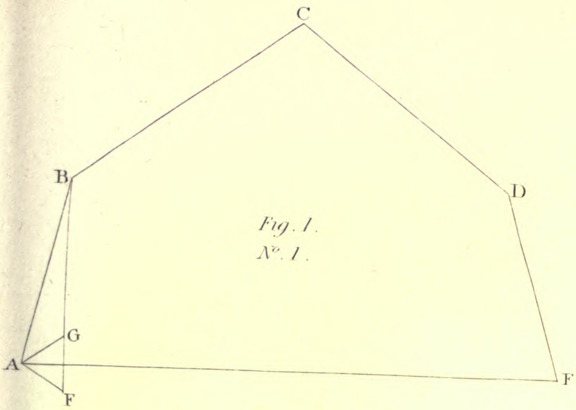
A truss for a still greater span is formed by suspending the tie-beam at three intermediate points, having a king-post between two queen-posts, without a straining-beam, the principals being carried to meet each other at the apex, as in the first description of roof; struts are carried from the foot of the king-post to the head of the queen-posts, and from the foot of the queen-posts to the principals. In many cases a roof with the same number of suspenders is somewhat differently constructed, and this consists, in the first place, of a roof precisely similar to the second above described, having, however, in addition, a king-post in the centre, carried up through and above the straining-beam, which is divided into two lengths, and abuts against the king-post on either side. Above and parallel to the principals is placed another pair of principals, which are continued to meet at the apex, where they abut against the king-post; these alone are termed principals, the other subordinate rafters which abut against the queen-posts, being termed *straining braces*, or *auxiliary rafters*. The principals are further supported at the upper part by struts, which spring from the king-post above the straining-beam, and below by a continuous bearing on the straining-braces, which, in their turn, are supported by the struts from the foot of the queen-posts. The last form of roof is calculated for a span of 60 to 80 feet, and the previous one for a span of 50 or 60 feet. Sometimes, instead of a single king-post, this kind of truss will have the king-post, as it were, split in half and hung on either side of the truss, from the heads of the upper principals, extending down to the tie-beam; in this case the straining or collar beam is in one piece, and passes between the halves of the king-post. Another variation consists in splitting the truss into two half-trusses, and keeping the king-post between them both, so as to form one mass. A roof of this kind was constructed over the basilica of St. Paul at Rome more than four centuries ago.

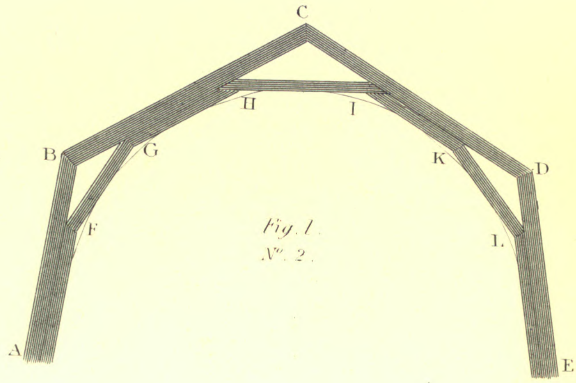
This expedient may be entirely obviated by the use of iron king-posts, which, in all cases, would seem preferable to those of wood, both for king or queen-posts, or, indeed, for any member of the truss which is subjected to tension, as for ties, where its employment, to a very considerable extent, obviates the difficulty which is experienced by the sagging of tie-beams of timber. The number of suspenders, especially if composed of iron-rods, may be still further extended to seven or eight, or, indeed, any number, the only limit being found in the length of the principals.

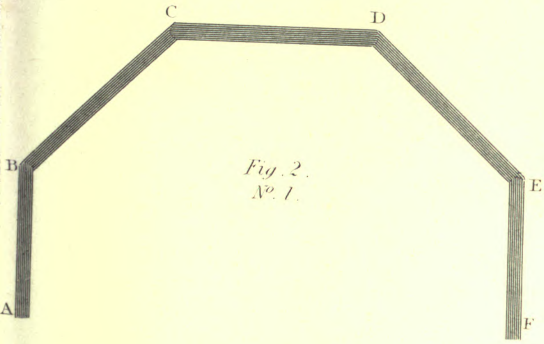
For the strength of different materials the reader may consult the article on that subject, but as a general remark it may be observed, that oak when exposed to tension is weaker than fir, and is therefore less adapted for ties. Being, however, less compressible, it is usually preferred for rafters, straining-pieces, and struts; but Tredgold observes, that its greater tendency to warping in summer renders it less fit for rafters and purlins than foreign fir. Cast-iron is not much used, except in fire-proof roofs, and each piece requires to be well tested. Wrought-iron is very useful for straps and also for ties and trussing-posts; but care is always necessary to guard against imperfections, which are more likely to pass unobserved than in wood. Wherever iron is applied, pro-

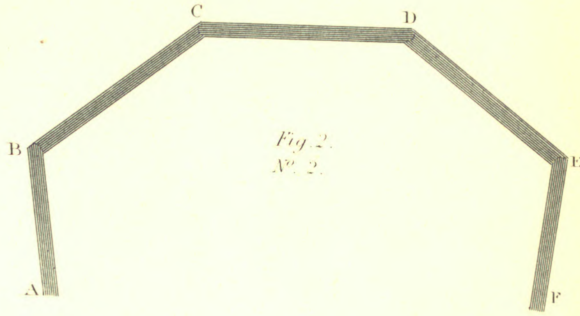
ROOF.

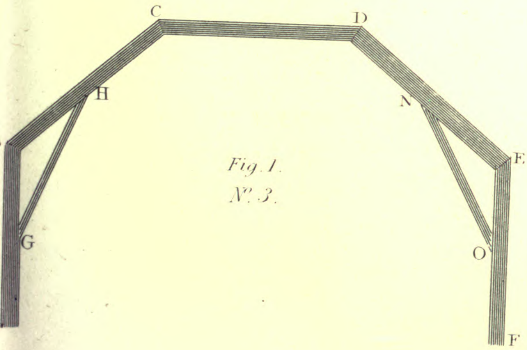
PLATE V.

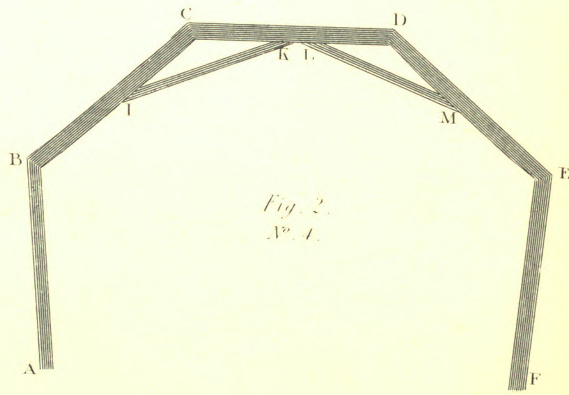


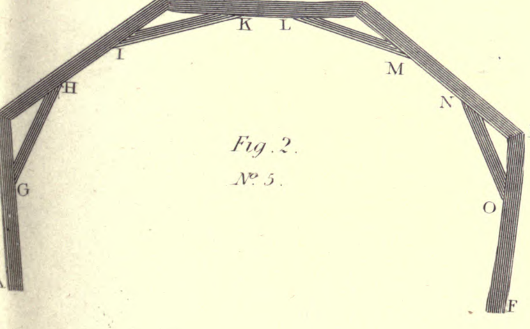


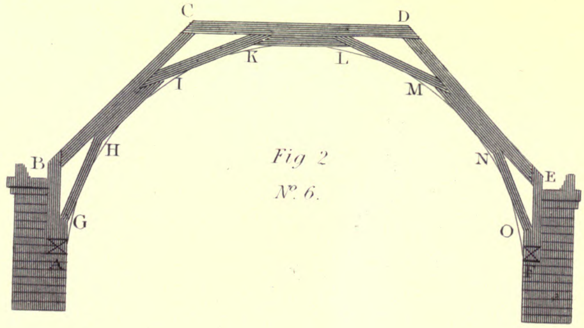












A. Nicholson.

Fig. 1.

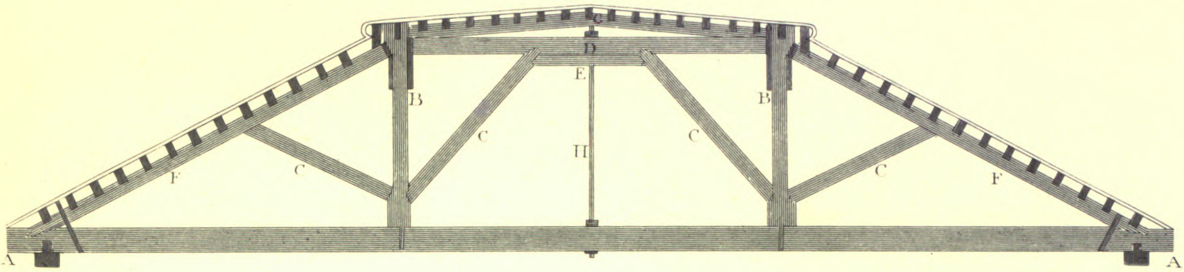


Fig. 2.

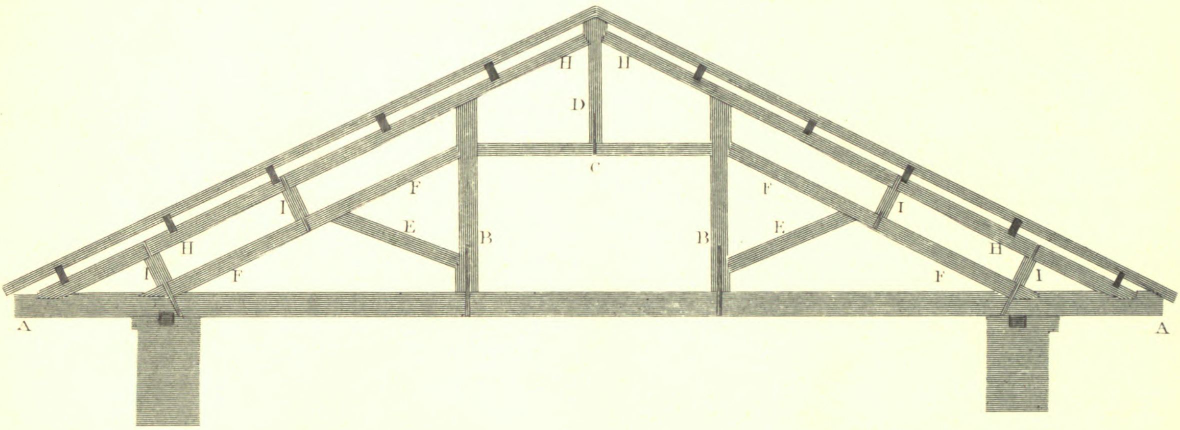
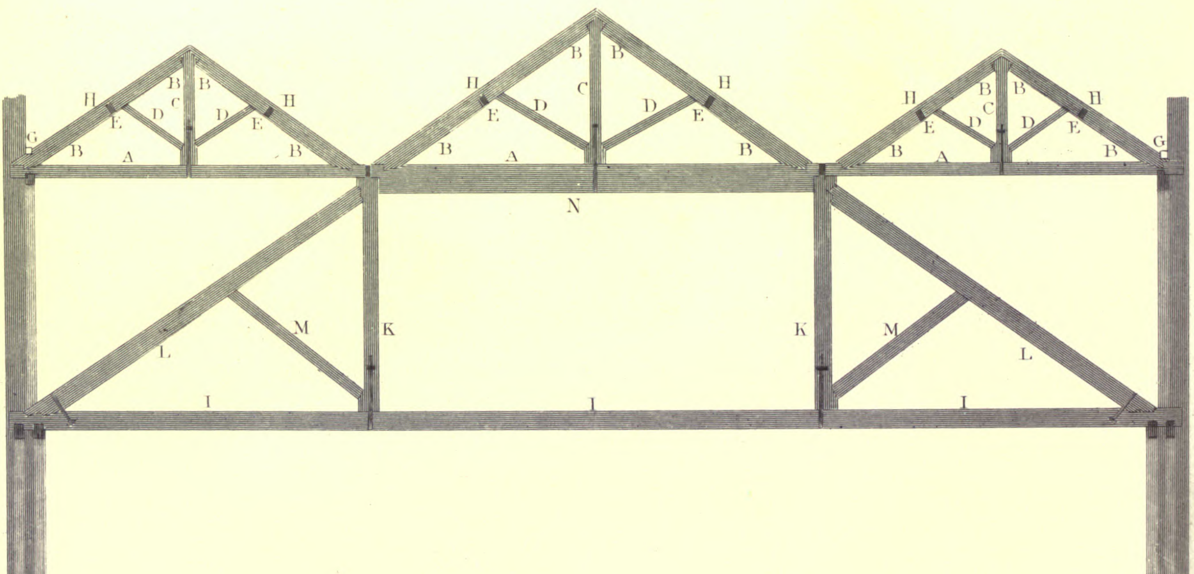


Fig. 3.



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ROOFS.

FROM COVENT GARDEN THEATRE.

Fig 1 Nº 5.

Fig 1 Nº 4.

Fig 1 Nº 6

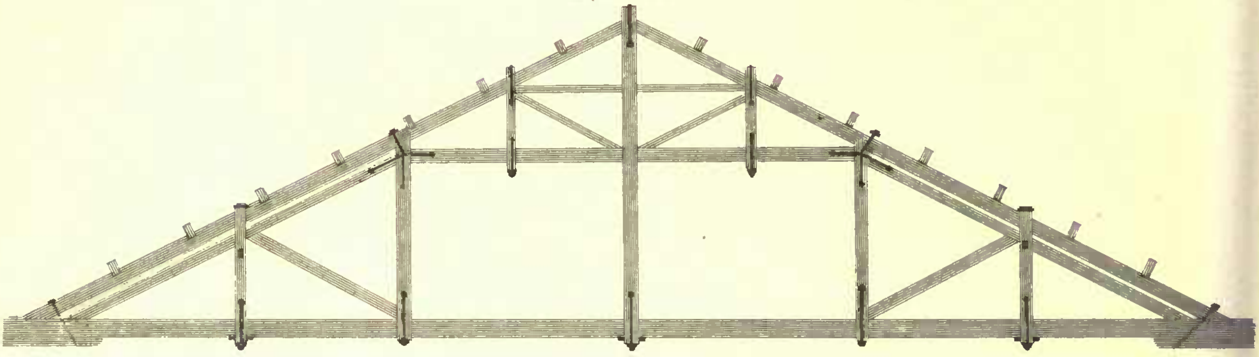
Fig 1 Nº 3.

Fig 1 Nº 7.

Fig 1 Nº 2

Fig 1 Nº 8

Fig 1 Nº 1



FROM DRURY LANE THEATRE.

Fig 2 Nº 2

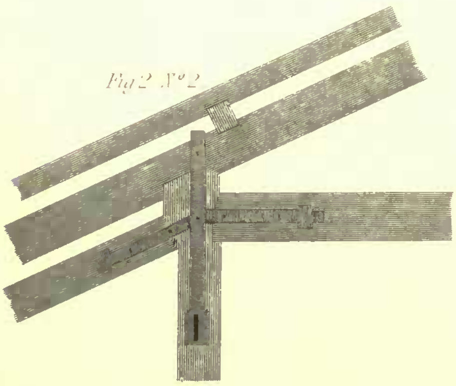


Fig 2. Nº 3.

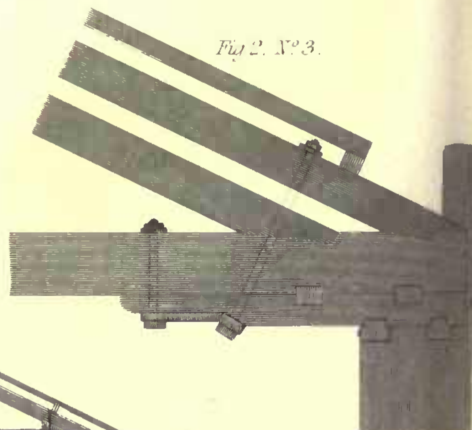
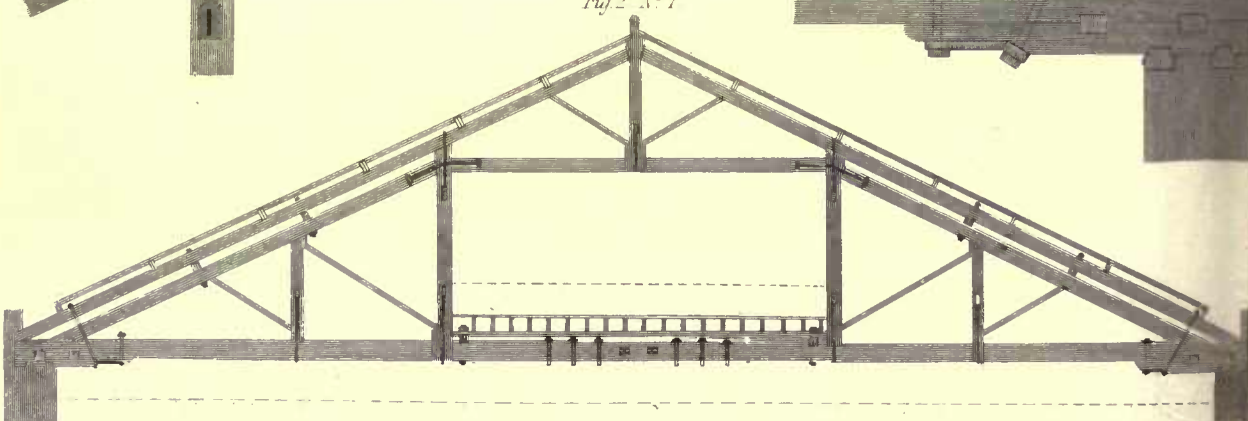


Fig 2 Nº 1



Drawn by P. Nicholson

Engraved by J...

ision should be made for its expansion and contraction, nd it is desirable to protect it from oxidation by painting. 'hough iron is far stronger for its size than any kind of imber, it is neither so strong nor so cheap as yellow-fir, *veight for weight.*

Plate VI. *Figure* 1, is the roof of the chapel of the royal ospital at Greenwich, constructed by Mr. S. Wyatt.

It is constructed with two queen-posts, and is similar to he second kind of roof above described, but it has in addiion two struts from the foot of the queen-posts to the strainng-beam, which abut against a second straining-piece undereath the first; the tie-beam is also further suspended from he straining-beam by an iron-rod, which answers the purose of a queen-post.

The following are the scantlings of the various timbers :—

		Inches Scantling.
A,	The tie-beam, 57 feet long, the span of the walls being 51 feet	14 × 12
,	Queen-posts	9 × 12
,	Braces	9 × 7
,	Straining-beam	10 × 7
,	Straining-piece	6 × 7
,	Principal rafters	10 × 7
,	Camber-beam, for the platform	9 × 7
,	An iron rod, supporting the tie-beam	2 × 2

The trusses are seven feet clear; the platform is covered vith lead, which is supported by horizontal beams six by our inches.

The timbers of this truss are well disposed, and perhaps ontain less wood than most roofs of the same dimensions.

Figure 2 is the roof of St. Paul's, Covent-Garden, esigned by Mr. Hardwick, and constructed by Mr. Wapshot 1796.

This roof, although of the same general construction as the st, varies from it in several particulars. The lower portion precisely the same as the second class of truss, but in addion there is a second pair of principals, which are supported the lower by studs, and the lower principals thus becoming ly auxiliaries; the queen-posts are continued up to the incipals, and a king-post is carried from the apex to the raining-beam.

The scantlings are :—

		Inches Scantling.
,	The tie-beam, spanning 50 feet 2 inches	16 × 12
	Queen-posts	9 × 8
	Straining-beam	10 × 8
	King-post, 14 inches at the joggle	9 × 8
	Strut	9 × 8
,	Auxiliary rafters, at bottom	10 × $8\frac{1}{2}$
,	Principal rafters, at bottom	10 × $8\frac{1}{2}$
	Studs supporting the principals	8 × 8

This roof is much better constructed than the original one Inigo Jones. A truss of the present design contains only cubic feet of timber, whereas that by Inigo Jones had , and was very insufficient at the joggles, and had some ts timbers very ill disposed: the interior truss is well coned for supporting the exterior, which reaches seven feet ond the walls. The tie-beam has, perhaps, too much cam being six inches; for since it acts as a string, it will gthen in the settling of the roof.

Figure 3 represents the roof of Drury-lane theatre, 80 feet ches span, and the trusses 15 feet apart; constructed by Edward Gray Saunders. This was destroyed by fire 1809.

This is rather a curious form of roof; the principal truss is simply one of the second class with queen-posts and straining-beam, but above this, and partially resting upon it, are three other smaller trusses, which form the outer-roof. These are simple trusses of the first class with king-post and struts, the central one having a continuous bearing on the straining-beam of the main truss, and the side ones resting at one end on the straining-beam, and at the other on the wall.

		Inches Scantling
A,	Beams	10 × 7
U,U,	Rafters	7 × 7
C,	King-posts	12 × 7
D,	Strut	5 × 7
E,	Purlins	9 × 5
G,	Pole-plates	5 × 5
H,	Common-rafters	5 × 4
I,	Tie-beam	15 × 12
K,	Posts to ditto	15 × 12
L,	Principal braces to ditto	14 and 12 × 12
M,	Strut	8 × 12
N,	Straining-beam	12 × 12

The principal beams are trussed in the middle space with oak braces, five inches square. This was requisite on account of its width, which is 32 feet, that the floors might carry the work-shops necessary for the use of the theatre. This truss, which is most admirably constructed, is hardly to be equalled for strength, stiffness, and lightness, and will safely bear a load of nearly 300 tons, which is four times more than ever it is likely to be loaded with.

Plate VII. *Figure* 1, exhibits the roof of Covent Garden theatre. The tie-beam in this case is supported by five suspenders, a king-post in the centre, and two queen-posts on either side; between the two innermost queen-posts is a straining-beam, and on the other sides of them are auxiliary-rafters, which abut against a shoulder near their heads. A strut is carried from the foot of the inner queen-post to the head of the outer. The straining-beam is suspended by two queen-posts, between which is another straining-piece, and a strut from their head to the angle formed by the king-post and straining-beam below. The posts are all made double, and are shown in the Plate above the roof in their respective places.

Figure 2 represents the present roof of Drury-lane theatre. There are here both principal and auxiliary rafters, the tie-beam being suspended at two points from the former, and at two from the latter, the two first queen-posts being the inner ones. These are kept apart by a straining-beam, against which they are pressed from the other side by the auxiliary rafters; struts are placed between the feet of the principal and the head of the secondary queen-posts, and the bearing of the sub-rafters is still further reduced by a strut from the foot, and on the other side of the smaller queen-posts. The straining-beam is supported by a king-post from the apex of the principals, which in their turn are supported by struts from the foot of the king-post, the other portion having a continuous bearing on the auxiliary rafters.

The Figure above on the left-hand, shows how the timbers join at the top of the queen-posts, and that on the right how the timbers join at the end of the tie-beam.

The roof over the church of St. Martin-in-the-fields, designed by Gibbs, is rather curious. The entire breadth of the building is 69 feet, which is divided into 3 parts, the nave measuring 40 feet, and the remaining 29 feet being divided between the two aisles. The central portion is covered by a truss, which is supported at either end by an upright timber-post above the columns, and at two intermediate points by braces from these posts to the tie-beam, which is suspended from the principals at three points by a king-post and two queen-posts; struts are carried from the foot of the king-post to the head of the queen-posts, and from the feet of the latter to the principals. Above the aisles, hammer-beams are supported at one end on upright posts in the wall; and at the other, on the post above the columns, and two intermediate bearings are afforded by struts from the same posts. The main principals have a continuous bearing on the rafters of the truss over the roof, another on a post which rests upon the hammer-beams, and at the extremities are strapped to the hammer-beams. From the last-named post there is a brace to the top of post over column. The scantlings of the timber are rather full, and are as follow :—

Main principal, 13 inches by 10 inches at bottom, and 11 inches by 10 inches at top.

Straining-brace or principal of nave-truss, 14 inches by 10 inches at bottom, and 11 inches by 10 inches at top.

King-post, 9 inches by 9 inches.

Strut on king-post, 7 inches by 7½ inches.

Queen-post, 8 inches by 9½ inches.

Strut on queen-post, 7 inches by 7½ inches.

Tie-beam, 14 inches by 9½ inches.

Post over column, 14 inches by 9½ inches.

Brace below tie-beam, 7 inches by 7 inches.

Hammer-beam, 14 inches by 9½ inches.

Brace from uprights to hammer-beam, 8 inches by 8 inches.

Post on hammer-beam, 8 inches by 9 inches.

Purlin rafters, 4 inches by 6 inches.

The roof the basilica of St. Paolo fuori le murà, executed in the fifteenth century, has double trusses, each consisting of two similar frames nearly 15 inches apart, and placed at intervals of 10½ feet from each other. The tie-beam, which is in two lengths scarfed together and secured by three iron straps, is suspended at three points by a king and two queen-posts, the latter being separated by a straining-beam, and having auxiliary rafters abutting against their heads. The king-post is of curious construction, and consists of three pieces for the double truss; that piece against which the principals abut, is very short, only extending as low as the straining-beam. Between the trusses another piece is placed, and sustained by a strong key of wood passing through it and the two upper short pieces; and this piece, in its turn, sustains the tie-beams by means of another strong key. The scantlings are :—

Tie-beams, 22½ inches by 15 inches.

Principal rafters, 21¾ inches by 15 inches.

Auxiliary rafters, 13¾ inches by 13¼ inches.

Straining-beam, 15 inches by 12¾ inches.

Purlins, 8½ inches by 8½ inches.

Common rafters 5¼ inches by 4¼ inches.

The purlins are 5 feet 7 inches apart, and the rafters 8½ inches.

The span of the roof is 78 feet.

The roof over the Passengers' Shed of the Croydon Railway, at London Bridge, is of simple construction, consisting only of tie-beam, principals, and iron suspending-rods, with timber-struts between each two, the tie being suspended at eleven points.

The tie-beams, principals, and struts being framed together, the suspending-rods are introduced, and screwed up by nuts upon their lower ends, until the whole is firmly united. The tie-beams camber 6 inches in the centre. There are 14 of these trusses, 12 feet 6 inches apart, connected by the ridge-piece and purlins. These extend to within 25 feet of either end, where a half-truss of similar construction is framed into the centre of each extreme truss at right angles to the same, to form the hip, with ridge-pieces as usual. The whole is covered in with 1¼-inch rough boarding, upon which zinc is laid and joined. The under side of the roll that covers the joint is grooved to admit the edges of the zinc, and the angle next it rounded, to allow the zinc to expand or contract. The rolls are painted, and are sometimes covered with zinc or lead.

The entire length of the Passengers' Shed (to which this roof belongs) is 212 feet, and 53 feet wide. There is room for about 24 carriages, which is divided into three lines of rails ; the outer lines being for the arrival and departure of trains, and the centre line for spare carriages. On each side of the shed is a platform raised nearly level with the floor of the carriages, 11 feet wide, and connected at the end; this is covered with asphalte, and coped next the rails with stone. In the centre of the shed is a carriage-truck, that moves transversely to the rails, for the purpose of shifting carriages from one line to another, when any extra are required in a train. Between the rails of each line (170 feet in length) the ground is sunk between walls a sufficient depth to enable workmen to get at the under side of the carriages and engines when required.

The roof of Christ's Hospital is well worthy consideration. It covers an area 51 feet wide by 187 feet in length, and consists of principal trusses running across the building, with smaller longitudinal trusses between every two main trusses, to carry the rafters. In the main truss the tie-beam is suspended from five points by king and queen-posts, which are however of iron, and bolted through the tie. Between the two innermost queen-posts, or suspenders, is a straining-beam, which abuts against their heads and is also bolted to the principals ; its length is 16 feet, and it is supported at two intermediate points by struts from the feet of the queen-posts ; there is also another strut for the other side of the post to the head of the further or outermost one. The extremities of the tie-beams and rafters rest in iron shoes, and partially upon cast-iron standards supported on stone corbels 10 feet below the ceiling line.

The five longitudinal trusses, to support the main rafter between the principal trusses, is extended from each queen-post in one cross truss to the corresponding one in the next; the distance between the main trusses, and therefore the length of the tie-beams, being 17 feet. These are simple king-post trusses without struts, and carry the main rafter on top of the king-post, which, in this case, is of timber, bolted to the tie-beam. Filling-in beams are placed between these trusses to receive the ceiling-joists. The scantlings of this roof are as follow :—

Principal truss :

Tie-beam, 14 inches by 14 inches.

Principal rafters outside the innermost queen-posts, 12 inches by 9 inches at lower end ; 10 inches by 9 inches at upper end.

Principals within and above the innermost queen-posts, 9 inches by 9 inches.

Straining-beam, 12 inches by 9 inches.

Struts, 6 inches by 6 inches, (longitudinal trusses.)

Tie-beams, 12 inches by 7 inches.

King-post, 6 inches by 6 inches.

Struts, 6 inches by 6 inches.

Main rafters between trusses :—

At lower ends, 12 inches by 7 inches.

At upper end, above queen-posts, 9 inches by 7 inches.

Common rafters, (longitudinal) 7 inches by 5 inches.

The roof over Exeter Hall is of simple construction, the span being not less than 76 feet, and the height of the roof from the underside of the tie-beam, 21 feet 6 inches; the trusses are placed at alternate intervals of 2 feet 6 inches, and 9 feet.

Each truss has the tie-beam, which is scarfed, suspended in six points by queen-posts, the innermost pair being provided with a straining-beam; and with auxiliary rafters on the other side of them, each of which is supported by two struts resting on the foot of the queen-posts. The two outermost queen-posts on either side are hollow, and are suspended from the principal rafters, as are also the inner ones, by means of straps. The straining-beam, which is 22 feet long, is suspended from the apex of the principals by a king-post, from which struts are raised to shorten the bearing of the principals. Two sloping timbers but against the feet of the inner queen-posts, from the apex of which an iron suspender is bolted to the tie-beam. The ends of the tie-beams and principals rest in iron shoes. The scantlings are:—

Tie-beams, 14½ inches by 7½ inches.
Principals, 8½ inches by 7½ inches.
Auxiliary rafters, or under principals, 14 inches by 7½ inches.
Inner queen-posts, 8½ inches by 7½ inches.
Outer ditto, 10 inches by 4½ inches.
Intermediate ditto, 12 inches by 4½ inches.
King-post, 6 inches by 7½ inches.
Straining-beam, 14 inches by 7½ inches.
Braces, 7½ inches by 7½ inches.
Upper ditto, 6 inches by 7½ inches.
Purlins, 7½ inches by 4 inches.
Common rafters, 5 inches by 2½ inches.
Ridge-piece, 8 inches by 3½ inches.
Wall-plates, 13½ inches by 6½ inches.
Pole-plates, 12 inches by 4 inches.

The truss over the arched roof of St. George's Hall, Liverpool, which is 65 feet in width, is of very simple construction. The tie-beam is sustained at five points by a king-post and four queen-posts. The principals have auxiliaries under them, but do not meet at an apex, reaching only as far as the inner queen-posts, which are kept apart by a double straining-beam at top, and by another at their feet. Struts are placed between the head of the king-post, and feet of the queen-posts, and thence again to the head of the outer queen-posts.

Having given these descriptions of various kinds of roofs, it will not be out of place to give some rules for finding the proper scantlings of the different members, as determined by Tredgold, and the manner in which each member is affected.

King-Post.—The king-post is intended to support the ceiling, and by means of the braces, to support part of the weight of the roof. The weight suspended by the king-post, will be proportional to the span of the roof; therefore, to find the scantling:

Rule.—Multiply the length of the post in feet, by the span in feet. Then multiply this product by the decimal 0.12 for fir, or by 0.13 for oak, which will give the area of section of the king-post in inches; and this area divided by the breadth, will give the thickness; or by the thickness, will give the breadth.

Queen-Posts.—Queen-posts and suspending-pieces are strained in a similar manner to king-posts, but the load upon them is only proportional to that part of the length of the tie-beam suspended by each suspending piece or queen-post. In queen-posts, the part suspended by each is generally half the span.

Rule.—Multiply the length in feet, of the queen-post or suspending piece, by that part of the length of tie-beam it supports, also in feet. This product multiplied by the decimal 0.27 for fir, or by 0.32 for oak, will give the area of the section of the first in inches; and this area divided by the thickness will give the breadth.

Tie-Beams.—A tie-beam is affected by two strains, the one in the direction of the length from the thrust of the principal rafters, the other is a cross strain from the weight of the ceiling. In estimating the strength, the thrust of the rafters need not be considered, because the beam is always abundantly strong to resist this strain; and when a beam is strained in the direction of the length, it rather increases the strength to resist a cross strain. Therefore the pressure of the weight supported by the tie-beams will be proportional to the length of the longest part of it that is unsupported.

To find the scantling of a tie-beam, which has only to support a ceiling, the length of the longest unsupported part being given:

Rule.—Divide the length of the longest unsupported part by the cube-root of the breadth; and the quotient multiplied by 1.47, will be the depth required for fir, in inches; or multiply by 1.52, which will give the depth for oak in inches.

Principal Rafters.—In estimating the strength of principal rafters, we may suppose them supported by struts, either at or very near all the points where the purlins rest upon. The pressure on a principal rafter, is in the direction of its length, and is in proportion to the magnitude of the roof; but the effect of this pressure does not bear the same proportion to the weight, when there is a king-post, as when there are queen-posts; therefore the same constant number will not answer for both cases.

Case 1.—To find the scantling of the principal rafter, when there is a king-post in the middle.

Rule.—Multiply the square of the length of the rafter in feet, by the span in feet, and divide the product by the cube of the thickness in inches. For fir, multiply the quotient by 0.96, which will give the depth in inches.

Case 2.—To find the scantling of a principal rafter, when there are two queen-posts:

Rule.—Multiply the square of the length of the rafter in feet, by the span in feet, and divide the product by the cube of the thickness in inches. For fir, multiply the quotient by 0.155, which will give the depth in inches.

Straining Beams.—A straining-beam is a horizontal piece between the heads of the queen-posts. In order that this beam may be the strongest possible, its depth should be to its thickness as 10 is to 7.

Rule.—Multiply the square root of the span in feet, by the length of the straining-beam in feet, and extract the square root of the product. Multiply the root by 0.9, for fir, which will give the depth in inches.

To find the thickness, multiply the depth by the decimal 0.7.

Struts and Braces.—That part of a roof that is supported by a strut or brace, is easily ascertained from the design; but the effect of a load must depend on the position of a brace; when it is square from the back of the rafter, the strain upon it will be the least; and when it has the same inclination on the roof, the same strain will be thrown on the lower part of the principal rafter, as is borne by the strut. But as the degree of obliqueness does not vary much, we shall not attempt to include its effect in the rule for the scantling.

Rule.—Multiply the square root of the length supported in feet, by the length of the brace or strut in feet, and the square root of the product multiplied by 0.8 for fir, will give the depth in inches, and the depth multiplied by 0.6, will give the breadth in inches.

Purlins.—The stress upon purlins is proportionable to the distance they are apart, and the weight being uniformly diffused, the stiffness is reciprocally as the cube of the length.

Rule.—Multiply the cube of the length of the purlin in feet, by the distance the purlins are apart in feet; and the fourth root of the product for fir will give the depth in inches; or multiplied by 1.04, will give the depth for oak; and the depth multiplied by the decimal 0.6, will give the breadth.

Common Rafters.—Common rafters are uniformly loaded, and the breadth need not be more than from 2 inches to $2\frac{1}{4}$ inches. The depth for Welsh slate may be found by the following rule:

Rule.—Divide the length of bearing in feet, by the cube root of the breadth in inches; and the quotient multiplied by 0.72 for fir, or 0.74 for oak, will give the depth in inches.

The largest roof ever executed was that of the Riding House, built at Moscow, in 1790, by Paul I. Emperor of Russia. The span was 235 feet, and the slope of the roof about 19 degrees. The principal support of this immense truss consisted in an arch or curved rib of timber, in three thicknesses, indented or notched together, and strapped and bolted with iron. The principal rafters and the tie-beams, were supported by several vertical pieces notched to the curved rib; and the whole stiffened by diagonal braces. The disposition of the parts of this roof is extremely ingenious; but it was too slight for the immense extent of the span, and it appears that it settled so much, that it was proposed to add another curved rib to the original design. This example affords an instance of the impropriety of adding material so near to the neutral line of the framing; a like want of attention to principle is sometimes found in a first design; a roof designed by Bettancourt for a riding-school, as given by Krafft, is an example. The external dimensions of the building were 1,920 feet by 310 feet; it was lighted from the top by a lantern; and there was a gallery round the inside of the building for spectators. The method of notching the timber in the curved rib, is objectionable, on account of the danger of the splitting of the timber under a considerable strain. This system of trussing is termed the *bow suspension truss*, and has been much used of late for bridges for railway-works.

Of a somewhat similar construction are the roofs executed by Philibert de Lorme, in the sixteenth century, which are constructed with a series of arched timber ribs in lieu of trusses, these ribs being formed of planks in short lengths, placed edgewise, and bolted together in thicknesses, the planks in one thickness breaking joint with those in the adjoining thickness.

A fine example of this class of roof was that constructed over the Halle au Blé, at Paris, 120 feet in diameter, which has been destroyed by fire.

A smaller example, but nearer home, is to be found over the central compartment of the Pantheon, Oxford-street; the span measures 38 feet. The roof is circular, and is supported by nine semicircular ribs. Each rib is in three thicknesses; the middle thickness is of teak, the side thicknesses or flitches are of fir; the pieces of timber forming these thicknesses are scribed on the under side to the curve of the roof, (and ceiling,) but the top edge is left straight; therefore at their abutting ends they are considerably broader than at their middle. Each abutment of every piece, throughout every rib, has a shoe of cast-iron interposed. Iron bolts connect the three thicknesses together at each end, with a washer connecting each pair of bolts, as explained on the section. The ribs rest alternately on the pillars, (hereafter described) and on the centre of the longitudinal plate extending the whole length of the roof. In the former case the ribs are framed into strong upright pieces, which become the king-post of a semi-truss. These semi-trusses, besides carrying the timber of the roof and ceiling over the galleries, are calculated to receive the lateral thrust of the semicircular roof, a large cast iron shoe laid upon a stone template, receives the end of the tie-beam of these semi-trusses next the outer wall; the object of this shoe being to prevent the possible decay of this end of the beam from affecting the stability of the roof.

There is also a cast-iron shoe receiving the other end of this beam, which is formed with sockets and flanges, so as to receive and connect together the king-post and tie-beam of the above named semi-truss, and the longitudinal plate alluded to above, and the head of the great iron upright or pillar. The chief use of this iron shoe is to prevent the lateral compression of the timbers, and to prevent the natural shrinkage of the horizontal plate from letting down the roof.

The intermediate ribs (those which do not rest on the iron pillars) rest on another iron shoe, which is fitted on to the head of an upright piece that rests on the centre of the longitudinal plate; but the bearing is thrown on to the iron pillars by stout braces framed into the said upright piece and longitudinal plate.

It will thus be seen, that throughout the skeleton of this roof there is no case of any important timber resting with its *end* upon the *side* of any other piece, but that they all bear with an *end-grain* abutment, so that the cracks and failures arising from the necessary shrinkage, as well as from the lateral compression of the timbers, are avoided. This was a precaution rendered necessary by the very large scantlings of the timbers, and by the discharge of the whole weight of roof and ceiling being thrown on so few points of support. The circular part of the roof is covered with copper laid on diagonal boarding, which is supported on rafters notched on to the great ribs, and running longitudinally. The roofs over the sides or galleries are slated, with a flat plaster ceiling; the ceiling of the circular part is deeply panelled, the main ribs forming the core for the cradling. The enrichments are of papier maché, a material that was well adapted for the large architectural ornaments, from its lightness, and from the safety with which it could be screwed up to the timbers.

The longitudinal plate above alluded to consists of two pieces of fir, each 12 × 6, bolted together: the bearings between the iron pillars are reduced by braces, which discharge the bearing on to the iron pillar, and at the same time receive the wood cradling for the spandrels. Each end of this plate is let into the wall, and is received by a corbel of teak wood, on to which it is bolted and locked down.

A considerable improvement upon the system of Philibert de Lorme was effected by Colonel Emy, a French engineer, in the early part of the present century, by the employment of *laminated* ribs. The principal difference between the two consists in this, that in Colonel Emy's improvement the direction of the fibres of the wood coincides with the curvature of the rib, and in consequence the joints are much less frequent, and the rib possesses greater elasticity, so as slightly to yield, rather than break, under any violent strain. The alternate thicknesses break joint, as in De Lorme's roof, and all are securely bolted together.

The earliest roof constructed after this fashion was at Marac, near Bayonne, in 1825. The span is 65 feet, and the main ribs are formed of planks bent round on templates to the proper curve, and kept together by iron straps, and also by the radiating struts which support the principals; they are in pairs, notched out so as to clip the rib between them. In this roof the entire weight of the roof is thrown on the walls at the feet of the ribs, which are considerably below the principals, so that the weight of the upper part of the walls serves to diminish the effect of any thrust against the lower part of the walls. A great saving of wall-material is hereby effected.

This principle has often been applied in the case of railway bridges, and there is at present one erecting at the London terminus of the Great Northern Railway. In this instance the spandrels are of cast-iron.

Of somewhat similar construction is the roof over the transept of the Great Exhibition building. The principals, or main ribs, of which are placed at intervals of 24 feet from centre to centre, and are made up of three planks, two of 2 inches in thickness, and the middle one 4 inches thick, with a moulded piece on the under side $2\frac{3}{8}$ inches thick, and two 11-inch planks at the top, each one inch thick, and nailed together to form the gutter-board, the whole being firmly connected together by wrought-iron bolts passing through belts of the same material, running at top and bottom of each rib. In order to form the ribs with the proper curvature, each plank, $13\frac{3}{4}$ inches wide, was cut on one edge to its proper segmental form, and the two complements cut off were nailed to the lower or straight edge of the flank; the whole being put together, so as to breach joint throughout, the length of each section so cut being about 9 feet 4 inches. The preparation for the reception of the ends of the purlins was on this wise: the two wide planks were cut across, so as to form a cavity to admit the ends of the purlins, the parts of the planks thus separated being connected together by cast-iron plates. The openings thus made were filled in temporarily with wooden blocks, until the joiners were ready to fit in the ends of the purlins.

The strength of every purlin has been duly calculated, according to its relative position in the arch; thus, the three uppermost purlins, having the greatest strain on them, are each $13\frac{1}{2}$ inches in depth by $4\frac{1}{2}$ in width; while the four lower purlins on each side, having gradually less strain to bear, diminish regularly in depth to 9 inches, all having the same width as those at the crown; whereas, the lowest one on each side of the arch, being nearly horizontal, is increased to a scantling of 8 inches by $6\frac{1}{4}$ inches.

Between each pair of main ribs are two intermediate ribs, or, as called in ordinary roofing, common rafters, 4 inches deep by 3 inches wide. On the top of these are gutter-boards, in two thicknesses, as those described for the main ribs. The gutters, each 5 inches wide, are formed by two splayed fillets, let into and nailed securely to the upper side of the boards. These fillets also serve as abutments for the skylight bars, which are rather larger in section and size, as those for the skylights in other parts of the building. Each bar is nailed at the lower end to the fillet, and at the upper end to the ridge-piece, which is formed of three pieces of fir, one above another, the lower section being 4 inches wide by $1\frac{1}{4}$ thick; the middle piece, 3 inches by $\frac{13}{16}$ths inch; and the upper piece, 2 inches by $1\frac{3}{8}$ths inch, the latter having a groove on each side to receive the glass. The three thicknesses are necessary, in order to suit the curvature of the arch. The lower end of each ridge-piece is carried down to, and rests on, the lead flat. Condensation-gutters are formed in this roof, as in the roofs of the aisles and avenues, but by a different method. A sloping fillet is nailed on to each side of the gutter-board, and continued from the springing of the arch on one side, to the corresponding point on the other. With a view to retain the ridges in their places, wrought-iron rods of $\frac{3}{8}$ inch diameter, extend from the purlins to the under side of the ridges. In order thoroughly to carry off the rain-water from every part of the roof, all the skylight bars are fixed diagonally from the ridge to the gutter, and the water collected in each curved gutter, is carried into a sloping trough at bottom, and thus discharged on to the lead flat, which is sloped towards the water-heads at tops of the hollow columns. Looking at the roof from the lead flats, the whole has a herring-bone appearance.

Temporary ladders, fixed to suit the arched roof, were used for fixing the ridge-pieces, skylight bars, &c.; but, in order to facilitate and expedite the glazing of this roof, travelling scaffolds were used, which could be raised and lowered at pleasure, by means of ropes and pulleys, and by the power of four men working a crab engine, placed on the lead flat contiguous. Each travelling scaffold is formed with sides and ends, and has boxes, in convenient positions, for the glass, putty, and tools; the whole running on small friction rollers, suited to the tops of the ridge-pieces, which serve as rails: without such a contrivance, the glazing of the roof of the transept would have been almost an endless job.

The vertical supports for the roof consist of cast-iron columns placed one above another in three tiers, sixteen in each tier on either side. Above the top pier are fixed the trussed girders, 3 feet in depth, spanning from column to column, which are each 24 feet from centre to centre; and across the intersecting lines of the middle arch, are two double trussed girders, 6 feet in depth, and corresponding in length with three spaces of 24 feet each; except under the columns of the south-east angle of the transept, the whole are placed on broad base plates, which rest on concrete foundations. In the exceptional case, the foundation consists of a solid brick pier, built in cement. At the top of each column which supports the roof, is a cast-iron socket, 4 feet 4 inches in height. The use of these sockets is to receive what may be termed the vertical legs or supports of the ribs, and which form parts of the ribs as framed together on the ground. In order to resist the lateral thrust of the roof, a strong gangway, 24 feet wide, is formed on each side of the transept, which may be considered as an abutment, being constructed of strongly-framed and braced flooring, supported by trussed girders. The main ribs have their bearing immediately above the columns, the intermediate ones on the girders between the columns.

The following is a description of a system of construction in roofs, invented by M. Laver, architect to the king of Hanover. It is also applicable to bridges, and similar works.

This new principle consists in a combination of the two principal forces of materials—that of resistance to compression and resistance to tension. The first of these forces has been used from the remotest periods in the construction of bridges, and arches in general; the second has been more lately employed—at least in Europe—for the construction of suspension bridges by the application of chains. The first requires great masses of materials and strong abutments; the second requires less materials than the first, but secure fastenings, for the chains are frequently obtained with difficulty. Very sensible vibrations and undulations are experienced where this last mode of construction is employed.

The disposition of the principal parts of this truss is, that of two segments of a circle, placed with the concave sides opposite each other, and tied together at the extremities, being further connected together, or rather kept apart, from each other, by vertical and diagonal struts. Imagine two bows so disposed; it will be perceived, the chain a k g, fastened at the extremities of the upper bow, acts with the positive force of tension, which the strongest materials possess, varying from 10 to 20,000 lbs. for every square inch of the transverse section of the several kinds of wood employed in construction, and from 20 to 100,000 lbs. for the several metals.

The bow, a d g, by its resistance to compression, serves to prevent the chain, a k g, from contracting or drawing together the extremities a and g. The lower bow a k g, acting as a chain, prevents the upper bow, a d g, from pushing or pressing out at the points of support. The vertical and diagonal struts unite in a firm manner the two bows, and the two forces thus neutralized form a complete whole, that sustains itself, and can neither thrust out nor draw in.

It must be observed, first, that the strength of the chains, which act in a similar manner to that of suspension bridges, depends upon the depth of the versed sine, and that the more they deflect below the horizontal line, or chord of the arc, the stronger they would be; secondly, that the upper bow, owing to the elasticity of the material, must absolutely have the convex form; so that, when any great sudden weight is thrown on it, causing the lengthening of the chains by tension, and the shortening of the upper bow by compression, the upper bow may not be reduced to a horizontal line, a n g, beneath which it could no longer serve by resistance to the statical equilibrium of the construction; thirdly, that the method of combining the extremities, a and g, of the bows, must depend upon the materials employed: for instance, in a wooden bridge, the notching and scarfing at the joints of the different pieces of wood ought to be calculated and executed to the force which they have the power of resisting. The rules and forms most applicable to these joints have also been proved by the experiments of the inventor.

This system of construction is applicable to roofs and bridges of every denomination, such as draw and swing bridges, but especially for suspension bridges, where the locality on either side, or on both, does not admit of secure fastenings for the chains. For covering large rooms, riding-schools, and other openings of large space, it is particularly useful; also the erection of scaffolding, and ladders of large dimensions, and to the stiffening of beams, masts, and supports in general.

The application of this system to roofs and floors of large span, is extremely economical and useful, and by simple modifications serves for the covering of large spaces, without any intermediate points of support, and also presents this farther advantage, that from its vertical pressure, it requires no other support than walls of moderate thickness. When applied to floors, bridging-joists will remedy the inequality of the surface in the beam itself. In roofs of larger span, the posts may be continued upwards, so as to receive the purlins, and when continued downwards, serve to hold up the ceiling, whether flat, vaulted, or mixed.

The open Gothic roofs of the middle ages, differing as they do in essential matters of construction from those at present in use, ought not to be passed over in silence. In many, if not the majority of such roofs, tie-beams were altogether dispensed with; the only tie between the principals, to prevent their spreading, consisting of a collar-beam placed high up in the roof. So much care, however, to prevent spreading, in these roofs, was not required; for the principals were laid at a high pitch, and therefore had not so much tendency to thrust outwards, as a roof of modern construction; beside which, the walls were built of very great thicknesses, and were often strengthened by massive buttresses. Sometimes, in lieu of a collar-beam, two cross-braces were used springing at about half way up the principals, and intersecting each other in their course upward to the opposite principal, and occasionally these and the collar-beam were employed in the same roof; not unfrequently we find the collar strutted up from the rafters. Sometimes again, the principals rest on arched beams or planks, of which some are carried down the walls, and rest on corbels projecting from them; by this means, the thrust is carried down lower, and you gain the advantage of the weight of the walls above, to resist it.

Sometimes tie-beams are used, which are usually of large scantling, and have the upper surface sloped upwards to the centre, so that the depth there is greater than at any other part. Occasionally, upon the centre of the tie-beam is placed a post, from which spring branches to prop up the collar beam, and sometimes the rafters also. This post must not be confounded with the king-post of modern roofs, for it is not used to hang up the tie-beams, but rests upon the tie-beams to support the upper part of the roof.

Such were the most usual form of roofs in the earlier Gothic examples; but at a later time, when the pitch of the roof was lowered, other methods were adopted. Sometimes, merely a horizontal beam was thrown across the upper side, being formed into two inclined planes similar to the tie-beams mentioned above; at others, inclined rafters were used with their ends resting upon upright posts, placed against the walls and resting on projecting corbels at a distance from the top of the walls, the rafters being connected with it by a curved strut, so as to prevent deflection of the rafters near the centre. The upright posts are termed pendant posts, and the struts are often cut out of thick planking, so forming solid spandrels.

Frequently a horizontal beam is laid across the roof on top of the pendant posts, supported by curved struts as before, and above this, rafters are introduced, strutted up in the centre from the horizontal beam. Where the pitch is somewhat higher than usual, inclined struts are added to the central strut, so as to divide the bearings of the rafters. This kind of roof is very similar in appearance to a king-post truss, but this is not the case; that which has the appearance of the king-post, not being employed to suspend the tie-beam, but to support the rafters.

The hammer-beam roofs so common in halls of the 15th and 16th centuries, are of a different description to any of the above. They are usually of a high pitch, and of considerable span, and often bear evidence of very great skill in construction: a simple roof of the kind, consists of two principals connected by a collar-beam, and resting on the ends of two hammer-beams, which project horizontally from the wall and carry two queen-posts. The queen-posts and the collar-beam are usually connected by a curved brace, as are also sometimes the hammer-beams with pendant posts. Of such roofs, the most remarkable are those of Hampton Court and Westminster Hall.

The roof of the great hall, Hampton Court, consists of principals which fall short of the apex, and are secured to a collar or straining-beam at their upper extremities, which is supported by three vertical posts resting on a lower collar-beam, at about halfway down the principals. Under the lower end of the principals, and resting on the top of the walls, is a hammer-beam projecting out about a quarter of the entire space, and supported at its inner extremity by a curved brace, which rests upon a pendant post, and this again upon a corbel projecting from the wall. The hammer-beam carries two uprights, one of which supports the principal rafters, and the other the lower collar, which is still further supported at its centre by a curved brace, which rests upon the extremity of the hammer-beam. A couple of inclined rafters springing from the top of the principals, meet at an apex over the centre of the roof, where they are supported by a strut resting on the collar-beam.

The roof of Westminster Hall has always been much admired; and to its great height and extensive dimensions, must be attributed much of the grandeur of the building. It is, indeed, impossible to enter this magnificent room, without being struck with admiration. An uninterrupted open space, nearly equal to the size of a large cathedral church, is presented in one view, and the scientific spectator, gazing with delight on its lofty roof, admires the elaborate and artist-like arrangement of its timbers. These serving at once the purposes of utility and decoration, and uniting the apparently opposite qualities of massive solidity and airy lightness.

The angle of the roof is formed on what country workmen still term common pitch, the length of the rafters being about three-fourths of the entire span. The cutting off the girders, or tie-beams, which, crossing from wall to wall in common roofs, restrain all lateral expansion, was the first circumstance peculiar to this construction. To provide against lateral pressure, we find trusses, or principals, as they are technically designated, raised at the distances of about eighteen feet throughout the whole length of the building. These trusses abut against the solid parts of the walls between the windows, which are strengthened in those parts by arch-butresses on the outside. Every truss comprehends one large arch, springing from corbels of stone, which project from the walls at twenty-one feet below the base-line of the roof, and at nearly the same height from the floor. The ribs forming this arch, are framed at its crown into a collar-beam, which connects the rafters in the middle of their length. A smaller arch is turned within this large one, springing from the hammer-beam which is level with the base-line of the roof, and supported by two brackets or half-arches, issuing from the springers of the main arch. By this construction of the trusses, each one acts like an arch, and by placing these springers so far below the top of the walls, a more firm abutment is obtained. The main arched rib is constructed of three thicknesses, somewhat after the principle of Philibert de Lorne. From the extremity of the hammer-beam rises a vertical post which supports the end of the collar-beam already alluded to, and this again, by means of two other cubical posts, supports a second collar-beam, and a central or king-post.

Of late years, many roofs have been constructed of iron, a material which at first began to be introduced for particular members, such as tie and suspension-rods, but afterwards became employed for the entire truss, and sometimes for the covering likewise. Iron roofs are for the most part of similar construction to those already described of timber, those members which are subjected to tension, such as ties and suspending rods, being of wrought-iron rods, and those which suffer compression, such as principals and struts, of cast-iron. Such roofs have been very extensively employed in railway works, for the covering of passenger and engine sheds, and such like.

The roof of the passengers' arrival and departure shed at Euston Grove has a very light and elegant appearance; it is constructed principally of wrought-iron, the bressumers, columns, and gutters, only being of cast-iron. The entire width is 80 feet, formed in two spans of 40 feet each, a row of iron columns and bressumers supporting the rafters in the centre and outside, and on the opposite side by iron corbels built in the wall, and further secured thereto by strong bolts and nuts; the rafters are six feet eight inches apart, and are of wrought iron, in form of the letter T; the slate battons, as they may be called, are of angle-iron, firmly riveted to the back of the rafters, at such a distance as the slates require, and to which they are secured by strips of copper. The roof is firmly tied from side to side by a tension-rod of one inch and a quarter diameter, to each pair of rafters, and is further supported and braced by struts of T iron and suspension-rods, with nuts and screws to adjust their length. The entire length of the roof is 200 feet; the gutters are cast in lengths of 10 feet each, joined together by flanges and bolts, and so fixed as to form an incline towards each column, which, being cast hollow, and having a pipe connected with a drain, they form a convenient and easy conveyance for rain from the roof.

The truss consists of two principals—a tie-beam, which is sustained by three suspending-rods and four struts, two on either side; one from the head of the central suspending-rod to the foot of the outer one, and another thence to the principal.

The roof of the locomotive engine-house at Camden Town is of very similar construction to the one above described: the rafters are of T iron, and the slates are supported by angle-iron riveted to the rafters. There are cast-iron chairs secured down to a stone coping on the walls, and from which the rafters spring; each pair of rafters is tied by means of a tension-rod, and otherwise supported and braced by struts of T iron, and suspension-rods of round iron, which make the whole very firm, and gives it a light and pleasing appearance.

Both these roofs were manufactured and erected by Messrs. Cubit, of Gray's Inn Road, under the direction of C. Fox, Esq., now resident engineer to the Company.

Of the numerous roofs of this material which have been erected over railway works, the following examples will give some of the principal varieties. The first, for a roof 30 feet span, consists of two principals, with tie-rod, which is suspended at two points, by two oblique rods meeting at the apex, by which means the king-rod is dispensed with. At the meeting of the suspension-rods with the tie-rod, a strut branches out at right angles to the principal, which it meets at half way. The rafters and rods are connected at the ridge in a separate casting, or the two ends of the rafters may be cast to half lap over each other, and the rods secured by wrought pins and nuts.

The rafters are of cast-iron of the ⊐ section, the dimensions of the lower table or flange being, in the centre of the length, $3\frac{1}{2}$ inches wide, and at the two extremities, $1\frac{1}{2}$ inch, with a thickness of $\frac{1}{2}$ inch; and those of the upper table $2\frac{1}{2}$ inches throughout the entire length, and $\frac{5}{8}$ inch thick. The depth is the same throughout, being $4\frac{3}{4}$ inches.

The tension-rods are 1 inch round at the outer ends, and $\frac{3}{4}$ inch midway; and the oblique suspension-rods $\frac{3}{4}$ inch round throughout.

The second example for the same span consists of two principals and tie-rod, which is suspended at three points by a king-rod and two queen-rods, dividing the bearings into three equal parts: struts rise from the foot of the king-rod to the heads of the queen-rods.

The rafters are formed of two parallel bars, 3 inches by $\frac{1}{4}$ inch, having a wooden rib $1\frac{1}{2}$ inch thick between them. The struts are of T iron, $2\frac{1}{4}$ inches wide over the top table, and $\frac{3}{8}$ inch thick; rib $2\frac{1}{2}$ inches deep, and $\frac{1}{2}$ inch in thickness.

The tension rod is $1\frac{1}{8}$ inch round, the king-rod $\frac{7}{8}$ inch, and the queen-rods $\frac{5}{8}$ inch round.

The timber between the bars in the rafters serves to fix battens for the covering,

The third example is for a roof 35 feet wide, constructed wholly of malleable iron. It consists of rafters and tie-rod, suspended at three points by king-rod and queen-rods, with struts from the bottom of the king-rod to the top of the queen-rods, and from the foot of the latter to the rafters.

The rafters and struts are of T iron, the rafters being $2\frac{1}{2}$

inches, and the struts 2 inches, deep; the rib in both cases being $\frac{3}{8}$ inch, and the top table $\frac{1}{4}$ inch in thickness.

The tie rods are 1 inch round, the king-rod $\frac{3}{4}$ inch, and the queen-rod $\frac{1}{2}$ inch.

The fourth example is for a span of 60 feet, and consists of rafters and tie-rod, suspended at five points by a king and four queen-rods, two on either side. The four struts spring from the feet of the inner suspension-rod to the head of the outer.

The rafters are formed in the same manner as in the second example, of two parallel plates of bar-iron, with plank between; the scantlings are, however, somewhat heavier, the depth of the bar-iron being 4 inches, and its thickness $\frac{5}{16}$. The struts are of T iron, the top table being 3 inches wide and $\frac{1}{2}$ inch deep, and the rib $3\frac{1}{2}$ inches deep and $\frac{3}{8}$ thick.

The tension-rod is of round iron, and is, from the extremity to the first suspension-rod, $1\frac{1}{2}$ inch thick, thence to the second rod $1\frac{3}{8}$ inch, and thence to the king-rod $1\frac{1}{4}$ inch. The king-rod is $1\frac{1}{8}$ inch round, the intermediate $\frac{3}{4}$ inch, and the outermost $\frac{5}{8}$ inch. The fifth example is for the same span, and consists of rafters and tension-rod, suspended at five points by king-rod and four queen-rods, placed closer together than in the last example. There are six struts placed as above, but the last on either side buts against the rafter where there is no queen-rod.

The entire roof is of malleable iron, the rafters of the T-form measuring 3 inches across the top table, which is $\frac{3}{8}$ inch thick, and $3\frac{3}{4}$ inches in the depth of the rib, which is $\frac{1}{2}$ inch in thickness. The struts are also of T iron, the inner ones being $2\frac{3}{4}$ inches wide over the top table, which is $\frac{3}{8}$ inch thick, and $3\frac{1}{4}$ inches in the depth of the rib, which is $\frac{1}{2}$ inch thick. The outer struts are $2\frac{1}{2}$ inches wide over the top table, and $2\frac{1}{2}$ inches in the depth of the rib, the former being $\frac{3}{8}$ inch thick, and the latter $\frac{1}{2}$ inch.

The tension-rods are $1\frac{3}{8}$ inch round near the springing, $1\frac{1}{4}$ inch in the middle, and $1\frac{1}{8}$ near the king-rod.

In all such roofs, it is necessary to strengthen them with iron tie-rods, passing obliquely from the springing to the ridge across one bay, and secured on the under side of the purlins. The distance between the principals varies from 5 to 7 feet.

The roof over the Museum of Practical Geology, Piccadilly, of which Mr. Pennethorne was architect, is entirely of cast-iron, which is somewhat differently applied to any instance we have alluded to. The total width of the building is 67 feet, but there is an intermediate bearing on either side 6 feet from the external wall, thus making the clear width of the roof 55 feet. Each rib is composed of five separate pieces or girders, securely bolted together at the ends; the first piece, one end of which rests upon the wall, and the other on the intermediate bearing, is of a triangular form, with a perforated spandrel; the lower side is horizontal, resting upon the supports, the upper taking the slope of the roof, and the inner one springing from the inner support, with a curve of 5 feet radius, to range with the curvature of the other part of the roof, the radius of which is 48 feet. This girder is 1 foot 6 inches in depth, with a rib on either side in the centre. The next girder is of the same depth throughout, viz. 1 foot 6 inches, and in the cross section has a rib in the centre, and one of less projection at the lower edge; this portion is covered with slate slabs, $\frac{3}{4}$ inch thick. The central girder differs from the rest, being 2 feet in depth, with a flanche at top and bottom, the girder between being perforated for the sake of diminishing the weight; this portion is covered with glass. Each of the girders have abutment plates at the end, by means of which they are bolted together. The total rise or versed sine of the roof is about 12 feet.

The roof over the palm-house, Kew Gardens, is also worthy of description, on account of its exceedingly light and elegant appearance. The total length of this house is 362 feet 6 inches in the clear, the central portion measuring 137 feet 6 inches long, and 100 feet wide, by 63 feet high in the clear, exclusive of the lantern, which is 6 feet. The wings are each 112 feet 6 inches long, and 50 feet wide, and 27 feet high from the floor to the bottom of the lantern. The roof is in this case entirely of wrought-iron, the main ribs being formed of 9 inch deck-beam iron of circular section, hollow at the core, with four double flanges at right angles to each other. These ribs are obtained in lengths of about 12 feet, and are welded together to the required length, about 42 feet, and then bent upon a template to the requisite curvature.

The roof of the wings is of a single span, the rib being curved of a semicircular form, the extremities of which spring from the ground on either side of the plan, and foot into a solid block of granite, upon a concrete foundation. In the main or central building this semicircle is divided into two quadrants, which cover the aisles of this compartment, the lower ends being bedded upon granite, as above, and the upper ends into the tops of strong cast-iron columns which divide the width of this portion of the building into three aisles. From the top of the same columns springs a circular rib, similar to that in the wings, which is again surmounted by a lantern 6 feet in height. From the top of the columns brackets project, which on one side carry a gallery, running round the bottom of the upper roof, and on the other side serve to assist in the strengthening of the ribs. The column heads are connected by a continuous curb of similar scantling to the ribs, and the whole of the ribs are braced together and strutted by wrought-iron tie-rods, passing through cast-iron tubes, which act as purlins. These purlins are formed of a round bar $1\frac{1}{8}$ inch in thickness, welded in long lengths, and passing through the ribs, so as to form a continuous tension-rod all round the house at each purlin, with means of straining them as tight as possible. This tension-bar is covered or enclosed in a tubular bar of wrought-iron, exactly fitting between the ribs, and acting as distance-pieces in opposition to the strain of the tension-rods: thus is the entire structure compacted together. The distance between the main ribs is 12 feet 6 inches, and between the purlins 9 or 10 feet. This is in every respect a very elegant roof, and astonishingly light for so great a span.

The iron roof erected over the railway station at Lime-street Liverpool, is of great span, and of novel and ingenious construction. The area roofed over in one span extends from the façade in Lime-street to the viaduct over which Hotham-street passes, and from the inner faces of the receiving offices to about the middle of the old parcel offices on the opposite side; thus making the extreme length 374 feet and the breadth 153 feet 6 inches. The roof consists of a series of segmental principals, or girders, fixed at intervals of 21 feet 6 inches from centre to centre: these are supported on one side upon the walls of the offices, as far as they extend, and thence to the viaduct, a distance of 60 feet 4 inches, upon a box-beam of wrought-iron, whilst on the other side they rest on cast iron columns. The principals are trussed vertically by a series of radiating struts, which are made to act upon them by straining the tie-rods and diagonal braces; they are trussed laterally by purlins placed over the radiating struts, and intermediately between them, as well as by diagonal bracing, extending from the bottom of the radiating struts to the top of the corresponding struts in the adjoining principal. These diagonal braces are connected with linking plates, by a bar of the same scantling, and also with the purlins already referred to. The curved ribs are thus firmly drawn together and attached to one another, and a rigid framework is formed, upon which the covering of corrugated iron and glass is laid.

Each principal girder is composed of a wrought-iron deck-beam, 9 inches in depth, with a plate 10 inches wide and $\frac{1}{4}$ inch thick, riveted on the top. The upper flange of the deck-beam is $4\frac{1}{2}$ inches wide and $\frac{1}{2}$ inch thick; the lower flange 3 inches wide and one thick: the web is about $\frac{7}{8}$ inch thick. This curved rib is formed of seven pieces connected with each other at the points where the radiating struts are attached, by means of plates riveted on both sides: these plates are 6 feet long, 7 inches broad, and $\frac{7}{16}$ inch thick. The beam is also strengthened at the haunches, for a distance of 27 feet from the springing, by plates 7 inches broad and $\frac{3}{8}$ inch thick, fastened by rivets.

There are 6 radiating struts in each rib, varying in length from 6 feet to 12 feet, the length increasing from the springing to the centre. They are similar in section to the principals, but are only 7 inches in depth, being attached to them, and to the tie-rods, by means of wrought-iron linking-plates. The top of the strut is made to touch the under side of the principal, in which position it is clasped by linking-plates, and secured by a bolt $1\frac{1}{4}$ inch in diameter.

The tie-rods in each rib are composed of three lines of rods between the two extreme radiating struts, and from these struts to the extremities of the principals they are in two lines, the sectional area in each case being the same, viz. $6\frac{1}{2}$ square inches. The ends of the tie-rods, which are prepared with eyes to receive the bolts, are placed side by side between the linking plates, attached to the struts, and a bolt is then passed through them: it will thus be evident, that if any elongation takes place in the ties, the struts will be acted upon.

The diagonal braces extend from the bottom of each strut to the top of one next towards the springing; they hold the struts tight up against the principal, and at the same time assist the tie-rods in their duty. These braces are formed of round-iron, $1\frac{3}{8}$ inch in diameter, secured at top by bolts passing through the linking-plates, and at bottom by wedges, so as to give an opportunity of tightening them up if required.

Each compartment of principals is thus separately trussed and tied, and the whole made fast at the extremities by passing a strap or stirrup iron round the back of a metal chair, in which each end of the girder rests, and to which it is bolted at the side; the jaws of this stirrup-iron are attached to the extremities of the rods by wedges.

The ends of the principals are fixed in cast-iron chains resting on one side of a metal pillar, and on the other on the wall, or upon the box-beam; those upon the pillars are cast upon the upper cap, and those upon the wall and box-girder rest upon two rollers, which can travel a space of 3 inches upon a metal plate, so as to admit of expansion and contraction.

The purlins are each formed by a combination of three T irons, the centre T iron running straight from principal to principal, and those at the sides branching off at 5 feet from each end, so as to strut the girder in three points. The purlins are secured to the deck-beam by angle plates, fixed on both sides, one limb being fixed to the blade of the purlin, and the other to the deck-beam.

In addition to the lateral trussing which the ribs receive from these purlins, diagonal braces are fixed between each two corresponding struts, connected at the top with the purlins, and at bottom with the linking-plates, by bars of their own scantling; thus the ribs are all braced together, and a firm and rigid mass of framing, formed to carry the covering.

The box-beam, upon which a portion of one side of the roof is supported, is 63 feet 4 inches long; 3 feet 2 inches deep at the ends; and 2 feet 6 inches at the centre, the versed sine being 8 inches. The upper chamber is 20 inches wide, and 8 inches deep, and the body is $13\frac{5}{8}$ inches wide, by 1 foot 10 inches deep. The bottom, $19\frac{5}{8}$ inches wide, is formed of two rows of plates, $\frac{8}{16}$ths inch thick in the middle, and $\frac{6}{16}$ths at the ends. The thickness of all the other plates is $\frac{5}{16}$ths inch. On the opposite side of the roof, 17 cast-iron columns, 21 feet 6 inches apart, serve to support the ribs. The columns are 19 feet high from the base to the cap, and 4 feet 3 inches from the cap to the metal chair. At the bottom they are fastened into stones of 5 tons weight each, at 3 feet below the base. The roof is covered with galvanized corrugated wrought-iron and rough plate-glass. The total cost was £15,000.

A patent was taken out recently by Mr. Nasmyth, for improvements in the construction of fire-proof flooring and roofing.

These improvements consist in constructing floors and roofs of iron plates, which are bent into the form of a segment of a circle, or into a conical, polygonal, or other shape, by the ordinary plate-bending machinery, or by any other suitable means. These bent plates are supported on chord plates, or tension-bars which have their ends bent upwards, whereby the plates are retained in their curved position, when subjected to pressure. The ends of the chords rest upon flanges of cast or wrought-iron girders, above which are cast or riveted knee-pieces, which prevent the bent ends of the chords from springing; or, instead of iron-plates, angle, or T iron, bent into the required shape, and supported upon chords resting upon the flanges of girders, may be employed. Over these curved ribs, iron-plates are bent, with their ends placed underneath the bent-up ends of the chords. The spaces above the iron-plates are filled up, to form the flooring with Portland cement, mixed with broken bricks and other suitable materials. The improved girders are formed by bolting iron plates to the sides and tops of stone arches and chords combined as before. The side plates are made with flanges to support the arches and chords which form the joists, and have also knee-pieces bolted to them to prevent the chords from springing, when the arch is subjected to pressure. The arches and chords may be made of one piece each, or may be made of several pieces, and bolted or riveted together.

Allusion has been made in a previous column, to the various materials used for the covering of roofs, with reference to the different degrees of inclination suitable for them. Thatched roofs have been considered by some to maintain the most equable temperature in the buildings covered by them; keeping out alike the extreme heat of summer, and cold of winter. They are objectionable on account of their harbouring vermin, being easily damaged by wind, and dangerously combustible. The frequent repairs required, make thatch also an expensive material. Besides straw, reeds and heath are sometimes used for thatching, and possess the adavntage of greater durability. Tiles admit heat and moisture more than good slates. Pantiles having no holes for nailing through, are simply hung by ledges, upon laths nailed to the rafters. Plain tiles, laid in mortar, and overlapping so as to be double thickness everywhere, make a very good, though heavy covering. Tiles of a peculiar form, called *hip-tiles*, are used for covering salient angles; and *gutter-tiles*, which are similar to them, but placed with the concave side upwards, in the valleys or receding angles. Slates are laid in various ways. They are sometimes nailed down on across boarding: or if large, on *battens*, or pieces of wood from two and a half to three inches wide, and three-quarters of an inch to an inch thick, which are nailed to the rafters at intervals regulated by the length of the slates. Lozenge-shaped slating is occasionally used, and has an ornamental appearance, but is easily injured, as there is but one nail through each slate. It is always laid on boarding. For what is called patent slating, the best large slates are selected, and fixed without either boarding or battening, the common rafters being placed at such a width as to come under the joints. The slates are screwed down, the courses over-lapping about two inches. The meeting-joints are covered by fillets of slate, about three inches wide, set in putty, and screwed down; and the hips and ridges are sometimes covered in the same manner, though it is best, in all such cases, to use lead. Patent slating, when well executed, is water-tight, with as low a slope as one in six. In some districts, laminæ of stone are used in lieu of slates or tiles. Shingles, which are like slates, but made of wood, were formerly much used in covering pyramidal steeples, and in roofs of steep pitch. They are still used in the United States, and are usually laid on boarding, in a similar manner to common slates.

Sheets of metal are very convenient for covering domes, and curved angular surfaces generally, and also for flat roofs, or such as have too little slope for slating. Lead is the most common material for such purposes, though copper, iron, tinned-iron, and recently zinc, are also used. Lead terraces, or flats, are commonly laid on boarding or plaster. The joints are sometimes soldered, but the most approved method is to roll or wrap the edges into each other, making allowance for expansion and contraction. A fall of a quarter of an inch in a foot, is sufficient for surfaces covered with sheet metal.

The weight of lead is somewhat against its use for roof-covering; it is used in sheets weighing from 4 lbs. to 8 lbs. per foot super. Copper is much lighter, and is used in sheets weighing about 1 lb. per foot super, but its expensiveness precludes its adoption for general purposes. Zinc is much lighter than lead, weighing from 12 to 20 ounces per foot super; and of late has been very widely employed on this account, as well as because of its cheapness; it forms a very useful covering. Iron galvanized, or coated with zinc, has also been very extensively used for this purpose, for which it is also well adapted. Sometimes it is corrugated, by which it is considerably strengthened, and thus some of the strength of the roof itself may be dispensed with, especially in small spans, where curved roofs of corrugated iron may be safely employed. Tiles of this material also, are sometimes used; they are treated much in the same way as common tiles, being simply nailed to battens or boarding. The following table, giving the weight per square of 100 feet for different kinds of roof-covering, may prove serviceable:—

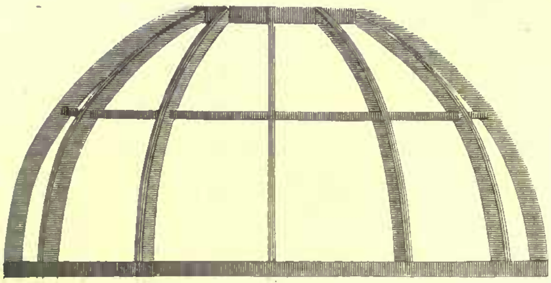
	Cwts.
Plain tiles	18
Pantiles	9½
Slating	7
Lead at 7 lbs. to foot super . . .	6½
Corrugated iron	2
Copper or zinc at 16 ounces to ditto.	1

Having now given a description of the several varieties of roofs covering a square or rectangular plan, it may not be improper to give a few examples of domes, and show how they may be constructed under various circumstances. If the dome to be constructed be on a circular plan, with no lantern above, the ribs may be built in the following manner, with planks of convenient lengths, in three or more thicknesses. Having ascertained the length of the ribs, and the number of pieces in that length, and having properly shaped all the pieces to the curve, the middle piece at the bottom may be one of these lengths; to each side may be joined two other pieces, one reaching to a third of the middle piece, and the other to two-thirds from the bottom, so that by continuing with planks of the whole length to the other extremity of the rib, the middle thickness will always be covered two-thirds from the bottom on one side, and one-third on the other; the deficiency at the top must be filled up with pieces, one of a third, and the other of two-thirds, as at the bottom; the whole being well bolted together, and strapped across the joints, will be nearly as strong as a solid rib.

Plate VIII. *Figure* 1, shows the manner of constructing this kind of dome; No. 1 being the semi-plan; No. 2, the elevation; No. 3, the manner of building the rib. In domes of this kind, it may sometimes be necessary to discontinue the ribs, that the spaces may be more equally divided for the horizontal ribs. It is evident that a dome built in this manner, may be carried to almost any extent, provided it have a sufficient number of horizontal ribs. Of this construction is the Halle du Blé, at Paris, of 200 feet in diameter, the invention of a judicious carpenter, the Sieur Molineau, a man of little scientific education, but of considerable mechanical experience. Being convinced that a very thin shell of timber might not only be so shaped as to be nearly in equilibrio, but that, if well connected with horizontal ribs, it would have all the requisite stiffness, he presented his scheme to the magistracy of Paris. The grandeur of the idea pleased them but they referred it to the Academy of Sciences. The members, who were competent judges, were struck with the justness of M. Molineau's principles, and astonished that a thing so plain, had not become familiar to every house-carpenter. It quickly became a universal topic of conversation, dispute and cabal, in the polite circles of Paris. But the Acadamy having given a favourable report of their opinion, the project was immediately carried into execution, and soon completed, and now stands as one of the greatest exhibitions in Paris. The circular ribs, which compose this dome, consist of planks 9 feet long, 13 inches broad, and 3 inches thick, made in three thicknesses, as in that already described. At various distances, these ribs are connected horizontally by purlins and iron straps, which make so many hoops to the whole. When the work had reached such a height, that the distance of the ribs was two-thirds of the original distance, every second (now consisting of two ribs, very near each other,) was discontinued, and the void glazed. A little above this, the heads of the ribs are framed into a circular ring of timber, which forms a wide opening in the middle, over which is a glazed canopy, or umbrella, with an opening between it and the dome, for allowing the heated air to get out. All who have seen this dome agree in describing it as the most beautiful and magnificent object they ever beheld.

The only difficulty in the construction of wooden domes is when they are loaded in the upper part by a heavy lantern, or cupola. Such a dome as has been described would be in danger of being crushed inwardly; the most effectual method of preventing which, is by making the ribs in the form of trusses, with an inclined timber extending from the base of the dome to the bottom of the lantern, connecting the two extremities of the exterior side, forming as it were the base of a truss in a common roof, and acting contrary to the nature of a tie-beam; they resist the vertical pressure of the lantern, without having any tendency to burst out the sides by acting entirely longitudinally on the wall-plate. In order

Fig. 1. No. 2.



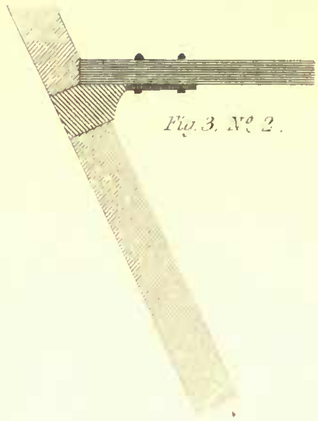
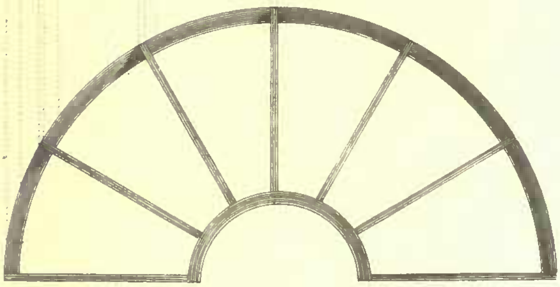


Fig. 3. No. 2.

Fig. 1. No. 1.



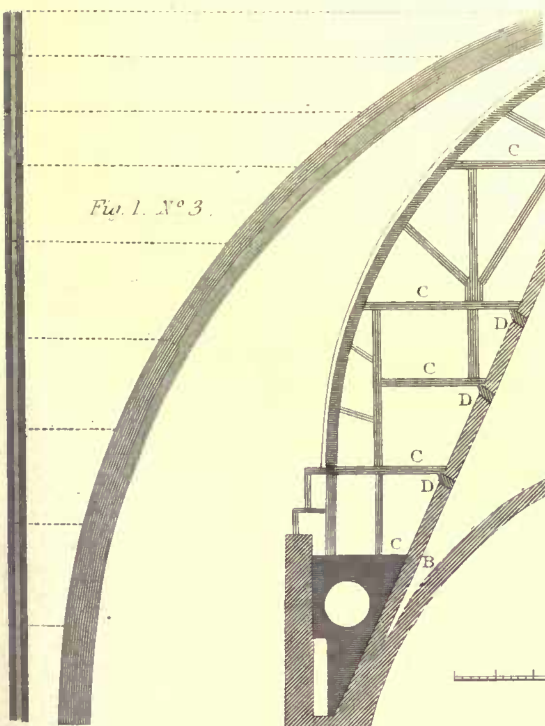


Fig. 1. No. 3.

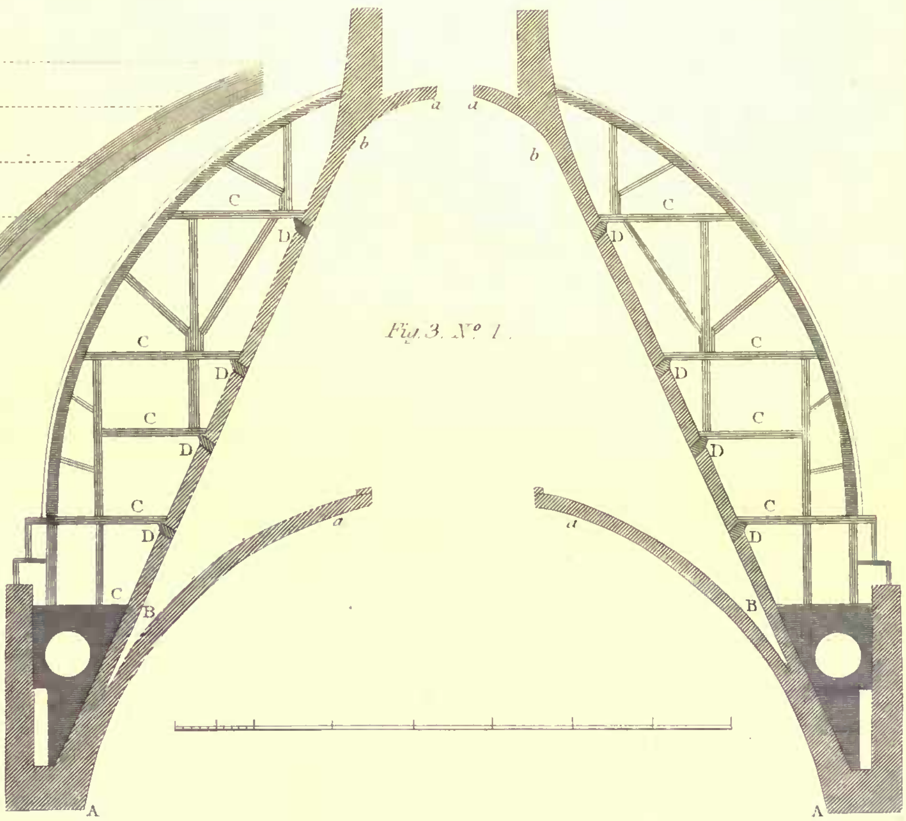


Fig. 3. No. 1.

wn by P. Nicholson.

Engraved by J.C. Buttre.

to secure the lantern, horizontal braces are fixed from the bottom of the lantern to the middle of the principal braces under the joggles, so that the whole is resolved into triangles, which are all immoveable at the angles. The wall-plates should be framed as the ribs of a dome constructed as in the last example.

When a dome is to support a heavy cupola of stone, such a construction as that of the cathedral of St. Paul's, London, may be employed. *Figure* 3, No. 1, exhibits the truss of this dome, taken from accurate measurement. A *a a* A, a dome of brick, two bricks thick, which, as it rises every five feet, has a course of strong bricks 18 inches long, bonding through the whole thickness. B *b b* B is a cone, built with bricks 1 foot 6 inches in thickness, for supporting the heavy cupola above, of Portland stone, which is 21 feet in diameter and near 61 feet high, and also the timber-work of the dome. The horizontal, or hammer-beams, C C, &c. are curiously tied to the corbels, D, D, D, &c. with iron cramps, bedded into the corbels with lead, and bolted to the hammer-beams. No. 2 shows more particularly the manner of tying the hammer-beams to the corbels.

This dome is boarded from the base upwards, and the ribs are therefore fixed horizontally, having their sides in planes tending to the centre of the dome. The contour of the dome is formed of two circular segments, which meet in the axis like a pointed arch. The scantlings of the curve rib of the truss are 10 inches by 11½ at the bottom, and 6 inches by 6 at top. It has a very strong double iron chain, linked together at the bottom of the cone, and several other less chains between that and the cupola. This dome was turned upon a centre, supported without standards from below. As every story of the scantling was circular, and the ends of the ledges meeting like so many rings, and truly wrought, it supported itself; and as it was both centering and scaffolding it remained for the use of the painter, there being a space of twelve feet between it and the dome. This machine, it is said, was original of its kind.

A description of a dome constructed mainly of cast-iron girders, over the cathedral of St. Isaac, St. Petersburg, will be found under the article DOME, to which we must refer for further information on the general subject, as well as to CURB ROOF, VAULTING, MECHANICAL CARPENTRY, &c.

Before concluding this article, we must state that we are much indebted for the descriptions, &c. to *Tredgold's Carpentry*, the *Transactions of the Institution of Civil Engineers*, the *Builder*, and other similar works.

ROOF, *Hipped*, see HIPPED ROOF.

ROOFING, in rural economy, a word sometimes applied provincially to the the ridge-cap of thatched roofs. It also signifies any sort of material employed in forming the roof of a building, whether in the framework or covering. In the business of roofing farm or other buildings, the chief circumstance necessary to be attended to, is that of tying the two side-parts well together, and in a safe manner, by means of the wall-plates and binding-beams; especially in those erections which are of the longer kind, without any cross-walls to stiffen and support them. It has been remarked, that it is generally for want of attention to these matters that farm-buildings, as well as those of other sorts, are so frequently seen propped up with shores and buttresses; or fallen to the ground half a century sooner, perhaps, than they would have done under a better and more judicious management. And it ought, indeed, to be a general principle, or line of conduct, which every careful and intelligent manager should follow in erecting such buildings;—a principle which is equally applicable to the other parts, as well as the timber and the covering;—which is, that of sparing no requisite expenditure, as a few shillings, or pounds, of additional cost in the first instance, may be the saving of ten times the sum in the end.

In the work of repairing buildings of this nature, the roofing claims equally the regard of the manager, with the foundations and other external parts. But the inside works, in all cases, more commonly and properly demand the notice of the occupiers.

ROOM, see APARTMENT, and BUILDING.

ROSE, an ornament applied to the centre of each side of the abacus of the Corinthian capital.

ROSE WINDOW, a circular window, divided into lights by mullions or tracery branching from the centre, and disposed in a variety of different patterns. Windows of this kind are also termed Catherine-wheel and marigold windows.

ROSTRUM (Latin, signifying *a bird's beak*, or *the prow of a ship*), a part of the Roman forum, where in orations, pleadings, funeral harangues, &c. were delivered.

The rostrum was a kind of chapel taken out of the forum, and furnished with a suggestum, or eminence, called more particularly *the rostrum*, where the orators stood to speak.

It was adorned, or, as Livy says, built, with the beaks of ships taken from the people of Antium, in a naval engagement; whence the name.

There are two kinds of rostra; *rostra vetera* and *rostra nova*. The latter was erected by Augustus, and decorated with the prows of vessels which he took at the battle of Actium. The first were those already described.

ROTONDO, or ROTUNDA (from the Latin *rotundus*, round), a popular term for any building that is round both within and without, whether it be a church, hall, saloon, vestibule, or the like.

The most celebrated rotondo of antiquity is the Pantheon at Rome, dedicated to Cybele and all the gods, by Agrippa, son-in-law of Augustus; but since consecrated, by pope Boniface IV., to the Virgin and all the saints, under the title of Sta. Maria della Rotondo.

The chapel of the Escurial, which is the burying-place of the kings of Spain, is also a rotondo; and, in imitation of that of Rome, is also called Pantheon.

ROUGH-CAST, or ROUGH-CASTING, see PLASTERING.

ROUND CHURCH, this appellation is given to a few churches which exist of a peculiar construction, being erected on a plan either simply circular, or circular with a rectangular projection: the circular portion in both cases being that which forms its peculiarity. There are only four such structures in England—the Temple Church, London, which is the largest and most magnificent; the Church of the Holy Sepulchre at Cambridge; one with the same dedication at Northampton; and a small church at Little Maplestead, in Essex. In all these, the round or circular portion bears evidence of greater antiquity than the other parts of the edifice: and there can be no doubt but that the latter are more recent additions to the original structure, which for the most part are employed as a choir, the circular part being retained as the nave. The round consists generally of two, sometimes of three stories, the upper stories being of less diameter than the lower one, and supported on massive piers and arches of Norman-work, by which an aisle is formed all round the interior, between the arcade and the external wall: above the arcade is a triforium, and above this again a clerestory, the roof above being vaulted.

It was at one time held that such buildings had been originally constructed by the Jews for synagogues; but this mistake is now exploded, and it is universally allowed that they were built by the Knights Templars, or Hospitallers, who were engaged in the Crusade to recover possession of the Holy Sepulchre at Jerusalem out of the hands of the infidels, and that the peculiar form was copied from that building. That the form of the church erected over the Holy Sepulchre by the empress Helena was of a circular form, there seems to be every reason to believe, for we have the evidence of written testimony as well as the form of the existing building; and although, no doubt, this has been rebuilt and much altered, by additions and otherwise, since the time of Constantine, still there is sufficient reason to satisfy us that its general form has not been departed from. It would seem very natural, too, that the Crusaders, when they returned from the East, and began to erect new churches, should adopt that form which they had seen employed in the building, for the defence of which they had undergone such labours; the novelty of the form, too, would be likely to attract their attention, and lead to their emulation of it. When, in addition to this, it is considered that no less than two out of the four churches are dedicated under the name of the Holy Sepulchre, there can be little question as to its origin. Further, a third is named the Temple Church; and there is evidence that it was consecrated by Heraclius, bishop of Jerusalem, when he came to England to ask subsidies for carrying on the Crusade; and there was never any question as to its erection by the Knights Templars, who were especially associated for the defence of the Holy Sepulchre at Jerusalem.

Two of these round churches—the Temple, London, and St. Sepulchre's, Cambridge—have, within these last few years, been very creditably restored; especially the former, on which no expense has been spared to restore it to its pristine splendour; it is one of the most spirited and liberal restorations which have been attempted, and reflects great honour upon those by whom it was carried into effect. The second has been also very well and carefully restored by the Cambridge Camden, now the Ecclesiological Society; but it is to be regretted that the effect of the restoration has been partially destroyed by the bigoted introduction of some ornamental accessories, which are totally misplaced in such a building.

ROUND TOWERS. This term is applied to a particular class of towers built upon a circular plan, which are found in considerable numbers in Ireland, and almost exclusively in that country. They are evidently of great antiquity, and have long been a subject of antiquarian dispute. Mr. Petrie has, within the last few years, published a very elaborate work upon the subject, upon which he brings to bear very considerable knowledge and a clear judgment. His general description of the towers is as follows:—

They are rotund, cylindrical structures, usually tapering upwards, and varying in height from 50 to perhaps 150 feet; and, in external circumference, at the base, from 40 to 60 feet, or somewhat more. They have usually a circular projecting base, consisting of one, two, or three steps or plinths, and are finished at the top with a conical roof of stone, which frequently, as there is every reason to believe, terminated with a cross formed of a single stone. The wall towards the base is never less than 3 feet in thickness, but is usually more, and occasionally 5 feet, being always in accordance with the general proportions of the building. In the interior they are divided into stories varying in number from four to eight, as the height of the tower permitted, and usually about 12 feet in height. These stories are marked either by projecting belts of stone, set-offs or ledges, or by holes in the wall to receive joists, on which rested the floors, which were almost always of wood. In the uppermost of these stories the wall is perforated by two, four, five, six, or eight apertures, but most usually four, which sometimes face the cardinal points, and sometimes not. The lowest story, or rather its place, is sometimes composed of solid masonry, and when not so, it has never any aperture to light it. In the second story, the wall is usually perforated by the entrance-doorway, which is generally from 8 to 30 feet from the ground, and only large enough to admit a single person at a time. The intermediate stories are each lighted by a single aperture, placed variously, and usually of very small size, though, in several instances, that directly over the doorway is of a size little less than that of the doorway, and would appear to be intended as a second entrance.

In their masonic construction, they present a considerable variety; but the generality of them are built in that kind of masonry called spawled rubble, in which small stones, shaped by the hammer, in default of suitable stones at hand, are placed in every interstice of the larger stones, so that very little mortar appears to be intermixed in the body of the wall; and thus the outside of spawled masonry, especially, presents an almost uninterrupted surface of stone, supplementary splinters being carefully inserted in the points of the undried wall.

His conclusion, with respect to the use to which such towers were put, and also as to their date and origin, is:—

I. That the towers are of Christian and ecclesiastical origin, and were erected at various periods between the fifth and thirteenth centuries. 2. That they were designed to answer, at least, a twofold use, namely to serve as belfries, and as keeps or places of strength, in which the sacred utensils, books, relics, and other valuables, were deposited, and into which the ecclesiastics, to whom they belong, could retire for security in cases of sudden predatory attack. 3. That they were probably also used, when occasion required, as beacons and watch-towers.

These conclusions, which have been already advocated, separately, by many distinguished antiquaries, among whom are Molyneux, Ledwitch, Pinkerton, Sir Walter Scott, Montmorenci, Brewer, and Otway, will be proved by the following evidences:—

For the first conclusion, namely, that the towers are of Christian origin:—

1. The towers are never found unconnected with ancient ecclesiastical foundations. 2. Their architectural styles exhibited no features or peculiarities not equally found in the original churches with which they are locally connected when such remain. 3. On several of them Christian emblems are observable, and others display in the details a style of architecture universally acknowledged to be of Christian origin. 4. They possess invariably architectural features not found in any buildings in Ireland, ascertained to be of Pagan times.

For the second conclusion, namely, that they were intended to serve the double purpose of belfries and keeps, or castles, for the uses already specified:

1. Their architectural construction, as will appear, eminently favours this conclusion. 2. A variety of passages, extracted from our annals, and other authentic documents, will prove that they were constantly applied to both these purposes.

For the third conclusion, namely, that they may also have been occasionally used as beacons and watch-towers:

1. There are some historical evidences which render such an hypothesis extremely probable. 2. The necessity which must have existed in early Christian times for such beacons and watch-towers, and the perfect fitness of the round towers to answer such purposes, will strongly support this conclusion.

These conclusions, or at least such of them as presume the towers to have had a Christian origin, and to have served the purpose of a belfry, will be further corroborated by the uniform and concurrent tradition of the country, and by authentic evidences relating to the erection of several of the towers, with the names and eras of their founders.

A description of one or two of these towers will assist in giving an idea of their varieties and general character. That at Monasterboice, near Drogheda, is 110 feet high and 17 in diameter; the thickness of the wall is 3 feet 6 inches. The ancient church, which is close to it, is now in ruins. In the churchyard are two very old and curious crosses; one about 18 feet high, covered with sculpture, is called St. Boyne's cross, and is esteemed the most ancient religious relic in Ireland. The round tower at Drumisken, in Louth, is 130 feet high; and that of Kildare 133 feet high and 18 in diameter. The walls of the latter are $3\frac{1}{2}$ feet thick, and are built of fine white granite, to about 12 feet from the ground.

Of the two round towers in Scotland, that at Brechin consists of sixty regular courses of hewn stone, of a brighter colour than the adjoining church; it is 85 feet high to the cornice, whence rises a low pointed roof of stone, with windows, and a vane at the top. The other tower at Abernethy is 75 feet high, and like that of Brechin, is about 48 feet in external circumference. On the front of the tower at Brechin are two arches, one within the other, in relief. On the point of the outermost is a crucifix, and between both, towards the middle, are figures of the Virgin Mary and St. John, the latter holding a cup with a lamb. The outer arch is adorned with knobs, and within both is a small slit or loop; at the bottom of the outer arch are two beasts, couchant, one of them, by its proboscis, is evidently intended for an elephant.

There are some few round towers in France, which some antiquaries are inclined to think similar in origin and employment. The French, however, are unlike the Irish towers. Those of the former are of various figures, principally octagonal, and of moderate heights. The tower of Quineville, called Cheminée de Quineville, is one of these. It is situated within eight leagues of Cherbourg, is hollow throughout, having neither stairs nor floors. It consists of a base, circular within, and 17 feet high, constructed in that style called by the Romans *opus reticulatum;* above this is placed a cylindrical column $11\frac{1}{2}$ feet in height and 20 feet in circumference. The external face is ornamented with Corinthian and Tuscan pilasters supporting an entablature, above which rises a dome, roofed in the form of a truncated cone. Some think that it has served as a pharos, others as a belfry. But it is neither within view of the sea, nor near to any church. There are, however, in France, isolated towers in the vicinity of churches. They belong to the middle ages. In the cemetery of the Innocents' at Paris, is one of an octagon form, surmounted by a dome; it is 44 feet in height and 12 feet in diameter. At Mouthran, near Martignon, is another octagon, 35 feet high and 16 in diameter. The door is 8 feet from the ground. In the cloister of the Monastery des Dames, at Fontevrault, is an ancient tower 76 feet in height and 20 feet in diameter. For our own part, we are not of opinion that these towers, or at least all of them, are of the same origin as those in Ireland.

RUBBLE-WORK, a rough, irregular kind of masonry.

RUDENTURE, (from the Latin, *rudens*, a rope,) the figure of a rope, or staff, sometimes plain, sometimes carved; with which a third part of the fluting of columns is frequently filled up. It is by some called a cabling; and the columns, whose flutings are thus filled, they call rudented or cable columns. There are also rudentures in relievo, laid on the naked of pilasters, not fluted; an instance of which we have in the church of S. Sapienza at Rome.

RUDERATION, (from the Latin, *ruderatio*,) in building, a term used by Vitruvius for laying a pavement with pebbles or little stones. To perform the ruderation, it is necessary that the ground be first well beaten, to make it firm, and to prevent its cracking. Then a stratum of small stones is laid, to be afterwards bound together by mortar made of lime and sand, called by Vitruvius *statumen.* If the sand be new, its proportion to the lime may be as three to one; but if dug out of old pavements, or walls, as five to two.

Ruderation, Davilier observes, is used by Vitruvius, lib. vii. cap. 1, for the coarsest and most artless kind of masonry; where a wall is, as it were, cobbled up.

RUINS, (from the Latin *ruina*,) a term particularly used for magnificent buildings fallen to decay through lapse of time, and of which there only remains a confused heap of materials. Such are the ruins of the Tower of Babel, or the Tower of Belus, two days' journey from Bagdad, in Syria, on the banks of the Euphrates; which are now no more than a heap of bricks cemented by bitumen; and of which we only perceive the plan to have been square. Such also are the ruins of a famous temple, or palace, near Schiras in Persia, which the antiquaries will have to have been built by Ahasuerus; and which the Persians now call Tchelminar, or Chelminar; *q. d.*, the forty columns; because there are so many columns remaining nearly entire, with traces of others; a great quantity of basso-relievos, and unknown characters, sufficient to show the magnificence of the antique architecture. The ruins of Palmyra may also be reckoned in the class of famous ruins.

RULE, or Ruler, (from the Latin, *regula*,) a very simple instrument, ordinarily of hard wood, thin, narrow, and straight, serving to direct the drawing of right lines. The rule is of principal use in all the mechanical arts. To prove whether or no it be just, draw a line by it on paper; then turn the rule about, the right end to the left, and apply the same edge this way to the line; if the edge now agree exactly with the line, the ruler is true.

The stone-cutter's rule is usually 4 feet long, and divided into feet and inches. The mason's rule is 12 or 15 feet long, and is applied under the level to regulate the courses, to make the piedroits equal, &c.

Rule, *Parallel.* See Parallel and Instruments.

Rule, is also applied to certain instruments which have other considerable uses besides that of drawing lines. Such are carpenter's joint-rule, Everard's and Coggeshall's sliding-rules, &c.

Rule, *Carpenter's Joint,* an instrument, usually of box, 24 inches long, and $1\frac{1}{2}$ broad, each inch being subdivided into eight parts; on the same side with these divisions is usually added Gunter's line of numbers. On the other side are lines of timber and board-measure, the first beginning at $8\frac{1}{2}$, and continued to 36, near the other end; the latter is numbered from 7 to 36, 4 inches from the other end. The division of the timber-line is formed from a consideration that 1,728 inches make a solid foot, in the following manner:—thus, 9 is so placed against one of the divisions of inches, or parts on the other side of the rule, beginning from the right hand, that its square, which is 81 inches multiplied by that number of inches and parts, must make 1,728 inches; which, dividing 1,728 by 81, must be placed against $21\frac{1}{3}$ from the right-hand; and 10 must be placed against $17\frac{28}{100}$ inches; because 1,728, divided by the square of 10 or 100, gives $17\frac{28}{100}$, &c. But, because a square, whose side is 1,2, &c., to 8 inches, requires more than 24 inches in length, as a multiplier, in order to produce 1,728 inches; and since the length of the rule is only 24 inches, there is a table upon the left end of it, which supplies its defect of length. In this table, the upper row of figures, viz., 1, 2, 3, 4, 5, 6, 7, 8, denotes inches, or the lengths of the sides of squares; and the second and third rows are the correspondent feet and inches to make up a solid foot. It is made by dividing 144 inches by the squares of 1, 2, 3, 4, 5, 6, 7, 8.

The line of board-measure is thus divided: suppose the division 7 to be marked; divide 144, the number of inches in a square foot, by 7, and the quotient will be $20\frac{4}{7}$ inches; whence the division 7 must be against $20\frac{4}{7}$ inches on the other side of the rule. To mark the division 8, divide 144 by 8, and the quotient, which is 18 inches, must be placed on the line of board-measure against 18 inches on the other side, &c. But because the side of a long square, that is, 1, 2, 3, 4, 5 inches, requires the other side to be more than 24 inches, the whole length of the rule, there is a table annexed, formed by dividing 144 inches by each of the numbers in the upper row, and then each of the quotients by 12 to reduce into feet.

Rule, *Use of the Carpenter's Joint.* The application of the inches in measuring lengths, breadths, &c., is obvious. That of the Gunter's line, see under *Gunter's Lines*, in the article Instruments. The use of the other side is all we need here illustrate.

1. *The breadth of any surface, as board, glass, &c. being given; to find how much in length will make a square foot.*—Find the number of inches the surface is broad, in the line of board-measure; and right against it, on the inches side, is the number of inches required. Thus, if the surface were 8 inches broad, 18 inches will be found to make a superficial foot.

Or, more readily, thus: Apply to the breadth of the board or glass, that end of the rule marked 36, laying it even with the edge; the other edge of the surface will show the inches and quarters of inches which go to a square foot.

To find the content of a given surface: Find the breadth and how much makes one foot; then turn that over as many times as you can upon the length of the surface, and so many feet does the surface contain.

2. *Use of the table at the end of the board-measure.*—If a surface be one inch broad, how many inches long will make a superficial foot? Look in the upper row of figures for 1 inch, and under it, in the second row, is 12 inches, the answer to the question.

3. *Use of the line of timber-measure.*—This resembles the former; for, having learned how much the piece is square, look for that number on the line of timber-measure; the space thence, to the end of the rule, is the length, which, at that breadth, makes a foot of timber. Thus, if the piece be 9 inches square, the length necessary to make a solid foot of timber is $21\frac{1}{3}$ inches. If the timber be small, and under 9 inches square, seek the square in the upper rank of the table, and immediately under it are the feet and inches that make a solid foot. Thus, if it be 7 inches square, 2 feet 11 inches will be found to make a solid foot.

If the piece be not exactly square, but broader at one end than the other, the method is, to add the two together, and take half the sum for the side of the square. For round timber, the method is, to girt it round with a string, and to allow the fourth part for the side of the square. But this method is erroneous; for hereby above a fifth of the true solidity is lost. *See* Sliding Rule, and Timber.

Rule, *Bow. See* Ship Carpenter's Rule.

RULER, *Parallel. See* Instruments.

RUSTIC, a mode of building in imitation of simple or coarse nature, rather than according to the rules of art.

Rustic Chamfered, that when the face of the stones are smoothed and parallel to the surface of the wall, and where the margins are bevelled, at an angle of 135 degrees with the face of the stone; and as the joints are at right angles to the faces, the margins will also be at an angle of 135 degrees with the joints: so that, when two rustics come together, the bevelling, or chamfering, will form an internal right angle.

Rustic Coins, (by Vitruvius called *lapides minantes*,) the stones which are frequently placed at the external angles of buildings, so as to project beyond the naked of the wall; the edges being either bevelled, or the margins recessed in a plane parallel to the face or plane of the wall. The recesses, which are at the joints, have, therefore, three sides; one in the plane of the wall, or parallel thereto; and the other two generally perpendicular to the said plane. Rustic coins were much in use about eighty years ago, particularly in brick buildings. *See* Quoins.

Rustic Frieze. *See* Frieze.

Rustic Order, an order decorated with rustic quoins, rustic work, &c. Felibien says, it is properly where the several parts of the five orders are not exactly observed; but this confounds rustic with Gothic.

Rustic Work is where the stones in the face, &c. of a building, instead of being smooth, are hatched or picked with the point of an instrument.

The most coarse or common kind of rustic work, is that where the edges are simply cut about one-half or two-thirds of an inch round the margin, so as to be in the plane of the wall, or parallel to the said plane, and the intermediate part is broken with the hammer, so that the protuberant parts may project generally about an inch beyond the margin.

The recesses of rustics either run with the horizontal joints only, and have, therefore, the appearance of boards placed at small intervals; and sometimes the recesses run with both the horizontal and vertical joints; and, therefore when disposed in this manner, they have the appearance of projecting tablets.

Rustic Work, *Frosted*, that where the margins are reduced to a plane, parallel to the plane of the wall, and where the intermediate part has the effect of ice, with an irregular surface in protuberant parts.

Rustic Work. *Vermiculated*, that where the margins are reduced to a plane parallel to the face of the wall, and where the intermediate part of the stone, or general surface, is so formed as to have the effect of being eaten by worms.

S.

SACELLUM, in Roman antiquity, denoted a place sacred to the gods, without a roof.

SACRARIUM, a small family chapel in a Roman house, also the place in temples in which sacred things were deposited.

SACRINGE, or SANCTUS BELL, a bell to be found frequently over the eastern or chancel end of a church, supposed to have been rung at the elevation of the host.

SACRISTY, or VESTRY, a room attached to a church, in which the sacred vessels, vestments, and other valuables, are deposited.

SADDLE-BACKED-COPING. Coping weathered on both sides, having two sloping tables on the top, falling from a central ridge.

SAG, or SAGGING, the bending of a body that would be straight in a vertical position; but, when included, or laid horizontallly upon supporters at each end, becomes curved in the middle, from its own gravity: in which case it is said *to sag*.

SAGITTA, in architecture, a name sometimes used for the key-piece of an arch.

SAGITTA, in geometry, a term used by some writers, for the abscissa of a curve.

SAGITTA, in trigonometry, &c. the same as the versed sine of an arc; and so called by some writers because it is like a dart, or arrow, standing on the chord of the arc.

SAINT PETER'S, a celebrated church, at Rome, better known by the name of *Basilica Vaticana*, from its original form, and the Vatican hill, on which it stands, founded by Constantine the Great, over the reputed grave of St. Peter, to whom it was also dedicated. In the days of Paganism, the circus of Caius, afterwards of Nero, stood upon its site; and when Constantine, urged by Sylvester I., bishop of Rome, determined upon erecting this basilica, he destroyed the circus, and began himself to dig the foundation, carrying away, on his shoulders, twelve troughs of the earth, in honour of the twelve apostles. *See* BASILICA. Some of the walls of the circus were, however, permitted to remain, and were used for the basilica, in order to accelerate its completion: a quantity of marble was also taken from various ancient buildings, for its decoration, and it was adorned with a hundred columns. Being magnificently finished, it was consecrated by Sylvester on the 18th November, A.D. 324, and was richly furnished and endowed by Constantine, as it was afterward by other emperors, kings, and particularly by the popes. In 460, or 461, Pope Hilary presented two gold vases, set with jewels, weighing 15 lbs. each, with ten chalices, and twenty-four silver lamps. His successor, Simplicius, gave twelve more silver lamps, and a golden vase, of 16 lbs. weight: Pope Symmachus, about the beginning of the sixth century, presented twenty additional lamps of silver, besides twenty-two arches of the same metal, weighing 20 lbs. each. His successor, Hormisdas, had a silver beam made, of 1400 lbs. weight, to sustain the lamps given by his predecessors, and which burned night and day before the tomb of the apostles. Pelagius I., about the middle of the same century, adorned the tomb with silver, and Gregory I. added a canopy, supported by silver columns, of 180 lbs. each. Honorius I., who was raised to the pontificate in 625, had silver doors made to the basilica, each weighing 975 lbs., and he covered the roof with sheets of gilt metal, taken from the temple of Jupiter Capitolinus. Adrian I., towards the close of the eighth century, had a lamp made, in form of a cross, with 1,360 branches, that were lighted four times a year; and he adorned the tomb, used as a confessional, with 1,328 lbs. of gold. His successor, Leo III., built a tower, then unequalled. In the year 846, the basilica was stripped of all its treasure by the Saracens; but after they had been repulsed, Leo IV. had new doors made, with some basso-relievos of silver; after which, the building seems to have experienced very little alteration till the time of Nicholas III., who ascended the papal chair in 1277. This pontiff adorned it with mosaic-work, and engaged Giotto to execute many paintings for it. He also erected a magnificent habitation, called the *Canonica*, for a chapter of canons, successors of the monks of four monasteries, who had formerly officiated in this temple, by turns, day and night. This Canonica has since been pulled down, to make room for the modern basilica.

About 1,200 years from its foundation, this costly edifice began to exhibit symptoms of considerable decay; and, in 1506, Pope Julius II. began the new basilica, by enclosing all the old one. The first architect engaged in this undertaking was Bramante (see BRAMANTE), who, dying in 1514, was succeeded by Raphael d'Urbino, with others; he dying in 1520, the building was prosecuted by Baldassare Peruzzi. The troubles during the pontificate of Clement VII. caused a suspension of the work; nor was it resumed till 1546, when Paul III. employed Sangallo to carry it forward; but he dying the same year, the work was committed to the celebrated Michael Angelo Bonarotti (see BONAROTTI), who converted the design into the form of a Greek cross, and executed the design for the cupola. Bonarotti lived to see the building carried to the height of the tambour; and, on his death, which took place in 1564, he was succeeded by Giacomo Barozio da Vignola, till 1573, when Giacomo della Porta, assisted by Domenico Fontana, in the pontificate of Sixtus V., raised up the wonderful cupola from Bonarotti's model; and, to complete the small cupola, he added a ball of metal, as a supporter to the cross; the concavity of which ball contains commodiously thirty-two persons sitting This building had been sixty-seven years in hand, under the superintendence of seven architects, and during the reigns of twelve popes.

In 1606, the plan of this building was changed from a Greek cross to a Latin one, by pope Paul V., who also erected the portico with the grand front, after a design of Carlo Maderno.

This church surpasses all the most celebrated buildings, ancient or modern, not only in its size, which is immense, but in the excellency of its construction, within and without, and in the admirable works in marble, mosaic, metal, and gilt stucco, with which it is adorned.

At the foot of the grand ascent to the church are the statues of St. Peter and St. Paul, executed for the old basilica in the pontificate of Pius II., by Mino da Fiesole. The basso-relievo on the front, under the benediction gallery, representing our Lord committing the keys to St. Peter's care, is by Malvicino. The portico is ornamented with statues of the first popes, who suffered martyrdom, surrounded by festoons, angels, and gilt stucco; the performance of Algardi: the marble columns, of surprising magnitude, are from the original temple. On the right is a marble equestrian statue of the founder, Constantine the Great, in the attitude of observing the celebrated cross in the heavens, with the motto, *In hoc signo vinces :* it is the work of Cav. Bernini. In the four niches of the vestibule of the portico are as many statues, viz., Hope, by Livoni; Faith, by Rossi; Charity, by Ludovisi; and the Church, by Frascari. At the other end, on the left, is the equestrian statue of Charlemagne, as defender of the church, by Agostino Cornachini. In the vestibule, on the near side, are four other statues, viz., Prudence, by Livoni; Fortitude, by Ottone; Justice, by Rossi; and Temperance, by Rafaelli. Over the middle door is a large basso-relievo, in marble, of Christ committing his flock to St. Peter, by Bernini: and opposite to it is the celebrated *Navicelli*, or small ship, painted by Giotto, about the year 1300: this was formerly placed in the yard of the square portico, as a symbol of the Catholic Church, agitated, but not overwhelmed, from the tempest of many persecutions.

The entrance to the basilica is by five doors: that in the middle is metal, and was executed by order of Pope Eugenius IV., at Constantinople, by Filareto; its ornaments represent the martyrdom of St. Peter and St. Paul, and some deeds of the pope who ordered it.

The fifth door called *Porta Santa*, or holy door, is only opened in the jubilee year; and under the portico, near this middle door, the first bull for the jubilee, composed by Boniface VIII., is inscribed upon marble. Near the Porta Santa are two other inscriptions; one consisting of verses made by Charlemagne, in 795, in praise of Pope Adrian I.; the other describing the donations of Pope Gregory II. to this church, of olive grounds and other lands, for supplying the lamps at the sepulchre of the Apostles.

On first entering this vast temple, the imagination is raised with the expectation of beholding exquisite beauty and elegance; but the admiration it excites does not equal its fame, till the spectator begins to observe its several parts. On drawing near to one of the basins of holy water, on the first pilaster, the marble cherubim, that support it, appear at first regular and natural; but afterwards they are found to be gigantic, and almost out of proportion; they are the work of Livoni, Moderati, Rossi, and Cornachini. The doves, of marble, with olive-branches, that seem at first as if they could be touched by the hand, prove, on a nearer approach, to be very high, and appear to be flying still higher: an effect observable in most of the other works.

The middle aisle has a magnificent marble pavement, and the ceiling is grandly ornamented with gilt stucco, worked in grotesque with fruits, by Provenzale, by order of Pope Paul V., whose arms are in the centre, in mosaic; and every part is embellished with beautiful marble columns, and excellent basso-relievos, among which are fifty-six large medallions, with the portraits of as many sainted popes, sculptured by Nicolo Salé, a Frenchman, from designs of Bernini. Fixed against the pilasters are two remarkable stones, on one of which, it is said, Pope Sylvester I. divided the bodies of St. Peter and St. Paul; and, on the other, many martyrs were tortured and put to death. There are also two round black stones, which the Gentiles tied to the feet of the martyrs when on the *eculeo*, an instrument of torture in the form of a horse. The bronze statue of St. Peter, sitting, in the act of giving his benediction, was executed by order of Leo I., from the Jupiter Capitolinus, as an acknowledgment of the liberation of Rome from the persecution of Attila the Hun.

In the centre of the cross aisle, under the grand cupola, is the altar, called the *Confessional of the Apostles;* and under it is the ancient altar, turned toward the east, beneath which are said to be half the body of St. Peter and half that of St. Paul, with those of the early sainted popes. Here was the Vatican cemetery, where Anacletes first buried the body of St. Peter: and a small temple was built over it, which was afterwards pulled down, by order of the emperor Heliogabalus, to enlarge the passage for the triumphal cars. Around this shrine were formerly a vast number of lamps, with wicks of asbestos, continually burning balsam. Pope Calixtus II., in 1119, repaired and adorned it with costly marble, and consecrated it in the presence of the fathers of the general council convoked by him, and consisting of about a thousand bishops. It suffered no change, though the church was rebuilt in the interval, till the time of Clement VIII., who, about the year 1600, without removing any part of it, had it erected over the present altar. Paul V., a few years afterwards, having enlarged the basilica, as already noticed, adorned this confessional with precious marble, jasper, four alabaster columns, the statues of the two apostles, in bronze gilt, with other ornaments of the same material; and erected two noble descents, for the convenience of devotees approaching nearer the sanctuary to pray, around which one hundred and twenty-two silver lamps are continually burning. Urban VIII., at an expense of 100 000 crowns for workmanship alone, employed Bernini to erect a canopy of bronze over this shrine, supported by four twisted columns of the same metal, ornamented with very fine cherubim, modelled by Famingo, and partly gilt; with other remarkable works cast by Rossi.

The height of this canopy, including the cross on its top, is 124 palms; 186,392 lbs. of metal were consumed in making it, and, for the gilding, 46,000 crowns of gold.

The grand cupola is said by some to equal that of the ancient Pantheon; but others insist that it exceeds it by 37 palms in breadth, and 30 palms in height; being in magnitude 200 palms. The ball is 12 palms in diameter, and the cross is 25 feet in height, cast in bronze. The inside of the cupola is covered with mosaic work, from the cartoons of Cav. d'Arpino. The cherubim and flowers are by Roncalli and Provenzale; the evangelists, St. Matthew and St. Mark, by Nebbia; and St. Luke and St. John, by Vecchi. In the pilasters, Bernini opened four galleries, for exhibiting the sacred relics kept within the tabernacles. In that over the statue of Sta. Veronica is said to be part of the holy cross; the spear that pierced the side of our Lord, (presented by Sultan Bajazet II. to Pope Innocent III.); and the veil of Veronica, on which the face of Christ is impressed, and brought by her to Rome; but to these precious remnants no one is permitted to ascend, except the canons, without special leave of the pope. Over the statue of Sta. Helena, are many other relics, which are publicly exhibited at various times of the year. The eight columns in these galleries are said to have stood originally in Solomon's temple. The four marble statues in the niches are each twenty-two palms in height; that of Sta. Veronica is by Mochi; that of Sta. Helena by Bolgi; that of St. Andrew, by Quesnoy Fiamingo; and that of St. Longinus by Bernini; which last also executed the angels and other ornaments in the galleries. Against the pedestal of each statue is an altar-piece in mosaic, taken from the paintings of Andrea Sacchi.

Near these statues is the descent to the Grotto Vaticani, or the old church, into which women are only permitted to enter on Whit Sunday, when men are prohibited to approach. Here is the sepulchre of the apostles, erected by Anacletes, and among the ornaments of the high altar, are a statue of St. James, a Poliandro col pro Christo, containing many bones found in various piles of marble; and a chapel, with an image of God the Father, in marble.

On leaving this chapel is observed the old tribune, of mosaic, repaired by Giotto; the verses were cut on the frieze of the cornice, and the large cross was on the top of the ancient front. In the chapel of the blessed Virgin are the statues of St. Matthew and St. John; two sepulchral urns; various basso-relievos; part of a bull of Gregory III. inscribed on marble; besides other curiosities, too numerous to be particularized.

In the front of St. Peter's church towards the east, in the ancient camp, or valley, where the gentiles performed the Vaticini, and prepared for the triumphal processions, is the piazza of the Vatican basilica, in the form of an amphitheatre, which, for extent, magnificence, the distribution and elegance of the porticos, columns, statues, and fountains, astonishes the beholder, and appears to be the *ne plus ultra* of human art and genius. This was the work of Pope Alexander VII. from designs by Bernini, about the middle of the 17th century. The colonnades are of the Doric order, consisting of three hundred and twenty large stone columns, distributed into tetrads, and forming a street in the centre for processions, with walks at the sides for spectators. They are covered, and surrounded with cornices, on which, for greater ornament, are erected a stone balustrade, and one hundred and thirty statues of saints of both sexes, whose relics are preserved in the church, with those of the various founders of the religious orders.

In the centre of this piazza is the celebrated Egyptian obelisk, the only one of its kind that has wholly escaped the ravages of barbarous hands, and the injuries of time. It is of plain red granite, 113½ palms in height, all of a single piece; or, from the base, including the pedestal and cross, 180 palms, the cross alone being 10 palms. This monument, of ancient but uncertain date, is said to have been one of two obelisks dedicated to the sun in Heliopolis, the On of holy writ, by Nuncorius, called also Pheron, son of Sesostris, king of Egypt, on occasion of his recovering his sight, after a blindness of ten years; where it remained till the reign of the emperor Caligula, who, according to Pliny, had it removed to Rome, in the third year of his reign, and set up in the Vatican circus. When Constantine the Great destroyed the circus, the obelisk was left standing, and it remained neglected upwards of one thousand two hundred and fifty years, till the pontificate of Sixtus V., who was made pope in 1585, by which time it was buried to the top of the base in the accumulated ruins and rubbish. Sixtus ordered it to be cleared to its foundation, and employed the architect Dominico Fontana, who, on the 10th of September, 1586, with the labour of eight hundred men, and one hundred horses, removed it to its present situation, and set it up on two large blocks of granite, brought from Egypt at the same time with itself, and which serve for the pedestal, supported by a base of white marble. On the angles are four lions of metal, appearing to sustain the obelisk, cast from a model of Bresciano. The same pope dedicated it in honour of the true God, and, instead of the large metal ball, that was originally on the top, he placed his own arms, consisting of three mounts and a star, and above them a metal cross; which last, being injured by lapse of time and the weather, was taken down in 1740, and being repaired, a particle of the wood of the holy cross was inserted into it, and various indulgences have since been granted to those who, in passing by, have saluted it with a *Paternoster* or an *Avemaria.* The removal of this obelisk to its present situation, was first contemplated by Pope Nicholas V., who intended to have it sustained upon four colossal statues of the evangelists; but his death, in 1445, prevented the execution of his design.

On the right of the obelisk is a fountain, made by Paul V. early in the seventeenth century; and on the left is another, by Clement X., about the year 1671. They are both admirable works, as well for the copious supplies of water they throw up, as for their basins of the finest Egyptian granite, each cut out of one solid block.

For a view of the dimensions of this church, compared with those of St. Paul's, London, the reader is referred to page 674 of this volume.

SALIANT, (from the French, *saillant*, of *sailler*, to project or advance outwards; derived from the Latin, *salire*, to leap) in fortification, a projecting part.

There are two kinds of angles; the one *saliant*, or such as present their points outwards; the other *re-entering*, which have their points inwards. Instances of both kinds occur in tenailles and star-works.

SALLY, (from the French, *saille*, a jutting out) more commonly termed *projecture*, an expression used respecting the end of a piece of timber, when cut with an interior angle, formed by two planes, across the fibres; in which case the interior angle is called *a sally*, or *bird's mouth.* In this manner the feet of common rafters, and the inclined pieces which support the flying steps of a wooden stair, are frequently cut; as are likewise the lower ends of all inclined timbers, which rest upon plates or beams.

Sally-Ports, or Postern Gates, in fortification, underground passages, leading from the inner to the outer works, such as from the higher flank to the lower, or to the tenailles, or the communication from the middle of the curtain to the ravelin. In every place of arms, there are two sally-ports, each ten or twelve feet wide, for the troops to sally out. In time of a siege, they are shut up with barriers, or gates.

SALOON, (from the French, *salon*, a hall) a grand, lofty, spacious apartment, vaulted at top, and usually comprehending two stories, with two ranges of windows.

The saloon is a grand room in the middle of a building, or at the head of a gallery, &c. Its faces, or sides, are all to have a symmetry with each other; and as it usually takes up the height of two stories, its ceiling, Davilier observes, should be made with a moderate sweep.

The saloon is a state-room, much used in the palaces of Italy, and from thence the mode came to us. Ambassadors and other great visitors are usually received in the saloon. It is sometimes built square, sometimes round, or oval; sometimes octagonal, as at Marly, and sometimes in other forms.

To ascertain the superficies of a saloon, find its breadth, by applying a string close to it across the surface; find also its length by measuring along the middle of it, quite round the room; and multiply these results together for the surface. To find its solid contents, multiply the area of a transverse section by the compass taken round the middle part; subtract this product from the whole vacuity of the room, supposing the walls to go upright all the height to the flat ceiling.

SANCTUARY, the presbytery, or eastern extremity of the chancel eastward of the choir, which was set apart for the officiating priests, and in which the altar was stituated. *See* Chancel.

SAND (Dutch), in mineralogy, a name given to all mineral matter that exists in minute detached grains, and more particularly denominated from the prevailing substance as *silicious sand*, *iron sand*, &c.

Sand is generally formed from the disintegration of hard stones, or rocks, by the agency of water, and the particles of silicious stones, possessing a greater degree of hardness than most other kinds. The use of sand in building is an ingredient in mortar. For this purpose, pit-sand is, of all others, the best; and of pit-sand, the whitest is always the worst. Of river-sand, that found in the falls of water is best, because most purged; and sea-sand is worst of all.

Pit-sand, as being fat and tough, is most used in walls and vaults. River sand serves best for rough-casting.

All sand is good in its kind, if, when squeezed and handled, it crackles; and if, being put on a white cloth, it neither stains nor makes it foul. That sand is bad, which, mixed with water, makes it dirty and muddy, and which has been long in the air: for such will retain much earth and rotten humour. Hence some masons wash their sand before they use it.

The sand of Puzzuolo, De Lorme observes, is the best in the world; especially for maritime buildings. *See* Puzzolana.

SAND-STONE, in mineralogy, a stone essentially composed of grains or particles of sand, either united with other mineral substances, or adhering without any visible cement. The grains or particles of sand-stone are generally quartz, sometimes intermixed with felspar, or particles of slate. When the cementing matter is lime, such sand-stones are called calcareous: frequently the cementing matter is oxide of iron intermixed with alumine. The particles of sand in these stones vary greatly in size, some being so minute as scarcely to be visible.

Sand-stone is generally distinctly stratified; and some kinds, which contain a considerable quantity of mica, split into thin laminæ, which are used for slates in some parts of England, particularly in the West Riding of Yorkshire.

The lowest of the principal beds of sand-stone has been called by Werner, and the German geologists, the old red sand-stone. It generally rests on rocks of slate or grey-wacke, and is covered by thick beds of limestone. It is frequently coarse-grained, consisting of particles of quartz, and sometimes of felspar, cemented by iron-shot clay, that gives it the red colour from which its name is derived. According to many geologists, the red sand-stone, which extends on the western side of England, from Penrith in Cumberland to Shropshire, belongs to this formation.

The number and variety of sand-stones in the secondary strata are very great, and the diversity of quality fits them for the various purposes of building-stones, grind-stones, filtering-stones, &c. *See* Stone.

SANGALLO, ANTONIO DE, a celebrated architect, born in the 15th century, in the territory of Florence. His father, Antonio Picconi, was a cooper by trade, and Antonio was brought up to the business of a joiner. Having, however, two uncles, Guiliano and Antonio Sangallo, architects, of considerable reputation at Rome, he placed himself under their tuition, and assumed their name. He soon exhibited considerable talents, and his progress in the art made him known to Bramante, who, in 1512, entrusted to him the execution of several works. He soon obtained employment from some Cardinals; and in the pontificate of Leo X, when his uncle Giuliano quitted Rome, he was appointed his successor as architect of St. Peter's, in conjunction with Raphael. He also manifested great skill as an engineer; and Leo adopted a plan which he gave for the fortification of Civita Vecchia. Under Clement VII. he was employed in enlarging and embellishing the Vatican Palace, and in repairing the fortifications of Parma and Placentia. He is also celebrated for the construction of a remarkable well at Orvietto which had two staircases for the descent and ascent of beasts of burden. He enjoyed the favour of Paul III., who employed him in many important works as architect and engineer; and when Charles V. visited Rome after his Tunisian expedition, Sangallo had the planning of the triumphal decorations with which he was received. The Pauline chapel, and the magnificent staircases by which the chapels of the Vatican communicate with St. Peter's, were of his construction. The grandest effort of his genius was a wooden model of St. Peter's, which, however, was not closely followed. As he was noted for the solidity of his building, he was employed in strengthening the foundations of the Vatican and of the great columns which support the cupola of St. Peter's. Being engaged by the pope to survey the inundations of the lake of Marmora, the heat and the exhalations from the foul water caused a disease, of which he died in the year 1546.

SAP (from the Italian *zappare*, to undermine), in building, a term used when a trench is opened in the ground at the foot of a wall, &c., so as to bring it down all at once for want of support.

To demolish the thick firm walls of old castles, &c, sapping is much the readiest way.

Sap, in the military art, denotes a work carried on under cover of gabions and fascines on the flank, and mantelets, or stuffed gabions, on the front, to gain the descent of a ditch, counterscarp, or the like.

It is performed by digging a deep trench, descending by steps from top to bottom, under a corridor, carrying it as far as the bottom of the ditch, when that is dry; or as far as the surface of the water, when wet.

SAPHETA, more commonly called Soffit, in architecture, the board over the top of a window, placed parallel and opposite to the window-stool at the bottom.

SARACENIC ARCHITECTURE. *See* Moorish Architecture.

SARCOPHAGUS (from σαρκοφαγος), a sort of stone coffin or grave, in which the ancients laid those they had not a mind to burn.

The word, as derived from the Greek, literally signifies *flesh-eater*; because, at first, they used a sort of stone for the making of these tombs, which quickly consumed the bodies. The quarries from whence they dug it were near a city of Troas, named Assum. They had the faculty to waste away a body, except the teeth, in forty days. This stone resembled a reddish pumice-stone, and had a saltish taste. The ancients also made vessels of it to cure the gout, into which they put their feet, not suffering them to continue there too long.

SASH (from the french *chassis*, a frame), a chequered frame for holding the squares of glass in windows, and so formed as to let up and down by means of pulleys. Sashes are either single or double hung.

Sash-frame, the wooden frame in which the sashes are fitted for the convenience of sliding up or down, or sideways, as the nature of the apartment to be lighted may require.

When one or both sashes are to be moved vertically, they are commonly equipoised by weights; and the weights are made to run in vertical trunks, or cases, formed in the sides of the frames, which are therefore said to be *cased;* but when the sides are not made hollow for weights, the frame is said to be *solid.* In a sash-frame, the under side of the head is most commonly disposed in the same surface as the soffit, or intrados, of the stone or brick head of the window on the outside; consequently, it partakes of the shape of the head of the window, whether straight or circular. In a cased sash-frame, each case consists of four pieces; the inside piece, on each side, or that next the aperture, is most commonly disposed in the same plain with the jamb of the stone, or side of the aperture, on the outside, the two sides forming parallel planes: these two pieces are called *pulley-pieces*, from their containing the pulleys, over which the ropes pass, by which the sashes and weights are suspended. The other three parts of each trunk are called *linings;* that parallel to the pulley-piece, and next to the jamb, on either side, is called

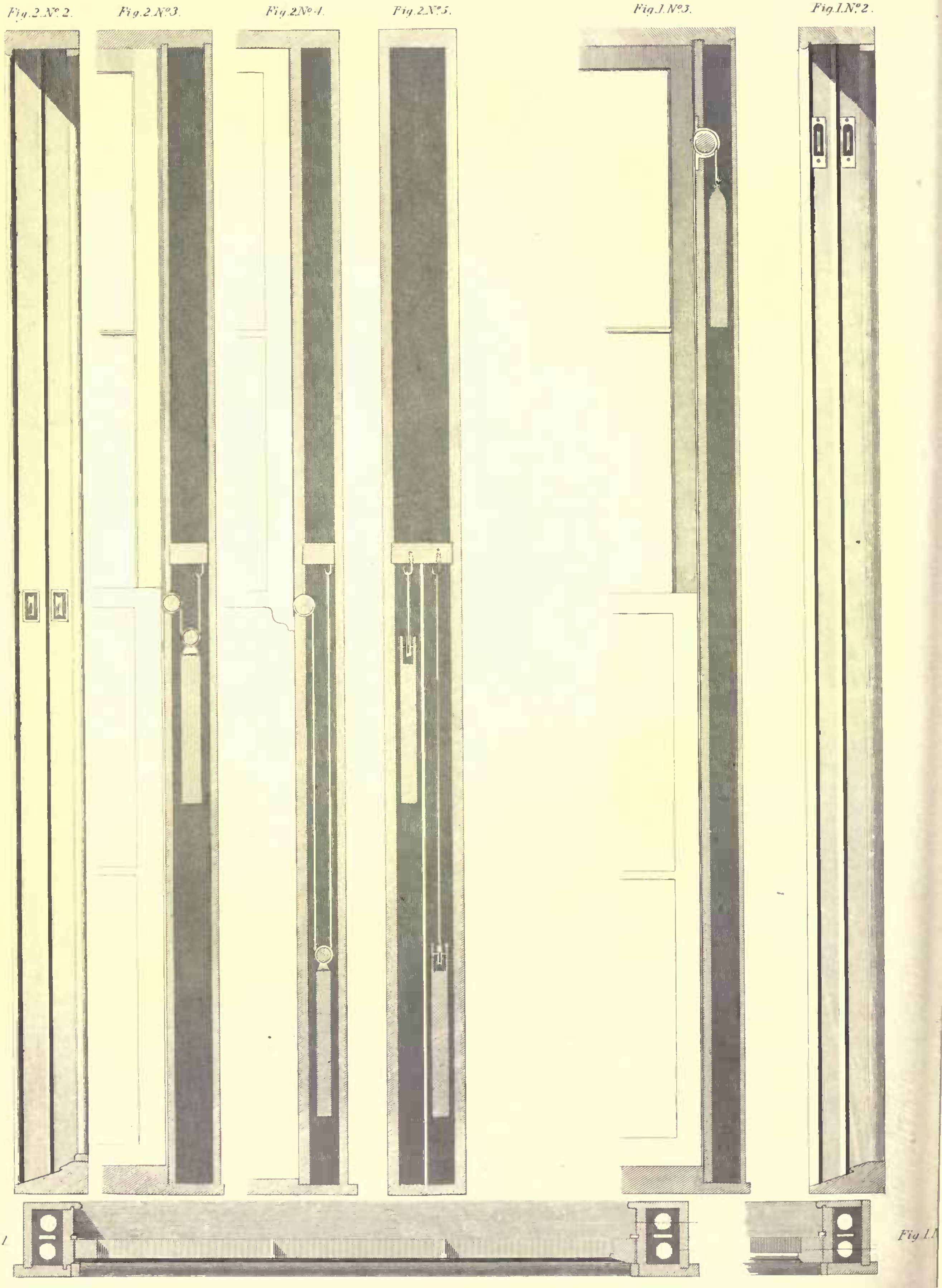


Fig.2.Nº2.
Fig.2.Nº3.
Fig.2.Nº4.
Fig.2.Nº5.
Fig.1.Nº3.
Fig.1.Nº2.
g.2.Nº1.
Fig.1.N

the back lining; the one next the outside, and parallel to the face of the wall, is *the outside lining;* and the remaining one next to the inside of the room, is denominated *the inside lining.* The best-made sash-frames have the pulley-pieces tongued into the outside and inside linings; the back lining is generally tongued into the outside, and nailed to the edge of the inside lining; on each pulley-piece two channels, of equal breadth, for the edges of the sashes to run in, are formed by nailing a slip of wood round the inner margin of the pulley-piece, and suffering the outside lining to project within it; between which a narrow slip is inserted in a groove, left in the middle of the intervening space. As the edge of this slip is generally rounded, it is called the *parting bead;* and the inner slip, for the same reason, is termed *the inside bead;* while the edge of the outer lining is called *the outside bead.* Within the case, there is also a vertical slip, suspended from the head, and passing longitudinally through the middle of the hollow space, for separating the two weights, which is therefore called *the parting slip.* The head, sill, and inside linings, have generally each a groove next to the inside of the room; the groove in the head and sill is commonly three-eighths of an inch from the edge next to the opening; that in the head is for inserting the edge of the soffit, and that in the sill for receiving the edge of the capping bead, upon the upper edge of the back. The grooves, in the inside lining, are for the edges of the back lining of the boxing; the distance of these grooves from the niner edge of the inside depends on the depth of the boxing, and the distance of each line of hinges from the inner edge of the inside lining, or of that next to the opening. The line of hinges is generally about three-eighths of an inch from the inner edge of the inside lining; so that the shutters, soffit, and capping bead, may have their terminating edges with the sash-frame of the same margin all round; that is, at the same distance as the inner edge of the sash-frame; this, however, is not positively necessary, but may be varied at the discretion of the architect or workman. The line of hinges being determined, the depth of the boxing is found by adding to the thickness of the wall that of the inside finishing, whether of plaster alone, or of lath and plaster (the former requiring about an inch and the latter $2\frac{1}{4}$ inches); and subtracting from the sum, the thickness of the sash-frame, and its distance from the outside of the wall; then, if the remainder be equal to, or exceed half the distance of the hinge-lines, such half distance is the breadth of both the boxing and the shutter; it must, however, be observed, that the outer edge of the shutter must not be rebated, as that would prevent the edges of both coming close to the architrave, or margin style which forms the side of the boxing, opposite to the inner lining of the sash-frame, when each shutter consists of one piece only; to remedy this, each shutter must either consist of two folds, *viz.*, a front part, and a back flap; and the breadth of the boxing must be contracted, either by introducing a margin style at the edge of each boxing; or, if one was necessary before, by making it broader; then the thickness of the two folds will be the neat distance of the groove from the line of hinges. If, on the other hand, the remainder, before mentioned, be less than the half distance between the hinge lines, it is the breadth of the boxing; divide the half distance between the hinge lines, by the breadth of the boxing, and the quotient will give the number of folds; and if there be a remainder, there must be one fold more than is shown by the quotient. The aggregate, or sum of all the folds, is the neat depth of the boxing: but, in order to make the folds clear each other and the back of the boxing, add the eighth or tenth part of an inch for each fold. Thus, suppose the wall to be of eighteen-inch brickwork, and the finishing within to be lath and plaster; suppose, also, the breadth of the window to be 4 feet, the sash-frame 6 inches thick, and its distance from the wall 4 inches: then, $20\frac{1}{4}$ inches is the thickness of the wall and finishing; the thickness of the sash-frame and its distance from the face of the wall are, together, 10 inches; this, taken from $20\frac{1}{4}$ inches, gives $10\frac{1}{4}$ inches for a remainder, which is the breadth both of the boxing and of the shutter, because $10\frac{1}{4}$ inches are less than 24 inches, the half distance between the lines of hinges: $10\frac{1}{4}$ is contained twice in 24 inches with a remainder; there are, therefore, three folds, *viz.*, a front fold and two back flaps; suppose the front fold to be $1\frac{1}{2}$ inch thick, each back $1\frac{1}{4}$ inch thick; then $1\frac{1}{2}+1\frac{1}{4}+1\frac{1}{4}=4$ inches; and because there are three folds, add $\frac{3}{8}$ of an inch more, and the depth of the boxing will be $4\frac{3}{8}$ inches. Sash-frames are made in Dublin with half-sills.

Figure. No. 1. Represents part of the frame of a common sash, showing a section through one of the sides, and a part of the plan of the sill.

No. 2 The side of the sash frame, with the pulley style, and the sections through the sill and head.

No. 3. Part of the elevation of the sash-frame, the inside lining being removed to show the weight.

Figure 2. No. 1. A complete plan of a sash-frame, where the lines are concealed; this, however, does not affect the plan, so as to make it differ from that of common sashes, as shown at *Figure* 1, No. 1.

No. 2. The pulley style, exhibiting the pulleys in the middle, instead of being much nearer the top than the middle.

No. 3. Part of the elevation, showing how the line is fixed to the lower sash, and hooked to a piece fixed to the trunk for the purpose.

No. 4. Part of the elevation on the other side, showing the manner of fixing the line to the upper sash, and to the dividing piece.

No. 5. The inside of the sash-frame, with both weights exposed.

SAW, (from the Saxon *saga*, or Danish *sawe*) a thin plate of steel, indented on the edge, for cutting, or dividing wood or soft metals, by a reciprocal change of motion in the hands of the workman, by pushing it from, and drawing it towards him. The cut which it makes, or the part taken away, in a board, is a thin slice, contained between parallel planes, or a deep narrow groove of equal thickness. Saws are of several kinds, as the *pit-saw*, the *bow-saw*, the *ripping-saw*, the *half-ripper*, the *hand-saw*, the *panel-saw*, the *tenon-saw*, the *sash-saw*, the *dove-tailed saw*, the *compass-saw*, and the *key-hole* or *turning saw.* The teeth of these saws are all formed so as to contain an angle of 60 degrees, both externally and internally, and incline more or less forward as the saw is made to cut transverse to, or in the direction of the fibres; they are also of different lengths and breadths, according to their use. The teeth of a saw are bent alternately to each side, that the plate may clear the wood; and, for this purpose, also, the edge on which the teeth are cut is thicker than the other edge.

The best saws are made of steel, ground bright and smooth. If, in bending the plate of a saw, the resistance be great, and the curvature uniform, it is a proof that it has been evenly ground, and well hammered. Saws intended to cut hard wood, must be so sharpened as to lean more from the perpendicular drawn from the internal angle, to the line passing along the bottom of the teeth, than those which are intended for cutting soft wood.

The *pit-saw* is used by two sawyers, for dividing the trunks of trees into boards of any thickness, or for dividing larger pieces of timber into smaller scantlings.

Wilfrid; he erected a great altar or shrine over the place where Edwin had been baptized. This shrine was adorned with gold, silver, and precious stones, and above it was suspended by a chain from the roof, a large chandelier or *corona lucis*, with nine rows of lights, three in each row, to light it up by night. A large cross was raised at the back of this altar, of equally precious workmanship.

In Alfred's reign, Grimbald erected the ancient church of St. Peter at Oxford, and also the cathedral church at Winchester, at both which places, remains of his work are still supposed to exist. It is not improbable that some portions of Oxford cathedral are his work. It has been supposed that Grimbald was the first architect in this country who raised an arched roof, such as is to be seen at St. Peter's, Oxford, and at Winchester, in the crypts of those churches. But it is plain from Alcuin's account of the church built by him and Eanbald at York, one hundred years earlier, that that church had an arched roof.

The cathedral at Durham was erected by Aldham, A.D. 998, and here also, as at York and other places, a temporary church of timber was first erected, in which service was performed during the erection of the larger stone edifice. St. Dunstan was a great builder and restorer of churches and monasteries, and it is related, that during his episcopate, no less than forty monasteries were built or restored, amongst which may be mentioned the restoration of Ely, Peterborough, Tewkesbury, Malmesbury, Glastonbury, Evesham, Bath, and Abingdon; as also the foundation of the new abbeys of Ramsey, Hunts; Tavistock and Milton Abbas, Devon; and Cerne Abbas, Dorset.

Some idea of the number of churches erected during the Saxon period, will be formed, when we learn that, at the time of the Conquest, there were in Northamptonshire, where the forests were very extensive, and consequently but a small proportion of inhabitants, upwards of sixty village-churches, while the county-town contained eight or nine. In Derbyshire, there were not less than fifty, and five at least in the county-town, and these are exclusive of monasteries and the churches belonging to them; of which there were three or four in Northamptonshire, without reckoning Peterborough. In the town of Newark and the manor round it, including twelve or fourteen villages, were ten churches. In Lincolnshire, which was one of the most populous counties at this period, there were more than two hundred village-churches, without reckoning those of Lincoln and Stamford, or the monastic establishments.

Having established this fact, we have next to ascertain as to the character and appearance of such buildings, and also as to the material and method of construction. An opinion has been entertained by many, and still obtains amongst some persons, that the Saxon churches were very mean buildings, of a temporary character, and mostly constructed only of timber. To a certain extent this is true; many of their churches were certainly erected of timber, and were also mean in character when compared with those of a much later date; yet at the same time there can be no doubt, but that many, if not the majority, especially in the later part of the Saxon era, were constructed in a durable manner of stone, and were by no means so insignificant as some would have us to suppose. Many of the accounts left us by Saxon historians, and some of those above quoted, would lead us to form a much higher opinion of such structures; and although we must receive the panegyrics of these men not without some modification, considering that they spoke of things as beautiful only in a comparative sense, and that the standard of their comparison was fixed only by their own churches; still, we must not cast them aside as utterly groundless, or wilfully exaggerated. If we may believe, as there is good evidence for believing, that some remains of these old Saxon foundations still exist in the crypts of some of our larger churches, we shall be induced to give more credit to the Saxon accounts, than many persons are inclined to yield them. That churches were at this period constructed of masonry, we suppose few would question, after reading the above accounts; for in many instances the fact is especially mentioned, and in one or two instances such buildings are spoken of, and contrasted with those of timber, as at the cathedral at York, built by king Edwin, and that at Durham, erected at a considerably later period by Aldham, in both which cases, the stone structure is especially mentioned as being a substitute for the original or temporary building of timber. It may strike the reader as perhaps somewhat strange, that timber churches should still be constructed at so late a period, when the method of building in masonry had been known and practised for three centuries. A sufficient explanation of this apparent difficulty, is readily afforded in this particular instance, in the fact of the timber building being erected only for a temporary purpose, until the permanent edifice was ready for use. This inconsistency does, however, really exist in other cases, the one method of building did not cease, when the improved system had become established, but both were adopted in churches erected about the same period; both being equally intended for permanent use: the explanation is thus given:—

It is not indeed altogether to be wondered at, that in every age when society was thinly scattered over the face of the country, and the resources upon which ecclesiastical architecture depended, proceeded chiefly from the bounty of individuals, many churches not designed for a temporary purpose, would be constructed of materials so ordinary and so cheap; but we have other and more satisfactory reasons given by Saxon historians for this fact. These writers distinguish the two methods of building under the two terms *opus Scoticum*, and *opus Romanum*, the former referring to the more fragile structures, which were composed of split oak, and the latter to the more durable erections of stone.

Of this Scotch method, Bede says, "that Adrian, the first bishop of Lindisfarn, having departed this life, Finan, sent and ordained by the Scots, succeeded him in the bishopric, where he built a church in the isle of Lindisfarn, or Holy Island, since called the bishopric of Durham, after the manner of the Scots. This he made not of stone, but of hewed oak, and covered it with reeds; and the same was afterwards dedicated in honour of St. Peter, the apostle, by the venerable Bishop Meadows. Eadburh, the seventh bishop of that place, afterwards taking off the thatch, covered it with plates of lead, that is, both the roof and the walls."

It is probable, then, that the Saxons learned this method from their northern neighbours, against whom they had been brought over by the Britons, but with whom they had afterwards allied themselves, and by whose assistance they had been enabled to drive out the British, and establish themselves in their country. Whether the method had originally been brought from Ireland by the Scots, or whether it was a method common to both them and the Picts, is not certain; but it would seem, from an incident which we shall afterwards allude to, that a similar mode of building was employed by both people; or, at any rate, that the Picts were not acquainted with the method of building in stone.

These timber buildings were constructed of split or reft timbers, stood on their ends, and placed in close contact to each other. The ends were laid on an oak sill, and the heads framed together in a sort of lintel: of such simple construction were the walls; and the roof consisted, in all probability, of nothing more than reeds or thatch. A description of a church of this kind, which there is good evidence to believe is of Saxon date, is given under the article CHURCH: it is situated at Greenstead, near Ongar (the Saxon Aungre), in Essex. In this village, they have a tradition that the dead body of some king once rested here for a short time, and that the first edifice was a wooden chapel, erected for its reception. This is supposed to have been the body of St. Edmund, the king who was slain A. D. 946. In a manuscript, entitled *The Life and Passion of St. Edmund*, preserved in the library of Lambeth Palace, it is recorded, that, in the year 1010, and the thirteenth year of the reign of Ethelred, the body of St. Edmund was removed from Ailwin to London, on account of an invasion of the Danes, but that, at the end of three years, it was returned to Bedriceworth. And in another manuscript, cited by Dugdale in the Monasticon, and entitled "The Register of St. Edmund's Abbey," it is further added, "he was also sheltered near Aungre, where a wooden chapel remains as a memorial to this day." Now, the parish of Aungre, or Ongar, adjoins to that of Greenstead, where this church is situated, and the ancient road from London to Suffolk lay through it. It seems therefore not improbable, that this rough and unpolished fabric was first erected as a sort of shrine for the reception of the corpse of St. Edmund, which, in its return from London to Bedriceworth, or Bury St. Edmund's, as Lydgate, the monk of that abbey, says, was carried in a chest. Indeed, that the old oaken structure now called Greenstead church is this wooden chapel near Aungre, no doubt has ever been entertained; and the very style and character of the building would claim for it a Saxon antiquity.

The missionaries who had been accustomed to the buildings of Rome, introduced the manner of building churches among the Saxons more substantially, with stone, and in the Roman manner. Thus we find the king of the Picts—a people inhabiting the northern parts of Britain—soliciting Ceolfrid, a monastic abbot, to send him architects to build a church in his nation, after the Roman manner, promising to dedicate the same in honour of St. Peter, the prince of the apostles: and that he and all his people would always follow the custom of the holy Roman and Apostolic Church, as far forth as, being so remote from the Roman language and nation, they could learn the same. Here we also see the deficiency of the Picts, as well as that of the Anglo-Saxons, in the knowledge of sacred architecture, one building with wood, and the other with rough unhewn stones: and these, as well as the Irish churches, are covered with reeds and rushes, and the walls with skins. The windows, in some instances, were formed with lattice-of-wicker; in others, of horn and shells, oil-paper, &c.; and the rafts were of oak.

Buildings of this class, however, would seem to have been of very rude construction, the walls being composed either of coarse rubble-work, or of flints, piled up irregularly, and bound together by cement of some sort: such walls were, of course, obliged to be of great thickness. Sometimes we find Roman bricks worked up in the walls with other materials, but they are not laid in regular courses, as in the structures which had been erected by the Romans during their residence in Britain; they are found built up with the other materials, without regard to order or regularity. By this means, the buildings erected by the Romans in this island may be distinguished from the works of the Saxons; and it is curious that this test is similar to that applied to the buildings of Babylon; for it is there noted, that in the earlier buildings, the bricks indented with arrow-headed characters are always placed in a particular position with respect to the inscriptions.

Whether, indeed, the method of building such stone erections was learned from the Roman missionaries, or originated in an imitation of the edifices which the Romans had left in the island, is by no means certain; we are inclined to think, however, that the latter is the more probable, for it would appear very unnatural that the Saxons should not have attempted to imitate the buildings which they found in the country even before Augustine made his appearance; although it is not unlikely that he and his companions might have given them further instructions, and imparted to them some knowledge of the method of building at Rome. This seems the more reasonable when we call to mind the letter which Gregory, bishop of Rome, sent by Melitus to Augustine, respecting the employment of existing buildings for places of Christian worship.

"When, therefore," says he, "Almighty God shall bring you to the most reverend man, our brother, Bishop Augustine, tell him what I have, upon mature deliberation on the affair of the English, thought of, viz., that the temples of the idols in that nation ought not to be destroyed; let holy water be made and sprinkled in the said temples: let altars be erected and relics placed; for if those temples are well built, it is requisite that they be converted from the worship of devils to the service of the true God, that the nation, not seeing those temples destroyed, may remove error from their hearts, and, knowing and adoring the true God, may the more familiarly resort to the same places they were wont."

From this it would appear, that the Saxons had erected temples for their worship before Augustine's appearance amongst them: and we hear, also, at a subsequent period, of Coifi, the heathen arch-priest in Northumbria, desecrating and destroying the idol's temple, upon his conversion to Christianity. That they had temples, therefore, there can be no doubt; the only question is, whether they built them themselves, or made use of such buildings as they found ready to their hands: the latter supposition is by no means improbable: whichever be the case, however, it is almost impossible, that, after a century's residence in the island, the Saxons should still remain totally unacquainted with the method of construction of those buildings which they had found there on their arrival.

"At the time the Saxons were converted," Mr. Bentham observes, "the art of constructing arches and vaultings, and of supporting stone edifices by columns, was well known among them; they had many instances of such kind of buildings before them in the churches and other public edifices erected in the time of the Romans. For notwithstanding the havoc that had been made of the Christian churches by the Picts and Scots, and by the Saxons themselves, some of them were then in being. Bede mentions two in the city of Canterbury; that dedicated to St. Martin, on the east side of the city, wherein queen Bertha performed her devotions, and which Augustine and his companions made use of at their first coming; and the other, that which the king, after his conversion, gave to Augustine, and which he repaired and dedicated to our blessed Saviour, and made it his archi-episcopal see. Besides these two ancient Roman churches, it is likely there were others of the same age in different parts of the kingdom, which were then repaired, and restored to their former use."

We do not suppose, however, that their acquaintance with the Roman method of building was very intimate, or that they had acquired much skill in the construction of vaults and arches, for their time was too much occupied with wars with the Britons, and quarrels amongst themselves, to admit of much opportunity for the cultivation of the arts of peace. All that we wish to assert is, that we were not entirely ignorant of Roman building, although practically, in all probability, not very expert in it, so that they would be ready to adopt some more easy method of construction, such as that afforded them by the Scots.

When at a later period the Anglo-Saxon Christians made a journey to Rome to visit the tombs of the Apostles, where churches were erected over them, and had seen those buildings, they blushed at the inferiority of their own low, dark, and gloomy fanes, and henceforth resolved to imitate what they had learnt to admire. Walls of wrought-stone, therefore, succeeded the rough material. After this we find that architects and work-people were frequently procured from abroad, to plan and raise ecclesiastical structures. The Anglo-Saxon churches, nevertheless, were of comparatively rude construction, until the time of Alfred the Great, when many, according to Asser, were rebuilt with stone, and, as far as can be ascertained, up to this time they were, with some few exceptions, of no great magnitude or dimensions, and almost entirely devoid of ornamental mouldings, though, in some instances, decorative sculpture and mouldings are to be met with. This improved method might be more properly termed the Roman manner, as being imported from Rome, and carried into execution by Roman and French workmen.

The general form of Saxon churches seems to have been that of a simple oblong or parallelogram, as we learn from Bede and other writers; some, however, were cruciform in plan, as that of St. Mary at Hexham, erected by St. Wilfrid, and which is described by Richard, prior of the same place, as being furnished with a "tower of a round form, from which four porticos or aisles proceeded." The church at Ramsay in Huntingdonshire, erected A. D. 969, was also of this form. This church also is said to have had two towers, one at the west end, and another in the centre of the transept, supported by four arches. Wolstan informs us that the old church at Winchester had a tower at the west end, but the new one at the east end of the church. Representations of buildings of this kind in some of the old Saxon illuminated books, tend to confirm this testimony. Dr. Milner observes that "The use of small bells (*nolæ*) in this country, if we may credit William of Malmsbury, may be traced as high as the fifth century. And it is clear from Bede, that even those of the larger kind (*campanæ*), such as sounded in the air, and called a numerous congregation to divine service, were employed in England as early as the year 680, being that in which the abbot Hilda died." Towers were also useful for other purposes, such as strongholds or places of refuge, to which the people might resort in cases of sudden incursion, to which they were especially liable from the Danes; also as beacons for travellers during the night, for we learn from Wolstan that the new tower at Winchester consisted of five stories, in each of which were four windows looking towards the cardinal points, which were illuminated every night. Such lights were most useful in those days, when the roads were few and bad, and the forests thick and numerous.

The few buildings which now remain, that can by written documents be proved to be of an age prior to the Conquest, have caused many writers to assert, that there is at present scarcely a true specimen of Anglo-Saxon architecture extant. This opinion has been very prevalent of late years; but we are strongly inclined to believe, that many more examples remain than is generally admitted. The causes by which the great scarcity of examples is accounted for by such writers, are principally these:—the necessary antiquity of the buildings; the furor of the middle-age architects for rebuilding churches in the latest styles; and the ravages of the Danes. Now we know from written testimony, as above shown, that a large number of churches were erected by the Saxons, and many of these built of stone in a durable manner. Will, therefore, the above causes be deemed sufficient to account for their total demolition? We think not. In the first place, then, as regards their antiquity, it may at the first blush appear unreasonable to expect to find many churches standing, after a lapse of twelve centuries; nor is it quite fair to cite such examples as those of Egypt, Greece, or Babylon, to refute this statement; for we are well aware, that they were constructed with much greater skill and strength than the Saxon churches. But there is no occasion to refer to such examples; we all admit that specimens of Norman architecture are still to be found without much difficulty, and in tolerable abundance; does it not, however, appear somewhat extraordinary, that we should have no lack of examples of structures built immediately after the Conquest, and yet scarcely any of the period just preceding that event; surely, it is not natural that the differences of numbers should be so very great; certainly, the difference of age will not account for it. This difficulty, which nullifies the first cause assigned for the paucity of examples, will equally affect the second. The third is somewhat more plausible, yet at the same time we cannot think that it accounts for such an extraordinary difference of numbers between Saxon and Norman remains as the advocates of this opinion would have us to believe; if so, the ravages of the Danes must have been of a more formidable description than we think history warrants us in believing.

But there are some positive reasons, which would lead us to conclude that a greater number of Saxon remains are now in existence, than is generally supposed. For instance, there are some churches in which Norman work is inserted into structures of a decidedly earlier, nay, much earlier date, which must in consequence belong to the period before the Conquest. The fact of work being anterior to the Conquest, is not, we are well aware, sufficient to prove it purely Saxon, for it is generally allowed as probable, that the Norman style was partially introduced into England before the invasion by William. In many of these instances, however, the older work is of a totally different character to the Norman, of a much more rude and barbarous description, and bears undoubted evidence of being of a date considerably antecedent to the Norman addition. In some cases, such remains are found in churches which are principally Norman, and this affords further proof of its antiquity; for it is reasonable to suppose, that a church partly re-edified in the Norman era must have been at that time a very old one.

An instance of the kind we allude to has recently come to light at Iver, Bucks, where it was discovered during restoration, that the north wall of the nave, which was apparently Norman, was in reality of earlier date, containing under the plaster the jambs of a door and window, as well as a string-course, both in the north and south walls, of an undoubtedly earlier epoch; a matter which was still further confirmed by the discovery of Roman bricks in the quoins of the east end of the nave-walls, thus proving that the shell of the building was of greater antiquity than its general appearance denoted.

On this subject, Mr. Freeman has introduced some very reasonable remarks, which we take the liberty of inserting:—

"I certainly think this," says he, "one of the strongest cases in favour of the existence, not only of buildings older than the Norman conquest, but of the existence of a distinct Anglo-Saxon style—two questions which ought never to be confused together in the way that they too often have been. To this subject I shall presently recur. In this Iver case, we have Norman work, and something older. There is no possibility of mistake; we have the marked familiar Norman work of the twelfth century, introduced into an older building; no piece of architectural history can be more certain than that these arches are more recent than the wall in which they are inserted, and the window whose mutilation they have caused. There is no room for any question as to chronological sequence. The only possibility is, that they might be *late* Norman arches, cut through an early Norman wall. Mr. Scott, however, thinks that the 'northern piers and arches were probably erected about the year 1100.' With every deference to so eminent an authority, I should have placed them rather later, as the bases of the responds certainly seem to me too advanced for that date. But even putting the Norman work later in the century, we still have the fact, that the earlier work is not at all like early Norman, or Norman at all. There is this *a priori* objection to its being since 1066; while against its being of Anglo-Saxon date, there is nothing but the disinclination that exists in some minds to admit anything to be Anglo-Saxon. And though it would prove nothing against documentary evidence or strong architectural presumption, still, without such evidence or presumption, we should be shy of supposing such frequent reconstructions of such magnitude in an obscure village-church, as would be involved in the supposition that we have here two pure Norman dates; for though I should place the arches later than Mr. Scott does, they are certainly pure Norman, and not transitional, the case is briefly this: we have unmistakeable Norman work; we have also something else, at once earlier in date and different in character. The inference seems unavoidable.

"I observed above, that the questions of Saxon *date* and Saxon *style* are quite distinct. The real question is, whether the English, before the Conquest, possessed a national style distinct from Norman, in the same sense as other forms of Romanesque are distinct from it. In this sense, it does not prove a building to be Norman, to show that it was built after 1066; or to be Saxon, that it was built before Edward the Confessor. Certainly Harold himself not improbably built in the Norman style before that period; and, in obscure places, one cannot doubt but that Saxon churches were built for some time after. Even St. Alban's abbey is in many respects distinctly Saxon in character; and I am well pleased to find these facts taken up under this aspect in Mr. Parker's newly published 'Introduction to Gothic Architecture.' He there says, that 'the ordinary parish churches which required rebuilding (soon after the Conquest) must have been left to the Saxons themselves, and were probably built in the same manner as before, with such slight improvements as they might have learned in the Norman works.' He then goes on to mention—I presume from historical evidence—the Saxon churches of Lincoln as having been built after the Conquest, by the English inhabitants, dispossessed of their dwellings in the upper city by William and Bishop Remigius. No fact could be more acceptable to the believers in a distinct Saxon style, if the Englishmen of Lincoln continued—even when the Norman cathedral was rising immediately over their heads—to build in a manner, not differing merely as ruder work from more finished, but having essentially distinct characters of its own: the inference is irresistible, that this was but the continuation of a distinct style, which, in those larger edifices, which have been almost wholly lost to us, would probably present distinctive features still more indisputable. The mere chronological proof of any existing building being older than the Conquest, would never have half the same value as such a testimony as this, which represents Saxon and Norman architecture co-existing in antagonistic juxtaposition. The fact is, however, only the same as we find occurring, to a greater or less extent, at every change of style. At all such transitional periods, we find not only every intermediate style, but the simultaneous use of the two styles, each in a state of tolerable purity. And the circumstances which attended the change from Saxon to Norman architecture, would naturally tend to make this phenomenon more conspicuous than in subsequent transitions. This change was no native development; it was the innovation not only of foreigners, but of conquerors and oppressors; and, whilst national honour might require, the circumstances of the time would compel, the rude and obscure structures which still continued to be raised by Englishmen, to adhere in all respects to the native precedents of better times. Wealth, art, ecclesiastical influence, and munificence were all enlisted on the side of their tyrants."

The tower of Earls-Barton church in Northamptonshire, as well as that of Barton-upon-Humber in Lincolnshire, bear marks of great antiquity, and are ascribed by Mr. Britton to the Anglo-Saxons. Both are evidently much older than the church to which they belong, which are good specimens of the Norman style. Nothing, Mr. Britton observes, can be found more resembling the towers now under notice, than the architectural drawings in certain manuscripts of acknowledged Saxon origin. In the British Museum, and in the Gregorian Gospels preserved in the library of Salisbury Cathedral, are drawings by Anglo-Saxon scribes, in which the triangular arch and columns, resembling balusters with two or three bands, are represented, and seem to be rude delineations of architectural members, very similar to those in the towers of the two Bartons and Barneck, in Northamptonshire, in which they are employed.

In some churches where work—supposed to be Saxon—exists, are to be seen Saxon and Latin dedicatory inscriptions, in which the founders, and others connected with the church, are alluded to, and by this means we are enabled to form some certain judgment as to their date.

"In the church of Kirkdale, in Rydale, in the North Riding of Yorkshire, over the south door, is a curious inscription in Saxon characters, of which a plate is given in the fifth volume of 'Archæologia.' The inscription is accompanied by an ancient dial, and is placed over a doorway with a plain semicircular arch. It is engraved on one entire freestone, 7 feet 5 inches long, and 1 foot 10 inches high, and is in perfect preservation, except a small part in the centre, where the inscription is disfigured, but not obliterated, by the weather. This seems in some measure to be owing to its being defended by the porch, which entirely covers it, except by two angles, and consequently must have been of later erection; which is further improved by its having been formerly plastered over with lime, or some other cement, as appears by the remains of it in the interstices of the letters, and in the vacancy where the hand of the dial has been broken off. The inscription may be read thus: Orm. Gamal. Suna. Bohte. Sanctus. Gregorius. Minster. Thonne, Hit. West. æl. To. Brocan. And. To. Falan. Chehitle. And. Man. Newan. From. Grunde. Christe. And. Sanctus. Gregorius. In. Eadward. Dagum. Cng. In. Tosti. Dagum. Earl. "Orm, Gamal's son bought St. Gregory's church then it was all fallen down. and gone to ruin. Chehitle and others renewed it from the ground to Christ and St. Gregory, in Eadward's days, the king, and in Tosti's days, the Earl;" and under the dial. And. Hawarth Me. Wroht. And. Brand. Prs. "and Hawarth me made and Brand the priest."

"Tosti, who was fourth son of Godwin, earl of Kent, and brother to king Harold, was made earl of Northumberland, by Edward the Confessor, in 1056, on the death of earl Leward. This earl was driven from his earldom by his oppression, and was killed at Stamford bridge, near York, in 1066.

The inscription must therefore be dated between those years. From Doomsday book it appears that Orm was the owner of Kirkdale and the districts adjacent, in Edward the Confessor's time; and from Simeon of Durham we learn, that a certain thane in Yorkshire, by name Orm, the son of Gamal, married Ethelrith, one of the five daughters of Aldred, earl of Northumberland," &c.

"On one of the walls of the church of Aldborough in Yorkshire, is the following Saxon inscription:—'Ulf hit araeran cyrice for Hanum and for Gunthard saula;' *i. e.*, Ulf commanded this church to be erected for the souls of Hanum and Gunthard." From many circumstances, this church is evidently the original Anglo-Saxon structure, with a few modern additions, as pointed windows, &c. The walls in general are made of round pebble-stones, supposed to have been gathered from the sea-shore in the neighbourhood, which kind of stones, by a strong cement, made very durable buildings; but the lower part of the south wall of the chancel is built with hewn stone, such as was generally used in our most ancient cathedral churches, upon which there are some grotesque figures; and in the north wall is a narrow window, about 5 feet high; the chancel door also, which is a south entrance, is low and narrow, and has over it an elliptic arch, ornamented with zig-zag work. Ulf, who is mentioned in the inscription as its founder, was lord of the whole of this part of the Saxon province of Deira, or the country bounded by the Humber and the Tees, about the time of Canute."

Another inscription-stone was dug up at Deerhurst, and is now amongst the Arundelian marbles at Oxford: it commemorates the construction of a church there by earl Odda, who died A.D. 1056. The most ancient inscription, however, is probably that at Jarrow, which is apparently of the same date as the erection of the church, A. D. 684.

Our object in bringing these examples forward, is not so much to prove each example of Saxon origin, but rather to establish the date of a particular class of work; for if in one or two cases this be indubitably proved to be Saxon, we have every right to conclude that the same kind of work is of the same origin wherever it may be found. It somewhat corroborates our position, that many churches in which such work has been discovered have been alluded to by the Saxon historians. Thus a probable inference may be deduced from the ancient chronicles of the monastery of Dover, that the old church near the castle was founded by Eadbald, king of Kent. The churches of Jarrow and Monk-Wearmouth, in which supposed Saxon work exists, are both mentioned as having been founded by Benedict Biscopius, A. D. 681: so also of the churches of Ripon and Hexham.

That the church at Brixworth, in Northamptonshire—which is one of the most perfect specimens of this kind of building—is of an age anterior to the Conquest, we have many proofs. Mr. Britton judges it to be a building of the time when the Romans were in possession of the island, after the Britons were converted. It is evident, from Doomsday book, that it was in existence at that time; and in Leland's Collectanea we may trace it to the time of Cuthbald, the second abbot of Medeshamsted, afterwards called Peterborough, who was contemporary with Wulphere, king of Mercia, who died in 670. The building is almost entirely formed of Roman bricks; it has, at its western end, in addition to the square tower, a round one, containing a newell staircase. In its original form, it appears to have consisted of a spacious nave and narrow aisles, a large chancel, and a western tower, with a clerestory to the nave, and the chancel divided from it by a large arch. The construction of this church is particularly curious, the walls being mostly built with rough red-stone rag, in pieces not much larger than common bricks; and all the arches turned, and most of them covered with courses of bricks, or tiles, as they may be called. The original doors and windows have all round arches; but many additions have been made in more recent ages.

Further proof in favour of such work belonging to the Saxon age, is to be observed in the similarity which exists between the details of such buildings and those found in the illuminated Saxon manuscripts, where representations of buildings are introduced. In the illuminations in the paraphrase of Cædmon, of which the date is supposed to be about A. D. 1000, are various representations of architectural details; and amongst these are specimens of *long and short* work, semicircular and triangular arches, graduated imposts or capitals, low pyramidal roofs to towers, and the well-known baluster-shafts.

Putting all this evidence together, we think there can remain little doubt but that the particular style in which many of our existing churches, or portions of churches, have been erected, is nothing else than decided Saxon.

It is now time that we give some description of the architectural peculiarities of this style; such description will be necessarily short and imperfect, on account of the comparative paucity of the remains, and the uncertainty respecting them. The general character is extreme rudeness of construction, and almost total absence of ornament; the workmanship, at the same time, being rough and unfinished.

The masonry consists of rubble or rag-stone, rudely piled together, and often rendered on the exterior with a coating of plaster. The angles are bonded together with quoins of ashlar-work, arranged in a peculiar manner, and termed *long and short* work. They are composed of stones of two different lengths, placed alternately one above another—first a short one, then a long one, and so on; or, in other words, of stones laid alternately flat and upright on the edge, the flat ones exceeding in horizontal dimensions, the upright in vertical; the latter, however, are usually of greater dimensions in the height than the former in width. We frequently find, also, projecting a little from the general face of the masonry, narrow square-edged strips of ashlar, carried up vertically from bottom to top of the walls, and consisting generally of long and short pieces of stone placed alternately. Not unfrequently strips of stone of a precisely similar character were carried horizontally along the walls, after the manner of a string-course, especially in towers, where they are employed to divide the height into different stories; they also serve for the upright strips to terminate against both at top and bottom. The vertical strips bear some resemblance to pilasters. By some persons this arrangement is said to be in imitation of timber-construction; but, for our own part, we think it bears a much closer likeness to the pilaster strip-work so common in the Lombardic structures of the continent. So remarkable, indeed, is this resemblance, that we consider it almost sufficient evidence of itself, to prove that such buildings have been erected in imitation of the continental ones. *See* LOMBARDIC ARCHITECTURE. In many cases, the walls are so covered with this strip-work as to be divided by them into a number of panels. Sometimes, as in the tower of Earls-Barton church, we have them arranged after a kind of ornamental design, in diamonds, semicircles, &c. Occasionally, in all probability, work of this kind is hidden from view by the rendering of plaster on the walls.

Roman bricks are frequently found worked up in walls of Saxon masonry, but, as we have said before, without any regularity or arrangement. Herring-bone masonry, which consists of stones or bricks laid at opposite inclinations in alternate courses, is also to be found in Saxon-work; but it is not peculiar to it, being also found in both Roman and Norman walls.

The arches in this style were either semicircular or triangular, if the latter can be properly styled arches, which consist merely of two long stones resting on imposts, and inclined towards each other till they meet, and abut against each other at the apex. The semicircular form is, however, by far the more common of the two; it is usually quite plain, having only a single soffit, without any recess or sub-arch: not unfrequently arches of this kind receive somewhat of a finish by the addition of a hood-mould, composed of square-edged strip-work, projecting a few inches from the surface of the wall: it follows the shape of the arch, and is either terminated by the impost, or continued down to the ground. Occasionally we find arches recessed, or having a sub-arch, as at Bishophill, York; but this is probably of late date, although truly Saxon, as is evident from the square-edged strip forming a hood-mould, as just described: rarely, also, the arch is enriched with bold roll-mouldings on the face or soffit, or on both, as at Wittering church, Northamptonshire; and these are sometimes continued down the impost to the ground.

The imposts on which the arches rest are usually nothing more than square-edged projecting blocks of stone, having sometimes the lower arris chamfered; occasionally they are moulded, the mouldings consisting chiefly of fillets or platbands varied with bold semi-cylindrical or roll-mouldings; and sometimes they are enriched with rude attempts at sculpture. The piers are mostly square, plain, and with no more capital than is formed by the impost.

The doorways are constructed with both kinds of arches; the semicircular being most prevalent, and in some of the more ancient examples, the archivolt is composed of Roman bricks; they are mostly, however, of stone, of the description given above, being frequently provided with the projecting hood-mould, which is sometimes stopped on the impost, or a horizontal string-course of strip-work, and at others continued to the ground. The imposts or abaci are of the same description as above, and the jambs are either composed of the usual long and short work, with the horizontal stone bonding into the wall, or of two long blocks placed upright on their ends with a shorter one between them, which is, however, no wider than the long ones. Triangular-headed doorways are of similar general description to the semicircular; there is an example in Brigstock church.

The windows are generally of a very rude description; those in the body of the church, consisting principally of single lights of small size, and having semicircular heads; they present a marked difference from the Norman windows to the same kind, in being splayed from the middle of the thickness of the wall both ways, that is to say equally both towards the interior and exterior of the building; whereas the Norman windows splay from the exterior only in one direction, the glazing being inserted near the external surface of the wall. Small windows are sometimes seen with square heads, of a rude oblong form.

The windows, which deserve the greatest attention, and which form a characteristic of the style, are those found in the upper stages of Saxon towers. They generally consist of two semicircular-headed lights, divided by a rude shaft of peculiar description, and termed *baluster-shafts*, from their appearance, which is that of a baluster with a bold capital and base, both of which are usually composed of cylindrical or roll-mouldings, and the former surmounted with a heavy abacus. This abacus runs nearly through the thickness of the wall, and from it the arch springs, being supported on the other side by an impost of similar description worked up in the wall. The baluster-shaft frequently swells out in the middle of its height, and is sometimes divided in the middle by a band of roll-mouldings, swelling out above and below midway between the band and capital and the band and base; it is often plainly cylindrical, without bands or other interruption. At Monk-Wearmouth, the shaft swells in the centre, but has neither capital nor base. Sometimes, such windows of two lights are coupled together by a semicircular hood of strip-work extending over both, and carried down vertically to the bottom of the lights. In the topmost story of the tower of Earls-Barton church, there is a window of the above description, divided by baluster-shafts into six lights. Triangular-headed lights are found in this and other situations.

Respecting Saxon vaulting, the following account of that in the crypt of Repton church, is given by Mr. Bloxam, in his valuable manual:—"The crypt beneath the chancel of Repton church, Derbyshire, is, perhaps, the most perfect specimen existing of a crypt in the Anglo-Saxon style; and of a stone-vaulted roof sustained by four piers of singular character, slender and cylindrical, with a spiral band or moulding round each, and the entasis exhibiting that peculiar swell we find on the baluster-shafts of Anglo-Saxon belfry windows; the vaulting, which is without diagonal groins, bears a greater similarity to Roman than to Norman vaulting; and the crypt was entered through the church, by means of two winding passages."

Amongst the more noted churches in which Saxon remains are supposed to exist, we may mention the following:—Barton-upon-Humber, Lincolnshire; St. Benedict's, Cambridge; Brigstock, Northamptonshire; Brixworth, in the same county; Bosham, Sussex; Clee, Lincolnshire; church near Dover-Castle; Earls-Barton, Northamptonshire; Deerhurst, Gloucestershire; Hexham, Durham; Jarrow, in the same county; Kingsbury, Middlesex; Lavendon, Bedfordshire; St. Michael's, St. Alban's, Herts; Monk-Wearmouth, Durham; Repton, Derbyshire; Sompting, Essex; Tintagel, Cornwall; Wing, Bucks; Worth, Sussex; St. Mary, jun., Bishophill, York.

For further information on this subject, we refer the reader to CATHEDRAL, CHURCH, and other articles of a similar character.

SCABELLUM, (Latin,) in ancient architecture, a kind of pedestal, usually square, sometimes polygonal, and very slender and high, commonly ending in a sort of sheath, or scabbard, or profile, in the manner of a baluster. It was used to support bustos, or relievos.

SCAFFOLD, (from the French, *eschafaut*, or Dutch, *schavot*,) an assemblage of planks, or boards, sustained by tressels, or pieces of wood fixed in the wall, upon which masons, bricklayers, &c., stand, whilst carrying up a wall; or used by plasterers, &c., when plastering the ceiling.

The different members of a scaffold are termed standards, ledgers, and putlogs. The standards are upright poles of fir of considerable length, and about 6 inches in diameter, fixed firmly in the ground; the ledgers are horizontal poles lashed to the standards, and running parallel to the work to be erected, and the putlogs are transverse pieces about 6 feet in length, laid horizontally from the ledgers to the walls, on which the scaffold-boards are placed.

Of late years, a much improved method of building scaffolds has been employed, especially on large works; they are more regular in their construction than the old method, being composed of a series of trussed frames, consisting of a number of vertical and horizontal timbers braced together diagonally; they have the advantage of being erected independent of the building itself. At the top of such scaffolds is frequently a carriage running on a rail in a longitudinal direction; and this carries a windlass, which moves across it in a transverse direction, and therefore can be brought to act at any point which may be desirable.

SCAGLIOLA, an imitation of the most beautiful marbles, such as sienna, jasper, brocatello, and porphyry: it is hard, and, when finished, bears a very fine polish. For the method of preparing it, *See* PLASTERING.

SCALE, (from the Saxon,) a line divided into a certain number of equal parts, each of which is subdivided into others, in order to express the parts of an object of a different size, either in a drawing or in a model, but in the same proportion as the original.

SCALE, a mathematical instrument, consisting of one or more lines drawn on wood, metal, or other matter, divided into equal or unequal parts, of great use in laying down distances in proportion, or in measuring distances already laid down. There are scales of several kinds, accommodated to the several uses; the principal are, the *plane scale*, the *diagonal scale*, *Gunter's scale*, and the *plotting scale*. *See* INSTRUMENTS, and PLOTTING SCALE.

SCALENE TRIANGLE, (from the Greek, σκαληνος, *oblique*, or *unequal*,) a triangle that has no two equal sides, nor any of its angles a right angle. A cylinder, or cone, whose axis is inclined to its base, is likewise said to be *scaleneous*.

SCAMILLI IMPARES, a term of uncertain meaning, used by Vitruvius, and much contended about among the critics, though, in effect, it signifies no more than certain zoccoes, or blocks, serving to raise the rest of the members of an order, column, statue, or the like, and to prevent their being lost to the eye, which may chance to be placed below the level, or below the projecture of some of the ornaments. The scamilli are well enough represented by the pedestals of statues. *See* PEDESTAL.

SCAMOZZI, VINCENZO, a celebrated architect, born at Vicenza in 1552. He was educated under his father, Gian-Domenico, an able artist in the same branch; and, at the age of seventeen, he made designs for buildings that were very highly esteemed. He went to Venice for improvement, where Palladio and others were then employed about works of magnitude and consideration, and he made very rapid advances in his profession. At the age of twenty-two, he composed a treatise, in six books, *De Teatri e delle Scene*, which has never been published. In a visit to Rome, he was engaged in the diligent study of the remains of antiquity to be found in that city, and in the study of mathematics under the celebrated Clavio. After extending his tour to Naples, he returned, in 1583, to his native city, and settled at Venice, where, Palladio being dead, he became the first architect, and was employed in various public and private works, of which one of the most remarkable was the additions to the library of St. Mark. He was sent for to Vicenza to finish the famous Olympic theatre, by which he gained credit. In 1588, Duke Vespasian Gonzaga engaged him in the construction of a new theatre at his town of Sabioneta. After this, he visited many of the chief places on the continent; and decorated several other cities in Italy, besides Venice and Vicenza, and few artists seem to have enjoyed a more extensive reputation. In 1615, he published a work, entitled *L'Idea dell'Architettura Universale*, in six books, which contains many useful observations and instructions. The sixth book, which contains the five orders of architecture, is most esteemed, and has been translated into the French language. Scamozzi died in 1616. Besides the writings above-mentioned, he published a work of descriptions, of which three chapters contained the buildings and topography of Rome.

SCANDULÆ, in ancient house-building, shingles, or flat pieces of wood, used by the Romans instead of tiles, to cover houses. This, according to Cornelius Nepos, was the only covering used in Rome till the war with Pyrrhus, 470th year of the city.

SCANDULARII, among the Romans, mechanics who prepared the scandulæ used in covering houses, who were exempted from all public services.

SCANTLING, (from the French, *eschantillon*,) the transverse dimensions of a piece of timber in breadth and thickness.

SCANTLING is also the name of a piece of timber; as of quartering for a partition, or the rafter, purlin, or pole-plate of a roof.

All quartering, under five inches square, is termed *scantling*.

In all scantlings for shoaring, the master-carpenter charges one-third for use and waste; though, when used in very considerable quantities, and in large scantlings, one-fourth is deemed sufficient.

SCANTLING, in masonry, the size of the stones in length, breadth, and thickness.

SCAPE, (from the Latin, *scapus*, a stalk, or stem) the fust or shaft of a column. It is also used for the little hollow, above or below, which connects the shaft of a column with its base, or the part where it appears to rise out of the base.

SCAPPLE, to reduce a stone to a plane surface, without working it smooth.

SCARFING, a term used to denote the junction of two pieces of timber, by being bolted or nailed transversely together, so that the two appear but as one. The joint is denominated a *scarf*, and the timbers are said to be *scarfed*.

In scarfing a beam, the joint or seam must have its dividing surface or surfaces perpendicular to one side of the beam, so as to resist a strain in the direction of the fibres. *See* CARPENTRY.

SCENOGRAPHY, (from σκηνη, *a scene*, and γραφω, *to describe*,) the method of representing solids in perspective; the ichnography is the ground-plan; the elevation, a representation of the vertical planes upon a vertical plane given in position; and when the whole is represented at one view, the representation is called *the scenography*.

SCENOGRAPHY OF A PYRAMID, the same as its perspective representation.

SCHEME, (from the Greek, σχῆμα,) the representation of any design, or geometrical figure, by lines, so as to render it clear to the understanding.

SCHEME ARCH, or SKENE ARCH, a circular arch, whose dimensions are not greater than a semicircle. *See* ARCH.

SCHOFEET. *See* SOFFIT.

SCHOLIUM, (from σχολιον) a note, annotation, or remark, occasionally made on some passage, proposition, or the like. The term is much used in geometry, and other parts of mathematics; where, after demonstrating a proposition, it is frequent to point out how it might be done some other way; or to give some advice or precaution, in order to prevent mistakes; or add some particular use or application thereof. Wolfius has given abundance of curious and useful arts and methods, and a good part of the modern philosophy, the description of mathematical instruments, &c., all by way of scholia to the respective propositions, in his *Elementa Matheseos*.

SCIAGRAPHY, or SCIOGRAPHY, (from σκια, *a shadow*, and γραφω, *to describe*,) the draught of a building, cut in its length and breadth, to display the interior: in other words, the profile, or section of it.

SCIMA. *See* SIMA.

SCOLLOPED MOULDING, a moulding commonly found in Norman buildings, of which the title is sufficiently descriptive.

SCOPAS, an eminent Grecian artist, of the isle of Paros, who flourished in the year before Christ 430. He was equally distinguished as a statuary and sculptor, and was the author of many works which placed his name on a level with those of Phidias and Praxiteles. One of the columns in the temple of Ephesus was his performance; as was one of the four sides of the famous tomb of Mausoleus. Rome possessed several fine works, the productions of Scopas; among which, the most admired were the great group of Neptune and other marine deities, in the Flaminian circus; which, of themselves, might, according to Pliny, have been the labour of a whole life. The same writer speaks of a Venus, the work of Scopas, surpassing that of Praxiteles.

SCOTIA, (from σκοτος, *obscurity* or *darkness*,) a recessed moulding, of an elliptical or circular section, placed between the tori, in the bases of columns. The scotia is most frequently formed by the junction of circular areas of two differant radii; but this is upon an erroneous principle, as it ought rather to be a regular portion of an ellipsis. *See* MOULDINGS.

The scotia has an effect just opposite to that of the quarter-round. The workmen frequently call it *the casement;* and, from its form, it is sometimes termed *the trochilus.* According to Felibien, the cavetto is a fourth part of the scotia.

In the Ionic and Corinthian bases, there are two scotias, the upper of which is the smallest.

SCRATCH WORK, (from the Italian, *sgraffiata*,) a mode of painting in fresco, by preparing a black ground, on which is laid a white plaster; which white being taken off with an iron bodkin, the black appears through the holes, and serves for shadows. This kind of work is lasting; but being very rough, it is unpleasant to the sight. It is chiefly used to embellish the fronts of palaces, and other magnificent buildings.

SCREEN, a partition, or means of separating one part of an edifice from another. Screens are very frequent in churches, especially in those of a more important character, where they are used to partition off chantry-chapels, and such like, from the main building; to enclose the choir, and to separate the chancel from the nave, &c. Such screens are of various materials, but usually of wood or stone, and many of them are of excellent designs and workmanship. *See* ROOD-SCREEN.

The term is also applied to any means of shelter or protection against heat, cold, light, &c.

SCREEN, (from the French, *escran*,) an implement used in making mortar, consisting of three wooden ledges joined to a rectangular frame at the bottom; the upper part of which frame is filled with reticulated wirework, for sifting sand or lime.

SCREW, (from the Dutch, *scroeve*,) one of the six mechanical powers; chiefly used in pressing or squeezing bodies close, though sometimes also in raising weights.

The screw is a spiral thread, or grove, cut round a cylinder, and everywhere making the same angel with the length of it. So that, if the surface of the cylinder, with this spiral thread upon it, were unfolded and stretched into a plane, the spiral thread would form the section of an inclined plane, whose length would be to its height, as the circumference of the cylinder is to the distance between two threads of the screw; as is evident by considering, that in making one round, the spiral rises along the cylinder the distance between the two threads.

Hence the threads of a screw may be traced upon the smooth surface of a cylinder thus: cut a sheet of paper into the form of a right-angled triangle, having its base to its height in the above proportion, viz., as the circumference of the cylinder of the screw is to the intended distance between two threads; then wrap this paper triangle about the cylinder, and the hypothenuse of it will trace out the line of the spiral thread.

When the spiral thread is upon the outside of a cylinder, the screw is said to be a *male* one; but if the thread be cut along the inner surface of a hollow cylinder, or a round perforation, it is said to be *female;* and this latter is also sometimes called the *box* or *nut*.

When motion is to be given, the male and female screw are necessarily conjoined; that is, whenever the screw is to be used as a simple engine, or mechanical power. But when joined with an axis in peritrochio, there is no occasion for a female; but in that case it becomes part of a compound engine.

The screw cannot properly be called a simple machine, because it is never used without the application of a lever, or winch, to assist in turning it. The force of a power applied to turn a screw round, is to the force with which it presses upwards or downwards, setting aside the friction, as the distance between two threads is to the circumference where the power is applied.

For the screw being only an inclined plane, or half wedge, whose height is the distance between two threads, and its base the said circumference; and the force, in horizontal direction, being to that in the vertical one as the lines perpendicular to them, viz., as the height of the plane or distance of the two threads, is to the base of the plane, or circumference, at the place where the power is applied; therefore the power is to the pressure, as the distance of two threads is to that circumference.

Hence, when the screw is put in motion; then the power is to the weight which would keep it in equilibrio, as the velocity of the latter is to that of the former. And hence their two momenta are equal, which are produced by multiplying each weight, or power, by its own velocity.

SCRIBING, a term applied to the edge of a board, when fitted upon any surface.

Thus the skirting of a room is scribed to the floor, in the most ordinary cases; and the method of doing it is as follows: —Lay the edge of the intended skirting upon the floor; then take a pair of compasses, and extend the points so as to be equal to the greatest breadth of the hollow between the floor and the skirting-board, taken in a vertical direction; begin at one end of the board, and, with one point upon the floor, and the other upon the wood, and both points in a line perpendicular to the horizon, draw the compass towards the other end, keeping both points always in a straight line, parallel to the floor, and in the surface of the board, or in the surface of the board extended; and the upper point will trade a line on the board, exactly similar to the surface of the floor; so that, if the superfluous part below the line be cut away, the board will fit close to the floor.

SCRIBING, in joinery, the act of fitting one piece of wood upon another, so that the fibres of both may be perpendicular to each other, and the end cut away across the fibres, so as to fit upon the side of the other.

This method is useful in doors and sashes, when it can be done; but in quirked mouldings, recourse must be had to mitering.

SCROLL, see VOLUTE.

SCULPTURE, (from the Latin *sculptura*,) the art of carving in wood, stone, &c. The term is also used for the carved work itself.

SCUTCHEON, an heraldic shield.

SCYRIUM MARMOR, a name given by the ancients, sometimes to a white, and sometimes to a yellowish marble; both used in the public buildings of the Romans, but seldom in statuary, not being capable of a high polish.

SEALING, the fixing of a piece of wood or iron on a wall with plaster, mortar, cement, lead, or other binding, for staples, hinges, or joints.

SEASONING TIMBER, the act of preparing it for building, by expelling the natural sap.

Added to the other defects of modern English building, particularly that of the metropolis and its immediate neighbourhood, is the improper state in which timber is used.

The major part of our best timber is imported from the north of Europe, *and is immersed in docks*, and lies there floating till it is sold for immediate use; the consequence of this is, that the timber (though even it may be previously seasoned) becomes swelled to much beyond its former and its ultimate bulk; is hastily framed together while the very water is running from it; and very soon after it is so converted, it shrinks to such a degree, that every tenon becomes loose, every joint strains falsely from the shrinkage, and every ceiling and quartered partition cracks by the opening, diminishing, and distortion of the wood.

Some persons fancy, that to immerse timber in water seasons it; however this may be, (and it may well be doubted,) it does not render it fit for use, but the very reverse of it. Timber for ordinary purposes should be shrunken to its smallest limits before it is worked up; the least possible change should occur in the timber after the work is framed and adapted; for all the oblique joints of it, by shrinkage, become perfect, each bearing-timber then hangs straining upon a single point, instead of upon a flat direct abutment; thence many of the struts and other bearing-timbers rend by the weight, hanging merely upon their angles.

In very many cases, dry-rot is engendered in our hastily-constructed buildings, by the quantity of dock-water pent up in the timber, by its mortises and other joints, by the plastering, by the brickwork, and by many other causes. While our timber is at the saw-pit, the water not unfrequently streams from it, and though it may appear choice and close when first selected and wrought, the sun and air in a very few days suffice to render it coarse, open, full of cracks, and wholly unfit for good work.

Our specifications are very strict in the requirement of the perfection and proper seasoning of timber, but these precautions are almost useless. The builder can hardly procure, at any price, timber which is not in a dropsical condition; and twelve months, in general, are sufficient to diminish in bulk, and to split our carpentry, alike whether it be framed for the palace or the cottage—for the public or the individual.

After timber is felled, it should be piled up perpendicularly in an airy dry place, with proper interstices to admit a free circulation of air; and thus both rain and the excessive heat of the sun being excluded, the timber will dry without shakes or fissures.

Some persons, however, prefer to keep the timber as moist as they can, by immersing it in water, to prevent its cleaving. In this case, when the boards have laid a fortnight under water, they have them set upright in an airy place during the heat of summer, and turned every day; by this practice, new-sawn boards, it is said by those who are the advocates for the soaking-system, will floor much better than those which have had many years dry-seasoning.

We are, as we have said, opposed to this practice; but to prevent all possible accidents, when floors are laid, let the edges be shot and brought to a joint, or nearly so; lay them down the first year, and finally fasten them the next, they will then remain without shrinking, provided they be kept dry.

The following particulars should be attended to in seasoning wood. The sudden decay of the timber is generally owing to the sappy nature of the exterior surface, which is by no means capable of being remedied by any application of paint previous to its being seasoned; on the contrary, it has been proved, that such application is actually injurious, since it hinders the free admission of air and heat, which would have the property of extracting that sappy quality which so much contributes to decay and rottenness. When this practice is adopted, the sap strikes inwardly, and, making its way to the heart of the wood, the substance is presently contaminated and destroyed.

As a means of preventing this evil, the timber is sometimes scorched over a flame, turning it about till every side acquires a sort of crusty surface; in doing this, it necessarily follows that the external moisture is dissipated. After this process a mixture of pitch and tar, sprinkled with sand and powdered shells, may be advantageously applied to the parts intended to be under water, while those more in sight, after being well scorched, and while the wood is hot, should be rubbed over with linseed-oil mixed with a little tar. This will strike deeply into the grain of the wood, and will soon harden so as to receive as many coats of paint as may appear necessary.

It has been found, that fir-timber, thus prepared is nearly equal to oak for durability.

The following valuable observations on the seasoning of timber are extracted from an able article on "Timber—Its Treatment and Uses," by Mr. James Wylson, published in the Second Volume of the "Builder:"—

"There are natural and artificial means of seasoning, both of which have their recommendations; but the former has certainly the right of preference, as it gives greater toughness, elasticity, and durability, and therefore should always be employed in preparing timber for carpentry.

"When there is time for drying it gradually, all that is necessary to be done, on removing it from the damp ground of the forest, is to place it in a dry yard, sheltered from the sun and wind, and where there is no vegetation; and set it on bearers of iron or brick in such a manner as to admit a circulation of air all round and under it. In this situation it should continue two years, if intended for carpentry, and double that time if for joinery, the loss of weight, which should take place to render it fit for the purposes of the former, being about one-fifth, and for the latter about one-third. If it is to be used round, it is good to bore out the core, as by so doing, the drying is advanced, and splitting prevented, with almost no sacrifice of strength. If it is to be squared into logs, it should be done soon after some slow drying, and whole-squared if large enough; as that removes much of the sap-wood, and facilitates the drying, and prevents the splitting, which is apt to take place when it is in the round form, in consequence of the sap-wood drying before the heart, from being less dense; also, if it may be quartered, it is well to treat it so after some time, as the seasoning is by that means rendered more equal. It is well also to turn it now and then, as the evaporation is greatest from the upper side.

"To prevent timber warping, it should be well seasoned before it is cut into scantlings, and the scantlings should be cut some time before they are to be used, in order that the seasoning may be as perfect as possible; and if they can be set upright, so much the better, as then they will dry more rapidly, and, as the upper dries sooner than the lower side, they ought therefore to be reversed at intervals.

"When there is not time for actual drying, the best method that can be adopted, especially for sappy timber, and if strength is not principally required, is immediately, on felling, to immerse it in running water, and, after allowing it to remain there about a fortnight, to set it in the wind to dry. This renders timber less apt to crack and warp in drying, and less subject to be worm-eaten, especially the more tender woods; but it must be altogether under water, as partial immersion is very destructive.

"Of steeping generally, whether in cold or warm weather, it must be observed, that it dissolves the substance of the wood, and necessarily renders it lighter; therefore the less that is necessary of it the better; indeed, it is known, that, notwithstanding wood that is completely submersed remains good for a very great period after the water has dissolved a certain soluble part, it is, when taken out and dried, brittle, and in every respect unfit for use.

"For the purposes of joinery, steaming and boiling are very good methods, as the loss of elasticity and strength which they produce, and which is so essential in carpentry, is compensated by the tendency to shrinkage being reduced; the durability also is rather improved than otherwise, at least from steaming. It has been ascertained, that of woods seasoned by these methods, those dry soonest which have been steamed; but the drying in either case should be somewhat gradual, and four hours are sufficient for the boiling or steaming process."

Langton's method of seasoning by extraction of the sap, is another that is considered well worthy of notice; it consists in letting the timber into vertical iron cylinders at top; and the water being heated, and steam used to produce a partial vacuum, the sap relieved from the atmospherical pressure oozes from the wood, and, being converted into vapour, passes off through a pipe provided for the purpose. The time required is about ten weeks, and the cost is about ten shillings per load; but the sap is wholly extracted, and the timber fit and ready for any purpose; the diminution of weight is, with a little more shrinking, similar to that in seasoning by the common natural process.

Smoke-drying in an open chimney, or the burning of furze, fern, shavings, or straw under the wood, gives it hardness and durability; and by rendering it better, destroys and prevents worms; it also destroys the germ of any fungus which may have commenced. Scorching and charring are good for preventing and destroying infection, but have to be done slowly, and only to timber that is already thoroughly seasoned; otherwise, by encrusting the surface, the evaporation of any internal moisture is intercepted, and decay in the heart soon ensues; if done hastily, cracks are also caused on the surface, and which receiving from the wood a moisture for which there is not a sufficient means of evaporation, renders it soon liable to decay.

Various methods have been from time to time proposed for seasoning timber, and preventing its rapid decay; but those which have most engrossed the public attention of late years, are those respectively distinguished as Kyan's, Payne's, Burnett's patents, &c. In the year 1833 to 1836, at the Arsenal, Woolwich, experiments were instituted, having for their object the establishing or otherwise the claims of that first mentioned, and the results of which were of a very satisfactory nature; the Kyanised specimens generally, which were submitted to the fungus-pit when taken out at the end of three years, being sound, while duplicate pieces unprepared were found in various stages of decay. Certain questions, however, presented themselves:—1st. Whether the impregnation to which the timber had been subjected, might not be removable by some cause, and perhaps generate an atmosphere noxious and injurious to health. 2nd. Whether the strength of the timber were impaired or otherwise. The first was satisfactorily determined by Dr. Faraday, who proved by experiment, that the combination was not simply mechanical, but chemical; and that a permanently compound material was formed; the second was formed by experiments made by Captain Alderson, C.E., upon ash and Christiana deal, and which showed that the rigidity of the timber was enhanced, but its strength in some measure impaired, its specific gravity also being somewhat diminished. Another question yet remains open—how far, since the impregnation has not been traced to a depth greater than half an inch, does this process meet our requirements, and after the satisfactory conclusion arrived at as above related, and the evidence of the facts upon which it was so reasonably founded, how are we to meet the assertion of Mr. Pritchard, C.E. of Shoreham, made in 1842. The sleepers Kyanised five years ago, and in use at the W. I. Dock warehouses, have been discovered to decay rapidly, and the wooden tanks at the Anti-Dry-Rot Company's principal yard are decayed.

Mr. Kyan's infusion is corrosive sublimate, and the process consists in submersing the timber in tanks for about a week, then taking it out and drying. Sir Humphrey Davy had previously recommended a weak solution of the same thing, to be used as a wash where rot had made its appearance. Dr. Birkbeck made a favourable exposition of the process as pursued by Mr. Kyan. Sir John Barrow and the Duke of Portland impugn it, and Lord Manners and Dr. Moore follow on the same side. The Payanising process, besides professing to preserve timber from dry-rot and the ravages of insects, is said to render it uninflammable, or at least to deprive it in a great measure of combustibility.

Sir William Burnett's patent process seems to have met with great, and, as we think, deserved success. The various testimonials that we have seen in favour of it, and the time that it has maintained itself in the opinion of the public, induce us to think well of its efficacy in performing what it professes to do. Even if not quite realizing all its inventors claim for it, it certainly will effectually preserve timber for a great number of years. The effects ascribed to it are, that it hardens and improves its texture. It enters into permanent chemical combination with the ligneous fibre, and does not come to the surface of the wood by efflorescence, like other crystallizable salts, and no amount of washing or boiling in water, will remove the chemical compound so formed. It preserves wood and other articles from the adherence of animal and vegetable parasites, and also from the attacks of insects, and from *wet* and *dry* rot. Further, it renders wood uninflammable, when used of a certain strength. The basis of his process is chloride of zinc, or, as it is more commonly called, the muriate of zinc, which seems to have a peculiar affinity to woody fibre, entering into intimate union with its component particles, and forming as it were a new mineralized substance. There is a chemical combination of the metallic base; not merely by a mechanical alteration of the position of matter, which might again be disunited. There is no decomposition produced, but the fibre of the wood appears to be permanently pervaded by the zinc, and the atoms of which they are formed enter into a new and fixed arrangement.

SECANT, (from the Latin *seco*, to cut,) a line that cuts another, or divides it into two parts.

In trigonometry, the secant is a line drawn to the centre from some point in the tangent, which consequently cuts the circle.

SECRETARIUM, the vestry of a church, the same as SACRISTY.

SECTION OF A BUILDING, a representation of the building as divided or separated into two parts, by a vertical plane, in order to explain the construction of the interior. The section of a building not only includes the parts that are separated, but also the elevation of the receding parts, which ought, therefore, to be shadowed with a darker tint. It is obvious that the section of a building ought to be taken so as not only to show the greatest number of parts, but also those that present the most difficulty in their construction. Every building ought to have at least two sections, at right angles to each other, and parallel to the sides of the building: a section of the flues will also be necessary, in order to conduct the interior walls, and to avoid the improper placing of timbers, or mistakes that might otherwise unavoidably take place.

SECTION OF A SOLID, the place of separation that divides one part from another; it is always understood to be a plane surface. *See* STEREOTOMY.

SECTIONS, *Conic*, see CONIC SECTIONS.

SECTIONS OF CYLINDERS, see CYLINDERS.

SECTOR (from the French *secteur*), an instrument for measuring or laying off angles, and for dividing straight lines and circles into equal parts. *See* INSTRUMENTS.

SECTOR OF A CIRCLE, the space comprehended between two radii and the arc terminated by them.

The area of a sector is found by multiplying the radius of the circle into half the arc of the sector.

SEDILIA, seats for the officiating clergy, frequently to be found in the south wall of the chancel of our old churches. They are usually arched recesses in the wall, and are often surmounted by canopies and richly decorated with carving, and sometimes quite plain. They consist of a series of from one to five arches, for so many priests, the usual number being three. The seats are sometimes level, but frequently graduated, following the level of the chancel steps; they are occasionally formed in the sill of a window.

SEGMENT (from the Latin *segmentum*, a shred or paring), any part of a whole.

SEGMENT OF A CIRCLE, the area comprehended by an arc and a chord.

All angles in the same segment are equal.

A very useful practical rule for finding the area of the segment of a circle is the following:—multiply the chord into the versed sine; then, to two-thirds of the product, add the quotient arising by dividing the cube of the versed sine by twice the chord. *See* MENSURATION.

SELL, the lowest piece of timber in a building. *See* SILL.

SEMICIRCLE, the half of a circle contained by the diameter and the circumference.

The angle in a semicircle is a right angle.

The arc of a semicircle is, of course, half of the circle. *See* CIRCLE.

SEMICIRCULAR ARCHES, arches constructed with semicircular arcs. They were much used by Roman architects, particularly in the decline of the Roman empire; and also by the Saxons and Normans in England, and their successors, until they were superseded by the pointed arch: they were again brought into use by the introduction of Roman architecture, in the time of Inigo Jones.

SEPTIZON, or SEPTIZONIUM, in ancient architecture, a term almost exclusively appropriated to a celebrated mausoleum of the Antonines, which, Aurelius Victor says, was built in the tenth region of the city of Rome, being a large insulated building, with seven stages, or stories, of columns.

The plan was square, and the upper stories, consisting of columns, falling back much, rendered the pile of a pyramidal form, terminated at the top with the statue of the emperor Septimius Severus, who built it.

It had its name Septizon, or Septizonium, from *septem* and *zona*, *q. d.*, seven zones, or girdles, by reason of its being girt with seven rows of columns. Historians mention another Septizon, more ancient than that of Severus, built near the Thermæ of Antoninus.

SEPULCHRAL (from the Latin *sepulchrum*, a tomb, or place for burial), something relating to sepulchres or tombs.

SEPULCHRAL CHAPEL, or chapel containing a tomb or sepulchral monument, or in which masses were chanted for the repose of the departed, and in this sense the same as CHANTRY CHAPEL. Such buildings were usually appended to churches, and formed a small kind of aisle.

SEPULCHRAL COLUMN, see *Funeral Column*, under COLUMN.

SEPULCHRAL MONUMENT, a monument erected to preserve the memory of some deceased person. They are of various designs at different dates and places; but probably those of the middle ages in this country will never be surpassed in beauty of conception or delicacy of workmanship. Many fine examples are to be found in our cathedrals. Amongst the most beautiful are those of Wykeham and Waynflete, Winchester.

SEPULCHRE (from the Latin *sepulchrum*, a tomb), or place destined for the interment of the dead. The word is chiefly used in speaking of the burial-places of the ancients: those of the moderns are usually called *tombs*.

Besides the usual sepulchres for the interment, either of the whole body, or of the ashes of such as were burnt, the ancients had a peculiar kind, called *cenotaphia*, which were empty sepulchres, in honour of some persons who, perhaps, had no burial at all, from a superstitious opinion, that the souls of those without burial wandered a hundred years before they were admitted into the Elysian fields. The pyramids are generally supposed to have been built as sepulchres for the kings of Egypt, and the obelisks were erected as mementos of eminent persons deceased.

In our old churches is frequently found, at the east end, usually on the north wall of the chancel, a sepulchral monument, enclosed in an arched recess. This is called the altar-tomb, as also the holy sepulchre, or Easter sepulchre, from the circumstance, that, previous to the Reformation, certain ceremonies were performed here between Good Friday and Easter-day. It is not unfrequently the tomb of the founder of the church.

Such tombs are frequently of very elaborate design, and enriched with sculpture and colour. Two magnificent specimens exist in the presbytery of Westminster Abbey.

SERAGLIO, among Oriental builders, the palace of a prince or lord. By way of excellence, the term is used for the palace of the grand signor at Constantinople.

SERLIO, SEBASTIANO, an eminent architect, a native of Bologna. He flourished, at Venice, in the early part of the sixteenth century. He afterwards travelled through Italy, and resided a considerable time at Rome, where he studied the fine arts, and made many excellent drawings of edifices, ancient and modern. He is said to have been the first who examined, with a scientific eye, the remains of ancient architecture. The knowledge he acquired was given to the public in *A Complete Treatise of Architecture*, of which he planned seven books; and the first that appeared was the fourth in order, comprehending the general rules of architecture, which he printed at Venice in 1537, dedicated to Hercules II., duke of Ferrara. The other six books appeared successively at different intervals; and the various editions made of them prove their popularity. In 1541, Serlio was invited to France by Francis I., and employed in the erections at Fontainebleau. Here he continued till he died, at an advanced age, in 1578. Though, as an author, he was much attached to the principles of Vitruvius, yet, in his designs as an artist, he very much neglected them. His school at St. Roche, and palace of Grimani at Venice, are built in a grand and magnificent style.

SESSPOOL, or Cesspool, a well, or deep hole, sunk under the mouth of a drain, for the reception of sediment, and other gross matter, which, if not there detained, would choke the passage. Sesspools ought to be so contrived, that they may be cleaned without difficulty; otherwise they will fill up, and the evil be communicated to the drains.

SET-OFF, that part of a wall where the face is broken by a projection beyond the general surface, such as where the lower portion of a wall is of greater thickness than the upper, and therefore leaves a ledge at the height where the lesser thickness commences, equal in width to the difference in thickness of the two portions of the wall. This practice is very usual in buttresses, and almost universal in those of mediæval date. Such ledges are usually covered with a sloping table of masonry to carry off the wet, and are termed *set-offs*.

SETTING, a term used in masonry, for fixing stones in walls or vaults. In this the utmost care should be taken that the stones rest firmly upon their beds, and that their faces be ranged on the proper surface of the work. This caution is necessary, as bad workmen, in order to make close joints, only make the beds come in contact adjacent to the face of the work; and, in order to bring the joints flush, they frequently do no more than round the work next to the joint: this convexity has a very disagreeable appearance in the sunshine, when the rays of light fall obliquely upon the work.

SETTING-OUT ROD, the rod used by joiners for setting out windows, doors, or other framing.

SEVERY, a bay or compartment; especially applied to the compartments of vaulted roofs.

SEWER, a large main drain, conduit, or conveyance for carrying off refuse, or soil, from a house, or number of houses.

SEWERAGE, the method of removing superfluous water, rain, filth, night-soil, and other refuse matters from a town or other locality.

The subject connected with this article, is of very considerable importance, as it affects the health, morals, and social well-being of the community; as it is now universally allowed, that the accumulation of refuse matter is dangerous to health, and especially in crowded and densely-populated districts, where it is certain to encourage, if it does not generate, various kinds of epidemic disease; besides which, it discourages habits of cleanliness, and so affects the morals of the lower orders. It is a matter which formerly was not sufficiently attended to; but has of late years forced itself upon public notice, and is at the present day receiving that amount of consideration which it so well deserves.

Although, however, the matter has been widely canvassed, and much elaborate investigation entered into, we regret to say, that hitherto, mere matters of detail have received comparatively more attention than they deserved, and general principles have been too much overlooked; not that we would for a moment undervalue the investigation which is being carried on with reference to minutiæ, which are indeed of the utmost importance; but we think that general principles should have had the first place in the order of investigation. Be this as it may, we must confess, that much useful and practical, as well as theoretical knowledge, has been eliminated by the process, and many improvements introduced which are of considerable public benefit. This branch of professional practice is as yet in its infancy, and we may hope that a few years will add considerably to our practical and theoretical acquaintance with it, when theories, which are now only upon trial, shall have been fully and fairly tested, and some further inquiry entered into with respect to the objects which are sought after, in laying out the drainage of a town.

In considering this subject, a question naturally arises at the very outset, as to the objects to be effected by proper drainage of any locality. Now, formerly the object, for there was but one, was very well defined, and very simple; it was this, to remove the refuse from the neighbourhood of inhabited districts, so that it might not become prejudicial to the health of the inhabitants. Within the last few years, however, some new data have been introduced, and in consequence the question has become more complicated. The inquiry has been mooted as to whether it be advisable to throw away as useless the collected refuse, or whether it may not be employed to some useful purpose; and if so, whether it may not be turned to account as a profitable article of commerce. Many subjects have been named, in the manipulation of which, such matters might be advantageously employed; but of all these, the most important, and that which has the highest claim to consideration, seems to be their application to agricultural purposes, in the shape of manure. Whether indeed the refuse of towns is of value for this purpose, has been, and still is a matter of dispute amongst persons well qualified to judge; but we think the evidence in favour of such application decidedly preponderates.

The value of manures as promoters of vegetation, is said to result from their possession of the essential element, nitrogen, in the form of ammonia, with the subordinate properties of alkalies, phosphates, and sulphates, and we learn from the experiments of Liebig, that the quantity of nitrogen contained in the excrements of a man during one year, is 16.41 lbs., and also that this quantity is sufficient for the supply of 800 lbs. of wheat, rye, or oats, or of 900 lbs. of barley. "This is much more," says the same authority, "than it is necessary to add to an acre of land, in order to obtain, with the assistance of the nitrogen absorbed from the atmosphere, the richest crops every year. By adopting a system of rotation of crops, every town and farm might thus supply itself with the manure, which, besides containing the most nitrogen, contains also the most phosphates. By using at the same time bones and the lixiviated ashes of wood, animal excrements might be completely dispensed with on many kinds of soil. When human excrements are treated in a proper manner, so as to remove the moisture without permitting the escape of ammonia, they may be put into such a form as will allow them to be transported even to great distances." Of the success of sewage matters applied as manure, we have favourable evidence in the practice adopted at Edinburgh, where the pasture-land has been made to produce crops very considerably above the average by this means. Experiments of an equally favourable description have also been tried in various parts of this country, as well as on the Continent; at Milan, and various parts of France and Germany. These, however, only speak as to the success of such manure in a liquid form, against which one or two practical objections may be urged. The first is the expense of distribution; for, in the first place, the sewage waters must be raised to a considerable elevation by artificial means, for the purpose of conveying them on to the surface of the surrounding districts, and this elevation will be greater or less according to the level of the neighbourhood. The second objection consists in the limited area to which such a manure could be advantageously applied; for if the distance were great, the necessary outlay for conveyance would form an effectual obstacle to its employment. Of a similar nature to the last, is the objection which arises from the uncertainty of the demand; for in wet seasons, the manure in this condition cannot be applied; and if at any time the soil be supersaturated, the vegetation is supposed to be injured thereby. Besides, if the sewage be allowed to remain on the surface, it will emit very offensive and injurious odours, and become not only detrimental to the land, but highly dangerous to the public health.

To meet these evils, several methods have been suggested for precipitating the valuable portions of the sewage, and preparing them in a dry state for the purposes of commerce, during which process the matters are also de-odorized and disinfected. It is a matter of dispute, indeed, whether the portions of sewage which are specially serviceable for agricultural purposes can be preserved in a dry form; but besides the evidence resulting from experiments with this form of manure, we have the favourable testimony of Liebig, who thus writes:—"Gypsum, chloride of calcium, sulphuric or muriatic acid, and super-phosphates of lime, are substances of a very low price; and if they were added to urine until the latter lost its alkalinity, the ammonia would be converted into salts, which would have no further tendency to volatilize. When a basin, filled with concentrated muriatic acid, is placed in a common necessary, so that its surface is in free communication with the vapours arising from below, it becomes filled, after a few days, with crystals of muriate of ammonia. The ammonia, the presence of which the organs of smell amply testify, combines with the muriatic acid, and loses entirely its volatility, and thick clouds or fumes of salt hang over the basin." And in the quotation which we have previously quoted, the same chemist states his opinion, that the moisture may be removed without permitting the escape of ammonia, and the sewage put into such a form as to allow it to be transported to great distances. In opposition to this, some persons have asserted, that where the smell does not exist, the fertilizing property has been lost; and others, that although the offensive odour is got rid of, the deleterious properties still remain. These opinions are indeed destructive of each other, and we are inclined to yield the greater amount of credit to Liebig's testimony. Mr. Richard Dover, who propounded a scheme for disinfecting the London sewage, and preparing it for transport in a dry state, made some experiments upon sewage-water taken from the Northumberland-street outlet, in the presence of several persons competent to form a judgment on the subject, and who testify to having been satisfied as to the success of the experiment. Manure prepared by this process has been experimentally applied to agricultural purposes, and, it is said, with very satisfactory results. Mr. Dover further proposes to apply the water, which is left, for the purpose of bleaching and other commercial undertakings.

Such are the statements with regard to the employment of sewage-matters for agricultural purposes: that they are useful fertilizing agents, there seems to remain no reason to doubt; but there still does remain a question as to whether it can be profitably employed for this purpose, considering the subject in the light of a commercial undertaking. Can it compete with other manures already in the market, or will the expense of its manipulation destroy its value as a marketable commodity. These questions still remain to be considered; for although the evidence which does exist seems to favour the speculation, yet this is not sufficiently decisive to justify an undertaking of the kind on a large scale.

Now the very first principles of drainage depend upon the resolution of such doubts; for if the sewage-matter is to be thus employed, we should adopt a very different system to that which would be adopted, had we solely to get rid of the noxious refuse. There would be also a difference of treatment, according to the condition in which the manure was to be applied, whether in a wet or dry state; for in the one case we should be tied down to the most economical method of distributing it over the surrounding country by means of pipes, and should have to regulate our levels and outlets accordingly; whereas, under the latter conditions, we should be left at much greater liberty in arranging such preliminaries.

In the first place, if we treat sewage matters as only deleterious to public health, and incapable of being turned to any useful account, we have to deal with a very plain and simple question; our sole object is to get rid of it. Simple, however, as may be the object to be attained, it is by no means easy of attainment; and of the two cases, this is probably the most difficult. We are well aware that we cannot annihilate the elements of which the matters are composed, however much we may be able to alter their combinations, and perhaps destroy their characteristic qualities. Granting, then, that the noxious properties of the soil can be removed, we find two courses open to us, either to disinfect it, and then dispose of it in any manner most suitable to the locality, or else to remove it, in its primary state, to a distance from human habitation. If we adopt the former course, we may disinfect it either during its passage to its outlet, or may collect the various streams into one or more reservoirs, as the nature of the locality may render advisable, and there disinfect it; after which there will probably be no difficulty of disposing of it, either by conducting it into a river or running-stream, or by some other means which the nature of the place may suggest. If the latter expedient be resorted to, we shall have much greater difficulties to encounter, for we can scarcely consider it inoperative for evil, until it is safely and fairly launched into the wide ocean; until it has arrived at this point, we are not secure against its fatal influence. This, however, is no easy matter to accomplish: to effect the object in view, we instinctively look for some natural channel, by means of which it may be conveyed to its proposed destination, and this is presented to us in the shape of a stream or river; to conduct it to the sea by artificial means, would, in the majority of cases, be entirely out of the question, on account of its enormous expense; we must therefore adopt the river as a last resource. We are well aware that this is objectionable on many accounts; but if we are compelled to get rid of the offensive matter, we would ask, what other method of effecting this object remains open to us. We know the question will arise, as to whether under such circumstances the sewage ever reaches its destination; and it would be very difficult to answer positively that it does, and therefore probably we must rest content with a palliative measure, and remove it from the more densely populated districts only. Where there is a good river, not a tidal river, this may be effected readily, for the sewage discharged into the river will be conveyed with its waters in an onward course without interruption, depositing probably some of its heavier particles, but not in such large quantities as to become dangerous. In a tidal river, however, the state of the case is altered, for although we have the advantage of the ebb-tide in conveying the refuse towards the sea, we have the corresponding disadvantage of the flow bringing it back again.

It has been suggested with reference to the drainage of London by the Thames, that as the flow is of only 5 hours' duration, and the ebb of 7, and that during that time the range of flux is 7 miles, and reflux 10, therefore a progressive movement of 3 miles is made towards the outlet every ebb and flow. This conclusion has been arrived at without sufficient data, for it has since been established by actual experiment, that not only is there a progressive and retrograde motion going on every tide, but that the same process takes place with a series of tides, and that after a float has made a certain progress down the river by the excess of the flux over the reflux, it turns, and makes an actual retrogression up the river, by the excess of the reflux over the flux, until it arrives once more nearly up to the point whence it started.

From this it will appear that, in a tidal river, there will be a great difficulty in carrying refuse matters to sea, or even from the vicinity of towns, if it be allowed to discharge at or near the town; it will constantly be carried about backwards and forwards, and depositing its solid matters in the bed, or on the banks, of the river. The sole remedy for this seems to be, to extend the sewer to such a distance from the town for discharge, that the tide may not at any time be able to carry it back near the town. Another object will be, to make the discharge at high-water, or as near high-water as possible, so that it may have all the advantage of the first ebb. This, however, is not always practicable in low-lying districts, unless, indeed, we employ artificial means for raising it ere it reaches the outlet.

Let us now consider the question under another aspect; supposing the refuse to be turned to account for agricultural purposes: this, although somewhat more complicated, we shall probably find more easily dealt with than the previous case. The question again resolves itself into two distinct parts,—the first where the sewage is used in a liquid state, the other where it undergoes a preparation previous to use, and is applied in a dry state,—and these two will require somewhat different treatment. The first arrangement, where the manure is expended entirely upon the surrounding neighbourhood, must depend, in a great measure, upon the character of the neighbourhood, and the comparative levels between it and the town to be drained. In this case it will be advisable to divide the town into different drainage levels, corresponding with the general or average altitudes of each distinct level of the adjacent country, and provide each drainage level with a separate outlet, situated as near the corresponding level of the adjacent land as may be in other respects convenient. By so doing we shall dispense to some extent with the use of pumps, and other expensive contrivances for raising the manure; we shall also save a considerable amount of excavation, and avoid very large main sewers. It must not be supposed, that here, or in any other places in this article, we lay down fixed rules of universal application, but rather throw out hints which may be found generally useful; the peculiarities of each particular locality must decide the method of drainage; there may be some localities where the above directions may not only be unadvisable, but simply impracticable, and we only bring them forward that they may not be left out of consideration in any instance, and may be adopted when found to be eligible. It is useless to think of laying down positive rules in such cases, where the nature of the subject to be treated of must necessarily vary in individual instances.

The last case which we have to consider is, when the sewage is to be applied for agricultural purposes in a dry state, and this will, we think, prove to be the most simple of the three. We have here only to collect the sewage, and conduct it into one or more tanks, in such situations as may be most convenient, where it will undergo a process of disinfection, and will be precipitated, or solidified for the purpose of conveyance to such lands as may require it, either in the neighbourhood, or at a distance. It will be advisable that the tanks be at some distance from the town, to obviate any danger or inconvenience which may arise during the preparation; and it is further to be desired, that they should be near a canal, river, or railway, so as to present facilities for carriage to distant localities; it would be well if they could be placed in proximity to both rail and river, for while the former will be very convenient for the purpose of conveyance, the latter will be further useful for the discharge of the sewage-water which remains after the extraction of the solid matter, if, indeed, it be not applied to some more useful purpose. This water may be discharged into the river without inconvenience or danger, for if not already sufficiently purified, it would be no difficult matter still further to purify it by filtration. If a ready means of discharge for the supernatant water be provided, the size of the tanks may be greatly diminished, and in the same, or rather greater, proportion, the expense and difficulty of their construction.

We have now considered the subject as regards the three different methods of disposal of the refuse most likely to occur in practice. We must again express our regret that greater labour has not been bestowed on the question of the practicability of the two last methods, yet at the same time we must take occasion to remind the reader, that even had this question been generally disposed of, it would not follow that any particular practice would be advisable in every individual case. The proper determination of the method to be adopted, must be the result of a careful investigation of the nature of the several districts to be drained; one method may be convenient in one place—another, a different one, in a second. We have here considered the subject solely as regards the disposal, and principally with reference to outlets, as these are the most affected by the various methods of disposal; let us now turn to the principles of town-drainage generally.

The first thing to be done in laying out a system of drainage, is to prepare a carefully surveyed map of the district to be drained, showing at least the main levels: at the outset, perhaps a block plan will be sufficient; but before the question is finally determined upon, and details entered into, it will be necessary to have the blocks filled in. To do this, it will be requisite that the map be on a sufficiently large scale; that adopted by the Ordnance Survey, five feet to a mile, or one somewhat larger, will be found convenient, and on this, additional levels must be laid down before entering into detail. It will be advisable ere commencing the consideration of the subject, to prepare from this a map on a reduced scale, containing in addition some considerable portion of the surrounding country, so that the consideration may not be confined to a limited space, without reference to the circumstances of the more immediate neighborhood; by so doing, much future trouble and expense may be avoided; by all means let the consideration of the subject be comprehensive. It will greatly assist, if the contour-lines be laid down on this map, so as to afford at a glance a tolerably accurate idea of the nature of the ground. It will be further necessary to obtain information respecting the geology of the district, as well for matters of construction as for other purposes, and also some general notion of the nature of the soil with reference to agricultural matters, in order to determine the extent to which the town-refuse may be employed as manure in the immediate vicinity. These, however, and other matters necessary to be known, will naturally suggest themselves to those engaged in such works.

The surveyor having made himself thoroughly acquainted with the character of the district to be drained, will be in a proper position to determine the system upon which to commence operations. The practice of our predecessors has been, to collect the sewage matter, and convey it by the shortest route to the nearest river, into which it was to discharge; this done, their object was attained; the matter was left to remove itself, or deposit on the banks or bed of the river, as best it might. This method is now generally allowed to have been based upon false principles; but it must at the same time be confessed, that to a certain degree it did follow out the course suggested by nature. That the drainage should be carried towards the river, is not to be objected to; for it amounts to nothing more than conveying it to the lowest level of the district; it is the very course which nature adopts, for rivers and streams are indeed the drains laid out by nature; the only mistake consists in polluting these waters with matters which are prejudicial to health; had we only to deal with surface-drains, the system would be rational enough. Some persons, because this method has been abused, have thought it right to discard it altogether; we cannot follow them thus far; if the area to be drained presents throughout one general slope towards the river, we are inclined to think that this would be the most suitable method of drainage, having the outlet or outlets at the lowest level. If the sewage is to be supplied in its liquid state to the surrounding country, it may be advisable to intercept a portion ere it reaches this point, but this the circumstances of each case must decide; by such means we should of course be better able to irrigate the higher lands, and should also effect a saving in the size of our sewers, for the lower branches will not have so large a quantity to discharge.

If again the levels of the main be greatly diversified, or especially if it consist of basins surrounded by higher ground, it would appear advisable, under any of the above conditions, to provide a separate drainage for each level, so as to avoid the great depth of excavation which would be necessitated, were the drainage of the higher levels to be connected with a main which had already received that of a lower level. The better plan would be to convey this line through the lower levels to its outlet, and to form a separate system for the higher grounds. Whether it would be advisable to drain all the low levels together by one trunk-line, and all the high levels by another, or to drain each level separately, must be determined by the circumstances of each special case; as we said before, no fixed rules can be laid down, we can only propose useful hints to be applied as the nature of each case suggests.

Having disposed of these general matters, we now come to consider the subject more in detail; but before doing so, let us clearly understand, and determine what we have to do, and what class of subjects we have to deal with. Our general object is to convey to a distance the refuse, or a certain portion of the refuse, of the town, or other area to be drained, and what does this consist of; it is mainly of two descriptions, viz., that which may be particularized as house-drainage, consisting of the excrements of the inhabitants, and all refuse matters connected with household economy; and that which is distinguished as surface-drainage, which has especial reference to rainfall and storm-waters. Formerly it was the custom to make no distinction between these two descriptions; but of late, we have begun to consider them as separate items, and a grand question has been raised as to whether it is correct to provide for them both by the same system of drains. In the one case, the supply is, or might be, made tolerably uniform; in the other, it is periodical and uncertain, nor can it be made otherwise; it therefore becomes a question, whether the two can be advantageously combined, but as the inquiry is so mixed up with the determination of the size and shape of sewers, it will be better to consider it under that head. We have made no allusion to subsoil drainage, for it is indeed very rarely required; if the surface be properly drained, there will be no necessity for subsoil drainage, except in cases where springs exist, or where the strata contain water, and, even in such cases, it is questionable whether the water might not be usefully employed, rather than carried away at a considerable expense. We shall leave this part of the subject therefore out of the question, and turn at once to the consideration of the sizes and forms of sewers.

Until the last few years, it was the custom to construct sewers of a very large size, varying in sectional area from 5 to 100 feet, the former being allotted to collateral sewers in courts, alleys, and side-streets, and the latter to the main outlets into the Thames, the average area for main lines being about 12 feet. Now, the fact is, that these sewers were seldom, if ever, fully charged, the sectional area of the stream usually flowing through them, averaging not more than $\frac{1}{10}$ part of the area of the sewer, and the flow being often scarcely perceptible. In continuous wet weather, the area of sewage was greatly increased; and also on such days as fresh water was supplied to the houses; in neither case, however, was the sectional area equal to $\frac{1}{4}$ that of the sewer, and the only occasion on which the sewers were anything like full, was the occurrence of some very heavy storm, such perhaps as does not appear once in the course of a twelvemonth. Now, it appeared to those who have recently brought forward this subject for investigation, that a much smaller size would answer the purpose much better, and be decidedly much more economical in construction. Under this impression, several experiments were made under the Metropolitan Sewage Commission, to test the fact, and the result appears to have been decidedly favourable to the new theory.

In a main line of sewer in Upper George-street, Edgeware-road, which communicates directly with the King's Scholars' pond sewer, and which is 5 feet 6 inches in height, by 3 feet 6 inches wide, an earthenware pipe 12 inches in diameter was inserted, laid immediately upon the invert of the larger sewer, and a head-wall built up above it in the sewer, for the purpose of preventing any sewage-matter passing out by a different channel. The total length of this pipe measured 560 feet, and the whole area drained through it amounted to about 44 acres. The results are stated to have been as follows:—"The velocity of the stream in the pipe has been observed to be $4\frac{1}{2}$ times greater than the velocity of the same amount of water on the bed of the old sewer. The pipe has not been found to contain any deposit, but during heavy rains the stones have been heard distinctly rattling through the pipe. When the pipe is nearly filled, the velocity and concentration of the water are sufficient to clear away any matter which may have been drawn into the pipe from the large sewers, much of which matter, it may be presumed, would never enter a well-regulated system of pipe sewers; also the force of the water issuing from the end of the pipe, is sufficiently great to keep the bottom of the old sewer perfectly clean for 12 feet in length; beyond this distance, a few bricks and stones are deposited, which increase in quantity as the distance from the pipe increases. Beyond a certain distance, mud, sand, and other deposits, occur to the depth of several inches, so that the stream there is wide and comparatively sluggish, and being dammed by the deposit, exerts an unfavourable influence on the flow of water through the pipe. On the invert of the original sewer, which now forms the bed of the pipe, deposit was constantly accumulating, and was only partially kept under by repeated flushes. The superficial velocity of the water in the pipe is generally three, four, and five times greater than the superficial velocity which obtained, under the same circumstances, in the original sewer, and the velocity of the whole mass of water in the pipe approximates much more to its surface velocity, as ascertained by a float, than does the velocity of the whole mass of water in the sewer approximate to its own surface-velocity."

Several experiments in this pipe were also made, to determine the propulsive force exerted by the water in removing obstacles, and it was found that quantities of sand, mud, and pieces of brick and stones, were carried from the inlet through the entire length of the pipe, where they were discharged with considerable force, and carried some distance along the invert of the original sewer. All these experiments were effected when the pipe was only or less than half-full of water. The period of year at which the experiments were made, was principally during the month of October, and the following is the detailed daily account of the depth of water in the pipe:—

September 28 and 29. Very wet both days and nights; there was at this period 96 hours' continuance of rain, and the pipe was never observed to be more than half-filled.

October 19. Morning, depth of water in pipe 3 inches; afternoon, depth 2 inches.

October 21. Heavy rain all day; depth of water in pipe 4 and 5 inches.

October 23. Morning, 3 inches; afternoon, very heavy rain, when the pipe filled.

October 24. Morning, depth varied from 2 to 2½ inches; afternoon, from 2½ to 3 inches.

October 25. During the day, depth of water varied from 2 to 2½ inches; afternoon, from 2½ to 3 inches.

October 26. Morning, depth varied from 4 to 3 inches; afternoon, from 2½ inches to 3 inches. During the above three days, the weather was mostly fine. The considerable variations are due to the times of the water being on at the houses; the sewage at such times is much clearer, as well as increased in quantity.

October 27. On this day a storm occurred, which, for a short period, was very violent; the waters filled the pipe, and rose above it 18 inches, but did not reach the top of the head-wall; when the waters had reached this maximum height, they receded to nearly the level of the pipe in twenty minutes.

October 28. Depth during day varied from 3 inches to 1½ inches.

October 30. Depth during day varied from 2 inches to 2½ inches.

October 31. Depth during day varied from 1½ inches to 2 inches.

November 1. Variation of depth from 1½ inches to 2½ inches.

November 2. Variation of depth from 2 inches to 2½ inches.

Another series of experiments was very carefully superintended by Mr. Lovick, Surveyor to the Commission, in Earl-street, Marylebone: the original sewer presenting a sectional area of 15 feet, and having a flat segmental invert 3 feet in width, in which deposit accumulated at the rate of 6,000 cubic feet in 31 days. The area draining into this sewer was 43.656 acres; and the number of houses drained 1135. Upon the invert of this sewer, a 15-inch glazed stone-ware pipe was laid for a length of 115 feet, and having an inclination of 1 in 153.

From these experiments, it appeared that the average consumption of water was about 5.7 gallons per individual per day, or 51½ gallons per house per day; the average quantity discharged when there was no rain, and no fresh supply of water, was 44½ gallons per house per diem; and on the days when the water was supplied to the houses, 209 gallons per house per day. Thus the mean flow on the days when water was supplied to the houses by the water companies, was nearly 4¾ times greater than the mean flow on ordinary days, or days when there was no supply.

The annexed table, deduced from those experiments, will give a correct idea of the several conditions of discharge on ordinary and water days:—

Days.	Quality of Flow.	Cubic feet per minute.	Sectional area of flow in pipe.	Diameter of circles, equal in area to the sectional area of flow.
			Inches.	Inches.
On ordinary days.	Least	1.78	3.05	2.00
	Mean Least	2.10	—	—
	Mean	5.64	8.57	3.4
	Mean Greatest ..	16.90	18.14	4.9
	Greatest	46.50	—	—
On water days.	Least	1.07	1.66	1.5
	Mean	26.46	27.94	6.00
	Mean Greatest ..	106.00	—	—
	Greatest	150.00	109.79	11.8

The maximum being greater than the minimum, on the water days 140 times, and on ordinary days 26 times. The experiment was continued for 30 days, 16 of which were water days, and the remaining 14 ordinary days, and the period of the year at which it took place was during the months of February and March. The *least flow* in the above table refers to the least flow which occurred at any one time during the range of observations; the *mean least*, to the average of the lowest discharges of every day; the *mean*, to the average of the mean of all the observations; so also of the *greatest* and *mean greatest*.

As an evidence of the false principles on which the old system was based, the same surveyor states that the sectional area of the drains in this block of houses was 596 feet, whereas the sectional area of the outlet sewer was only 15 feet, or about one-fortieth the aggregate sectional area of the house-drains. He also states, as the result of his experience generally, that blocks of houses drained with 3, 4, 6, and 9-inch pipes, have been more efficiently drained than under the old system.

The same opinion, with reference to the size of sewers, was given by Mr. Phillips, also Surveyor to the Metropolitan Commission and the late Westminster Commission, in his examination before the Sanitary Commissioners; but he considers a constant supply of water indispensable, if smaller sizes be adopted. In answer to the question—

"Have you at all considered the capacities of sewers necessary for draining the different areas of ground?" he replies, "Yes; I have given the subject much attention. If the consideration of the sizes of sewers was confined solely to the carrying off the water supplied by the several water-companies, then I apprehend that pipes somewhat larger in size than the supply-pipes themselves, would suffice; but provision has to be made for receiving and carrying away the waters of heavy rains. In London, continuous heavy falls of rain are not of long duration, lasting seldom more than from one to four hours. About one-fifth of the quantity that falls, is absorbed partly by the dryness of the surface of the roofs, the paving, and the ground, and partly by the porosity of the ground itself. A farther proportion is also prevented from flowing to the drains and sewers at all by hollows in the surface, and again reascends into the atmosphere as vapour. There is also a small quantity that enters into the composition of animal and vegetable bodies. Then there is the resistance the flow experiences from the friction of the entire surface, being accelerated or detained in proportion as the surface is more or less inclined. To provide for the discharge of a fall of rain of two inches in depth, has been considered by Mr. Hawksby, C. E., the extreme datum upon which to proportion the capacities of town-sewers generally. Now I believe that, practically, the sizes in his table, although they may appear theoretically correct, are (excepting for the smallest sizes) too large for sewers in London. It is extremely violent rains alone that produce a depth of two inches per hour, and such rains occur only once in four or five years, if so much. I am of opinion that it is unnecessary to proportion the size of the sewers to meet an extraordinary occurrence that may probably happen only once in so many years. My reason for not fearing any serious damage from an excess of rain at remote intervals, being provided for in surface-channels, excepting perhaps in situations peculiarly liable to inundation, (for instance, at the foot of a long or steep declivity, or where the waters may from any cause be suddenly congregated at one focus,) is that I have observed, that in towns entirely destitute of underground drains, no such inconvenience is felt as would justify the formation of enormously large sewers, or the expenditure of large sums of money to provide against it."

The evidence of Mr. Roe, late chief Surveyor to the Metropolitan Commission, and previously to the Holborn and Finsbury Sewers, will be deemed most valuable, if not conclusive on this subject, both on account of his long experience, his straightforwardness, and unbiassed judgment; he was also the first to pay attention to the subject, and introduced many improvements, before it had become the topic of general consideration. In his evidence before the Sanitary Commission, he states as the result of his experience, that a cylindrical sewer, 48 inches in diameter, with a fall of 1 in 240, is sufficient to drain 100 acres of town-area, allowing for a fall of rain unusually large. Also that in a street 924 feet in length, containing 93 houses on an area of 6 acres, 1 rood, 8 poles, a fall of rain 2 inches in depth, producing 346 cubic feet of water per minute, would require a sewer of 2.44 feet capacity, with an inclination of 1 in 480. Allowing further for a supply of water of 75 gallons per day to each house, he would add to the capacity of the sewer .16 of a foot, making a total of 2.6 feet. With respect to uncovered land, he gives as the result of five months' observation, that the greatest amount that was found to reach the invert from a fall of rain of $\frac{1}{2}$-inch in the hour, averaged 3 cubic feet per acre per minute at the period of the greatest flow, and that that period was generally from the greatest to one hour after the heaviest portion of the rain had fallen.

Mr. Roe's observations on the flow of water in the Fleet Sewer are of great practical value. This sewer, at its outlet into the city, is 12 feet high by 12 feet wide, with a superficial area of 120 feet; it receives the discharge of 60 sewers, the total sectional area of which amounts to about 550 feet, and its inclination varies from 1 inch in 100 feet to 1 inch in 2 feet, while some parts are on a level. The area drained by it consists of 1,181 acres of town-area, and 2,656 acres of rural district. During the unusually heavy thunder-storm which occurred on August 1, 1846, the area of flow at this part of the sewer measured 106 feet; in a heavy thunder-storm in July, 1844, the sectional area of flow was 79 feet, and on an extraordinary thaw, after fall of snow in 1841, the area occupied was 54 feet, while the ordinary flow does not cover an area of 10 feet.

The following table, made under the directions of the same gentleman, are from gaugings of several sewers under his charge, and will give a fair notion of the true state of the case:

Table of Gauging of Sewers.

Area drained.	No. of Houses.	Capacity.	Run of Water.			Area occupied.	During greatest rain in 1846, area occupied.	Distance from the Thames.	Height above Thames high-water mark.	Inclination.
			Average common run.	Area occupied.	When water let on from pipes.					
Acres.		Feet.	Inches.	Feet.	Inches.	Feet.	Feet.	Chains.	Feet.	
110	..	13	3	..	..	..	13.00	120	36	$\frac{1}{2}$ Inch in 10 feet, a main line.
5	100	9.0	$1\frac{1}{2}$	0.08	2	0.13	2.50	150	47.0	3 Inches in 50 feet, collateral Sewer
2.70	69	7.65	$\frac{3}{4}$	0.024	$1\frac{1}{4}$	0.06	2.10	166	52.0	
5.15	104	9.65	..	..	$1\frac{3}{4}$	0.11	2.70	145	47.0	5 Inches in 100 feet.
1.09	49	9.09	..	..	$2\frac{1}{2}$	0.33	1.43	265	120.0	
0.25	32	..	..	..	1	0.04	0.33	157	110.0	
1.36	41	7.65	..	..	$2\frac{1}{4}$	0.23	1.40	151	46.0	
2.16	50	7.65	..	..	1	0.034	1.13	160	51.0	
4.16	120	9.65	..	..	3	0.23	4.17	140	49.0	2 Inches in 100 feet, current impeded by height of water in outlet Sewer.
0.25	16	9.09	..	..	$\frac{3}{4}$	0.03	0.30	155	102.0	
19.10	482	9.09	3	0.23	..	..	6.33	140	50.0	$2\frac{1}{2}$ Inches in 100 feet, current impeded by height of water in the outlet Sewer.
1.00	22	7.65	$\frac{3}{4}$	0.03	..	..	1.13	147	47.0	
1.36	37	..	..	0.05	..	..	1.25	149	47.0	
1.08	31	..	..	0.04	..	..	1.20	151	46.0	
3.42	65	3.14	..	0.09	..	..	1.60	180	118.0	12 Inches in 100 feet.
0.84	40	1.22	..	0.17	.. Engine waste water.	..	1.22	92	48.0	$5\frac{1}{2}$ Inches in 100 feet.

In opposition to this evidence, we have the authority of such names as Walker, Cubitt, and Brunel, names which may not be passed by unnoticed, although with the previous statements before us, it seems somewhat difficult to coincide with their views. While, however, we pay due deference to gentlemen of such high standing in their profession, we must not forget that such men as Mr. Roe have probably had the greater experience in this particular class of works. Let us attempt to simplify the question as much as possible.

The objections raised against the old system are, 1st, that they are unnecessarily expensive—2ndly, that they are inefficient Their great expense arises from their size, therefore we have to show that their size is unnecessarily large. That they are larger than required for the ordinary drainage cannot, we imagine, be a matter of question, after the result of the above observations and experiments have been made known; nor can we attempt to disprove the unvarying evidence on this point, given by persons practically acquainted with the subject; the table of gaugings by Mr. Roe seems to decide this question, for during the extraordinary storm, in 1846, we find that by far the majority of the examples were not full on that occasion, nor, indeed, nearly so. Out of 16 examples only two were filled on this occasion, one of which was a main line of 13-feet capacity, draining an area of 110 acres, and the other a 15-inch drain, relieving an area of 0.84 acres. During the experiment in the Earl-street sewer, which happened in a wet season of the year, a 15″ pipe was found more than sufficient for the drainage of 44 acres of covered ground, with only one exception, which occurred during a heavy storm, when the discharge amounted to above 300 cubic feet per minute. In the experiments in Upper George-street, during a continuance of 96 hours' rain, the 12-inch pipe was never observed to be more than half full; but on one occasion, during a violent storm, the water rose 18 inches above the pipe; this state of things, however, lasted but a short time. The area drained by the Upper George-street sewer was also 44 acres.

Now, putting aside for the present the question as to whether the pipes used in the above experiments were of sufficient capacity, Mr. Roe's experiments, which give, we think we may say, the very greatest amount of discharge which can ever take place, are decisive thus far—that by far the majority of existing sewers are very much larger than can at any time be necessary; and with respect to the exceptional two, it remains a question, whether under an improved system of drainage they would ever have been put to such a test, but under the old system, when, occasionally, a sewer got smaller towards its outlet, the levels were ill-arranged and defective, &c., it is not to be wondered at, that sometimes one sewer had to perform more than its fair share of work, whilst others were almost inactive; if the sewage had been more equally distributed, no one sewer would have been so much overcharged.

Taking then the maximum quantity ever discharged, as the rule to guide us in fixing the proper dimensions of sewers, we find that the old system is too capacious; but beyond this it is questionable whether it is necessary or advisable to provide for such extraordinary flow, and this question becomes of more importance, if it can be proved that extra capacity is detrimental to the efficient discharge of sewage matters. In this state of the case, the real matter at issue is, whether it be preferable to be subject to a constant inconvenience, or a temporary and problematical one. Some say we must provide for all emergencies; others would rather run the risk. We are inclined towards the latter opinion. But there remains another argument in favour of large sewers, and that is, that they admit the passage of a man, for the purpose of inspection and periodical cleansing, which the advocates of the old system deem to be necessary; if, however, it can be proved that smaller sewers will keep themselves free from deposit by the extra velocity and scour of the water, this objection will be removed. Again, this objection will not hold good against the substitution of very small pipes for those sewers which, although much larger than requisite for the ordinary flow, cannot conveniently be entered for this purpose; for if the work causes great discomfort to the labourer, it is certain that it will not be performed efficiently, if, indeed, it be performed at all; we should imagine that sewers less than 4 feet in height, are not inspected much more frequently than a 15-inch pipe would be.

We have now to consider whether drainage may be more efficiently discharged by a small than a large sewer. The small quantity of water ordinarily passing through the large existing sewers, is allowed, on all hands, to be very sluggish in its movement; and that a deposit of solid matter is always going on, and that to a considerable extent, is evident from the fact, that large quantities of solid matter are obliged to be periodically removed by flushing or hand-labour, and in several cases when old drains have been opened, they have been found to be almost choked up by such accumulations. It is certain, therefore, that large sewers do not of themselves efficiently remove the refuse matters. This defect was observed some years since by Mr. Roe, and the cause being determined upon, it was attempted to remedy it by reducing the width of the invert of the sewer, and thus narrow and deepen the channel for the water, thereby producing less frictional area, a greater depth of water, and consequently a greater velocity and improved scour. This practice was found to succeed, and was afterwards adopted in other localities. It may be noted in passing, that where much deposit has taken place, it is observed that the stream forms for itself a sort of gut or narrow channel, thus giving visible evidence of the requirements of nature in this particular.

As the question relating to the velocity and scour of a body of water in various-sized channels was of considerable importance in determining upon a system of drainage, a series of experiments upon the flow of water through various-sized pipes was made, under the direction of the Metropolitan Commission; and amongst the results given, we find that a 3-inch glazed stone-ware pipe, 50 feet in length, with an inclination of 1 in 120, and being fully charged at the head, will discharge 100 gallons of sewage water in 3 minutes; and that a 4-inch pipe under precisely similar circumstances, will discharge 200 gallons in the same time; and further, that such a flow is sufficient to remove any, and even more than ordinary and usual semi-fluid deposit, such as is usually found in house-drains. A mixture of sand with water, in proportion of from $\frac{1}{16}$ to $\frac{1}{40}$ the volume of water, was also removed. Also that the hydraulic mean pipe of a 3, 4, 6, and 9 inch pipe, when half full, is respectively .749, 1.00, 1.5 and 2.18 inches, and that the fractional line, under the same circumstances, would be 4.71, 6.28, 9.42, and 14.13 inches respectively. Further, that 1 gallon of water through a 3-inch pipe, moved 1 lb.; through a 4-inch pipe, 3 lb.; and through a 6-inch pipe, $\frac{1}{2}$ lb.; and that 3 gallons of water will carry off 1 lb. of solid fæces through a 6-inch pipe with a fall of 1 in 10; but to make these results of use, we ought to be acquainted both with the fall and velocity. Another statement is this: if 81 seconds suffice for the discharge of 50 cubic feet of clean water, 84 will suffice when $\frac{1}{40}$ of solid matter is added, and 91 seconds when the solid matter amounts to $\frac{1}{16}$.

Such results are generally in favour of the small pipes, but it is to be regretted that the experiments were not carried on on a more extensive scale, for they afford little information respecting the larger kinds of pipes. It will be generally allowed, however, that a concentrated body of water will move with greater velocity than the same amount where spread over a large surface, the resistance offered by friction will be less effective in retarding its progress, and the greater depth afforded by narrowing the channel will tend to improve the scour. The scour will depend both upon the depth and velocity of the stream, and will therefore in both ways be more efficient in a contracted channel. On these two properties, depend the efficiency of the drain; for if the velocity be greater, the discharge will also be greater, and the power to keep the sewer free from deposit will increase in like manner; for, in the first place, there will be less tendency to deposit; and in the second, when a deposit takes place, it will be more readily removed. This is both reasonable in theory, and has been proved in practice, for the evidence of Mr. Lovick and others, who have had opportunity of examining the state of small pipes after they have been in use some time, goes to prove that they keep themselves almost perfectly free from deposit. It will be perceived by the following table, prepared from the experiments made in the Earl-street sewer, that the quantity of solid matter in suspension in sewage-water, bears but a small proportion to the liquid, and it is therefore probable, that with a fair velocity of flow there would be but little tendency to deposit.

Tables of Solid Matter in Suspension in the Flow.

No. 1.—On the Extra Water-Days.

Quality of flow analyzed, and period when taken.	Solid matter in one Imperial Gallon.			Proportions.	
	Soluble Grains.	Insoluble Grains.	Soluble & Insoluble Grains.	Soluble to Insoluble.	Soluble & Insoluble to Liquid.
Greatest taken, 5½ P.M.	33	19	52	2 to 1	1 to 1346
Mean of 2 analyses, taken at 12 A.M.	119	46	165	2½ to 1	424
Mean of 2 analyses, taken at 8½ and 10½ A.M.	119	37	156	3½ to 1	448
Least taken at 12 P.M.	111	11	122	10 to 1	574
Total	382	113	495		
Averages	96	28	124	3½ to 1	564
When water first laid on, or at commencement of overflow from cisterns	80	192	272	1 to 2½	257

No. 2.—On Ordinary Days.

Quality of flow analyzed, and period when taken.	Solid matter in one Imperial Gallon.			Proportions.	
	Soluble Grains.	Insoluble Grains.	Soluble & Insoluble Grains.	Soluble to Insoluble.	Soluble & Insoluble to Liquid.
Greatest mean of two analyses taken at 12 A.M.	114	34	148	3½ to 1	1 to 473
Mean taken at 8½ A.M.	154	71	225	2 to 1	311
Least taken at 12 P.M.	114	14	128	8 to 1	546
Total	382	119	501		
Averages	127	40	167	3½ to 1	419

The principal objections against the use of small-pipe sewers are: 1st. That if any obstruction occur in the pipe, so as to cause accumulation of deposit, the pipe rapidly becomes completely stopped up, whereas, in the larger sewers, even though obstructions may occur, they will not entirely stop the flow, or at least the accumulation must proceed for a considerable period ere the entire area be filled up. 2nd. That if such stoppage take place, there is no means of ready access to the sewer to examine it, and that the road will probably have to be broken up in several places ere the drainage be repaired; and even then it is almost impracticable to reinstate the pipes in the same conditions as when first laid down. 3rd. That owing to the nicety required in laying the pipes, an uniform inclination is not easily preserved, nor is there any satisfactory means of knowing when the invert is perfectly smooth; that if the pipes be defective in form, or imperfectly laid, or if the cement with which the joints are made be allowed to project within the pipe above the general surface, an obstacle is at once offered to the flow, which is not unlikely to cause deposit, and thereby a stoppage in the pipe.

Now, in the case of the first objection, it does appear feasible, that a small pipe would be more rapidly filled up than a large sewer, but yet there are some grounds for supposing the contrary to be the case; for as the water-way becomes contracted, so also does the scour of the stream increase; and moreover, the stream being ponded back, we shall have a full head of water to increase the power of the flow, so that it would appear, that unless the matter causing the obstruction be extremely difficult of removal, the water-way is not likely to be entirely closed up.

The second objection must be allowed to possess considerable weight; in case of stoppage, it would, in truth, be a matter of great difficulty and inconvenience to remedy the accident; yet, at the same time, we must not forget, that even in brick sewers, if they be of the smaller class, there is no very ready means of access; and moreover, they are more likely to encourage deposit; we are inclined to think, that if pipe-sewers be carefully laid, and fairly used, they would not be likely to silt up. The objection to breaking up the roads, for the purpose of discovering the stoppage, can scarcely be overrated; and it is also true, that it is very difficult to relay the pipes in their former position, unless indeed they be made with half-socket joints, or be made of two semi-cylindrical pipes one laid over the other.

The nicety required in laying the pipes, and the difficulty and uncertainty attending the practice, is certainly objectionable; there is no means of seeing the interior of the pipe, to observe how the work is performed, and it is not unreasonable to suppose, that the cement at the joints, by the carelessness of the workmen, is sometimes left to form a projecting ridge above the surface of the invert. To prevent any obstructions at the joints, it has been proposed to make the pipes of a slightly conical form, inserting the smaller end of the first into the large end of the succeeding pipe; this, however, seems rather an awkward method of meeting the difficulty; and we are inclined to think, that a better method would be, to make the pipes in two pieces, as suggested above, first laying the inverts and securing their accuracy, and then covering them over with the upper half; but neither is this plan without objections.

As regards the separation of house from surface drainage, so long as the latter bears so small a proportion to the former, we do not think it advisable to form a separate system for each; but in cases where the proportion of surface-water is increased, and the house-drainage tolerably uniform, it may possibly be advisable to separate them, if the sewage be intended for dry manure; otherwise, we should scarcely deem it expedient: with reference to the size of sewers, we do not think it necessary to provide for extraordinary storms; we would rather have the advantage of a good general drainage, and the occasional and temporary inconvenience caused by a heavy storm, than be safe from the latter, with the constant inconvenience of imperfect drainage. Generally speaking, we should advise a system of pipe-sewage, somewhat larger in proportion to the area drained, than that observed in those laid down for experiment in Earl-street; for besides, that on such occasions the pipes are likely to be more carefully laid than in ordinary cases, we find that on one occasion during that month, the water reached a height of 9 inches above the head of the pipe. We would allow for such storms as are likely to occur once a month, but not such as occur only once in three or four years. On this one occasion, at Earl-street, the discharge was above 300 cubic feet per minute, and as a similar overflow is recorded in Upper George-street, we may reckon that such discharges are not unfrequent during the rainy season: we must not forget, however, that the pipes in these instances were connected with an imperfect system of collateral drains; and that under a perfect system, the surface-water would have been carried off more rapidly, and there would not have been so great an accumulation at this point. A little experience of the working of a perfect scheme of this description, would readily determine the requisite sizes.

In main lines of sewer, and where they pass under main roads, we should recommend the construction of brick sewers of such size as would be sufficient for the passage of a man, and for room to work in when requisite. In these we would lay not only a pipe-sewer of sufficient capacity for the usual run of water, but also the gas and water-mains, where practicable, in order to obviate any necessity for breaking up the roadway on occasion of repairing, &c. We are convinced that this arrangement is of considerable importance, where the roads have to sustain much traffic, for it is impossible to maintain good roads while they are constantly being broken up by gas and water companies. The expense of this system, as far as regards the sewers, would not be much greater than the present, and there can be no doubt but that the management of the roadways would be much more economical. Under such circumstances, it would be worth while to construct a good solid roadway, which, though a little more expensive in the first outlay, would in the end prove much more economical, not only as regards the repair, but also as requiring a less amount of tractive power, and doing less damage to the vehicles passing over it. It is very advisable, that all subterranean works should be treated of together as separate portions of one system. The pipe-sewers should be laid in the invert, and might be so arranged as to allow of an overflow into the large sewer, when requisite; or the water might be poured back, for the purpose of flushing when deemed advisable. Access would be obtained into the sewer, for the purpose of inspecting and repairing the various pipes by side-entrances, as at present; and the sewer ventilated by shafts in the roadways, without detriment to public health, the pipes which convey the sewage being impermeable. The only difficulty which limits the application of this system to main roads and sewers, is its expense; were it not for this, it might be adopted in every street with much advantage.

Many forms of large sewers have been adopted, but that which appears to be best adapted for the purpose, is the egg-shaped, which was introduced by Mr. Roe; the older forms having mostly a semicircular crown, with upright side-walls, and a semicircular or flat segmental invert. The main improvement effected by the egg-shaped sewers, consisted in narrowing the invert, thereby contracting the lower part of the channel, and increasing the depth of flow, by which means the velocity and scour was much improved; the same quantity of water which moved but sluggishly when spread over the wide surface of a flat invert, being now concentrated in a narrow channel, was made to move with accelerated flow; in short, this alteration had a similar effect to that produced by the employment of small pipe-sewers. Another advantage obtained by this form, was the attainment of greater height with a given area, which enabled men to pass through them with greater facility; it must be confessed though, that the narrow invert is rather inconvenient to walk upon. The shape, moreover, is economical, and based on sound principles as regards construction.

Many proportions, and many methods of describing the egg-shape, have been observed at different places, some being constructed with a semicircular top, flat segmental sides, and a sharp segmental invert; the curves of the sides and invert varying according to varying proportions of height and width, and other circumstances. Others are constructed with six centres, the upper part being described with two radii, instead of being semicircular. Of all these varieties, however, the most eligible is thus described:—Let the height of the sewer be to the width as 3 to 2; then having described a semicircular crown with radius 1, with radius 3, equal to the height, and with the centre on the springing-line, describe a segment touching the semicircle already described; for the invert, with a radius $\frac{1}{2}$ or $\frac{1}{6}$ of the entire height, describe a circle which will be found to touch the segments just described. This form is generally applicable, and has the advantage of being drawn to certain proportions.

The above are the most usual forms for sewers, but occasionally the levels will not allow sufficient height for them beneath the roadway; and, in such cases, it is necessary for the purpose of obtaining sufficient capacity, to construct them of a cylindrical or elliptical form; but even then, the same end may frequently be obtained by placing two or more egg-shaped sewers side by side. Where there is a large and constant flow of water, cylindrical sewers are not objectionable.

The above sewers, if not more than 4 feet in height, and if in good building strata, may be constructed of half-brick work, but in other cases require to be a whole brick thick, unless the sewer be very small. They are constructed mainly of stock-bricks in mortar, the invert or lower portion only being laid in cement; the inverts are usually formed in blocks in cement before they are finally laid in the sewer; the invert consisting of three or more blocks, according to its dimensions. Sometimes blue vitrified bricks are used for the invert; they are very hard and durable, but do not adhere well to the cement. It has been proposed to construct sewers with radiated bricks, and they probably might be used with advantage where the curve is sharp: the joints of common bricks are very open in such cases. Radiated hollow bricks have also been suggested, and, if moderately cheap, they might doubtless be employed successfully.

The pipe-sewers, as at present made, are of a cylindrical form; they are constructed in lengths of 2 or 3 feet, and have a socket at one end for the adjoining pipe to fit into; sometimes, however, they are made with half a socket on either pipe, and this is of advantage in facilitating their removal, if at any time they be required to be taken up. With the whole sockets, it is difficult to take them up without breaking them, and it is almost impracticable to replace them correctly after removal.

If whole-socket pipes be generally used, we should advise the occasional adoption of half-sockets, so that in case of stoppage, or other accident, they may admit of easy removal and replacement, without either destroying the pipes or disturbing the adjoining ones. Cylindrical pipes are made from 3 to 2 feet in diameter. It has been suggested, that such pipes should be made of the egg-shape, rather than cylindrical; but it must be borne in mind, that the contraction of the invert is not of so much consequence in a small pipe, where there is likely, at all times, to be a large current compared with the capacity of the pipe; and if the pipe be generally full, we know that the circumference of a circle contains a larger area than the same extension of boundary-line arranged in any other form; therefore, if a cylindrical pipe be full, there is less frictional surface than in any other kind of pipe of the same capacity. As, however, in present practice, the flow of water varies to a great extent at different times, it might not be unadvisable to adopt the egg-shape, supposing that they can be manufactured with the same accuracy, and at no higher cost. If they be adopted, we should advise their being made in two pieces, the lower one forming the invert, and the upper the semicircular crown; a flange, or socket, might be formed at the edge of the bottom-piece to receive the top, and make a correct joint; the same practice might be adopted in cylindrical pipes of a large size. The advantages attaching to this method are, that the inverts can be laid with great nicety, a matter of considerable importance, and are open to inspection after they are laid, so as to admit of opportunity of testing their accuracy; the objections against the whole pipes, on this head, are of considerable weight. Another advantage is, that the top-half can be taken off at any time for examination or inspection of the pipes, without disturbing the invert, or interfering with the flow.

These pipes are manufactured of stoneware, and various kinds of clay, glazed and unglazed, some being glazed on the interior, and others on both surfaces; the stoneware, glazed on both sides, are most frequently adopted, and are found to answer best; but there is a process of manufacture which produces unglazed pipes equally efficient as the glazed stoneware. The peculiarity of this process consists in submitting the pipe, when half-dry, to an extreme pressure between two polished iron surfaces, whereby a density of substance, and truth of form, is attained, which is equivalent in practice to the best glaze, so far, at least, as the flow of water is concerned. Pipes of the above materials and manufacture have a great advantage over brick-sewers, on account of the comparative smoothness and evenness of surface, which offers very little or no resistance to the current; the amount of frictional resistance being naturally greater over the rough surface of the brick work. In the following table will be found the result of some experiments, for the purpose of determining the advantage gained, in this respect, by glazed pipes:—

Table of Comparative Time of Run of Water through Brick Drains and Glazed Pipes.

Inclination.	Depth of water.	Time through Glazed Pipes.	Time through Brick Drain.
	Inches.		
Level	5	38	50
2 Inches in 50 feet	4½	16½	25
3¾ ditto	5½	19	27
1¼ ditto	3	18	26
½ ditto	3½	25	36
3¼ ditto	4	15	22
1¾ ditto	6	13½	21½

The rate of inclination is a matter which requires some consideration in laying out a system of drainage; the greater the fall, of course the greater the velocity, and, in consequence, the more rapid the discharge; the scour is also proportionately greater. It will thus be seen, that the efficiency of sewers depends a great deal upon their rate of fall towards the outlet; this, however, will depend mainly upon the nature of the locality to be drained. Supposing there exists a certain fall from the highest point to be drained to the outlet, it will be well to see how it can be laid out or expended to the greatest advantage:—the rule is this, give the greatest rate to the house-drains; the next greatest, to the pipes with which they are immediately connected; and so on, diminishing the rate gradually as you get towards the outlet. The reason for this is obvious; for, in the first place, your main object is to remove the sewers from immediate proximity to the houses, so that perfect drainage is of less consequence at a distance than it is in the houses themselves. But beyond this, there is another more important object in this arrangement, for as the body of water is less in the sewers or drains more remote from the outlet, it is more likely to be sluggish in its movements than where there is a large volume of water, and this tendency to sluggishness is overcome by an increased rate of inclination, so that the want of velocity caused by the small body of water in the smaller sewers is compensated by the extra fall, and thus the flow in all cases is rendered equal, or nearly so. In the larger sewers, where the water is collected from the tributaries, the mass of water is sufficient to preserve a good velocity with even a small inclination. The rate will depend, as we said before, upon the nature of the ground; but, as a general rule, it is advisable that the fall in main-pipes should not be less than 1 in 240, and in main-sewers not below 1 in 1,000. It has been deduced from experiments, that no proportionate advantage is gained by a fall of more than 1 in 60. The requisite size of the pipes is dependent, in a great measure, upon their fall, for as the velocity is increased in proportion thereto, so is also the rate of discharge, and therefore the greater the fall, the less will be the sectional area required for the sewers.

Where one sewer discharges its contents into another, the junction should be effected by a curve, drawn tangent to the directions of both sewers, so that the direction of the stream may be changed in as easy a manner as possible, and may not experience any shock either in leaving the smaller or entering the larger sewer. It was formerly the practice to make the junctions rectangular, but by this method the stream from the tributaries, crossing that of the main at right angles, had a tendency to change its direction, the amount of change depending on the comparative force of the two streams; in any case, however, the flow in the main stream was impeded, eddies caused, and deposit thereby accumulated. If, on the contrary, the two streams be tangential at the point of junction, little or no impediment will take place, as they have both a tendency to move in the same direction. It is advisable, that the curve be struck with as large a radius as practicable. In the pipe-sewers, junction-pipes are made for the purpose, in which the junction-curve is commenced on the main-pipe, so that we have a straight pipe, and a portion of a curved one, in the same length; the pipes are made to suit different circumstances, some with one, others with two junctions, and these of various sizes as required. With respect to the time occupied by the passage of water through different junctions, the following results have been arrived at by Mr. Roe, after various experiments:—

Time occupied by the passage of equal quantities of water through similar lengths, and with the same inclination.

Along a straight line—90 seconds.
With true curve—100 seconds.
With turn at right angles—140 seconds.

It is to be observed with reference to junctions, that it is not necessary to increase the capacity of the main line at every junction with a tributary, or that the area of the main should be equal to the area of all the junctions. The reason of this apparent inconsistency is, that although a pipe be full at its head, it will be found to be not nearly full at its outlet, and this is caused by the increased velocity of the particles of water acquired by running down an inclined plane. At a little distance from the head, therefore, some portion of the sectional area of the pipe will be vacant, sufficient to afford room for the discharge of a tributary, which will in its turn add to the velocity of the main stream, and leave space for a second tributary at a joint lower down. There is, of course, a limit to the addition of tributaries, for in time the areas of the main will be comparatively full, and will dam up the water in the junctions; the extent to which the principle can be carried, is to be determined by practice; it will depend to some extent on the fall of the main line.

Where sewers are constructed with the intention of being entered for inspection, it is necessary that they should be properly ventilated; otherwise, the noxious gases generated by the sewage, would forbid entrance, except at considerable risk of life: fatal accidents have occurred, for want of such precaution. The usual plan for effecting this, is to construct a long, narrow, and tapering shaft from the crown of the sewer to the roadway; but this practice is objectionable, on account of the gases vitiating the atmosphere, and thus encouraging disease; and it does appear somewhat inconsistent, that while gullies are trapped to prevent the ascent of the effluvia, other shafts are constructed for the purpose of effecting it. It is true, there is some advantage gained in ventilating by the vertical shaft, but not sufficient, it may be imagined, to counterbalance the inconsistency. Several methods have been attempted, to obviate this difficulty: amongst which may be mentioned, the connection of the ventilator with the rain-water pipes of the houses, and extending them a considerable height above the houses; the passage of the air through a furnace; the ventilation by steam-jet, &c.; each of which plans have been more or less successful. If we adopt the pipe-sewers, all difficulty on this score is at once obviated, for the pipes themselves are impermeable, and if the gullies and house-drains be properly trapped with syphons or flaps, there will be little danger of the escape of noxious vapours; and it must be remembered, that in this case, the sewers themselves are not required to be ventilated, seeing that they do not admit of passage by a man. That they are ventilated, however, to a certain extent, is very probable; for it is well known, that the rapid motion of a stream of water will produce a sensible current of air, and in proportion as the velocity of flow is greater in small than in large sewers, so will their ventilation be more completely effected: besides this, as the deposit is likely to be less, there will be less need of ventilation.

In large sewers, it is necessary that there should be ready means of access to them, and this is best provided for by side-entrances, which consist of vertical shafts descended by iron ladders or step-irons, and covered with cast-iron flaps. These shafts are placed at any convenient spot, at the side of the sewer, generally in the footpath, where the sewer is in the middle of the road, and from the bottom of the shaft an arched passage is carried with a slight inclination under the roadway into the sewer, the lowest level of the bottom being from 6 to 18 inches above the invert.

Gullies require to be constructed at certain intervals, to carry off the surface-water from the roads. The water is carried by gratings in the channel of the road into a cesspool or well, and thence by an overflow-pipe with syphon trap into the sewer. The grating should be made to open, or other access afforded to the cesspool, in order to remove the deposit when requisite.

Having treated upon the subject of drainage generally, we now come to the consideration of house-drainage, which requires a few remarks. The old system of carrying the house-drainage into the main-lines, consisted simply in laying down a drain from each house, connected at the one end with the sinks, water-closets, &c.; and at the other with the main sewer, which ran in the centre of the road. Amongst the recent improvements, a new plan has been adopted, by which the drainage of the house is conducted into a pipe at the back of the premises, and by it into a main sewer; this is termed *back-drainage;* and the old system, *front-drainage;* or whereas in the former case, the sewage is collected at the back, in the latter it is collected at the front of the houses. The system of back-drainage is certainly in many respects an improvement upon the old, but it is not so universally applicable as some persons would lead us to believe; it provides a convenient variation, but not an extensive substitute. One great improvement is effected by carrying the drainage at once away from the premises, instead of its running under them, as before. The objections to the old system in this respect, are, the passage of the drains under the houses, whereby, if not perfectly constructed, the effluvia is likely to be spread all over the interior; and the inconvenience which is thereby occasioned in case of stoppage, or other necessary examination or repair which involves the removal of floors, &c., and the opening of drains in the house; matters not only inconvenient, but sometimes dangerous, on account of the escape of effluvia. In some cases, where the old brick drains have been employed, and, as is not unfrequently the case, improperly constructed, the drainage has been allowed to escape through crevices in the brick-work, and saturate the foundations of the premises; this is frequently the cause of damp basements, and of unpleasant and noxious odours in the lower part of the house. A further objection exists in the frequent apertures required to be made into the main sewer for the insertion of the house-drains, and the many interruptions which are occasioned in the flow of the sewage in the main sewer, by the discharge of so great a number of house-drains.

These objections are obviated almost entirely by the new system; the drains, instead of being carried through the house, are at once removed from it, and the dangers and inconvenience attending the old practice entirely done away with. Such at least is the case in by far the majority of instances: occasionally, where the position of water-closets in front of the house requires the drains to be brought through the house to the back, the employment of the new system would not be so advantageous; the carrying of drains from sinks through the house, is not so objectionable. The large sewers will not be interfered with, except at distant intervals, for the insertion of the main back-drain, discharging the sewage of a block of several houses. There are several other advantages attending the new system, amongst which may be mentioned the following:—The flow of sewage is very considerably improved by its concentration into one drain, instead of being spread over many; the frictional surface is also much reduced. In the old system, the occasional flow of water from each house was so inconsiderable as to produce a mere dribble, which flowed sluggishly, and deposited its solid matters in abundance, under the very dwellings; it was but a small portion that eventually reached, and was discharged into the sewer; whereas, where the back-drainage is adopted, the water is discharged almost immediately into the main back-drain, and the collection of the sewage of all the houses therein produces a considerable volume, sufficient at all times to keep up a moderate flow into the main sewer, and thus prevent deposit; if, however, deposit should occur, it is less objectionable than where it takes place under the house. There is a fair objection to this system when stoppage does occur, for the stoppage in one place will occasion the same in every house which happens to be situate between the stoppage and the first inlet; under the old system, this would not take place. In the separate system, each occupier is subject to the inconvenience occasioned only by his own negligence or carelessness, whereas in the combined system he is, to a certain extent, at the mercy of his neighbours; when, however, we take into consideration the improved flow in the main back-drain, and the less probability of stoppage, this objection will not have so great weight.

It will also be frequently found, that a considerable length of drain is saved by adopting the combined system, and where this is the case, back-drainage is decidedly preferable; for not only is the expense lessened, but the fall is likewise improved, and the contents are more rapidly and more efficiently discharged. Where length of drain can be effected by back-drainage, there can be no question as to its adoption; yet there are some instances in which this is not the case, but the contrary rather; and under such circumstances, considerable discretion will be required in selecting that system which shall be most efficacious.

The drains employed in carrying the sewage from the houses, need not be more than four inches in diameter, of the same material and descriptions as those above recommended for sewers; 6 or 9-inch pipes will generally be found of sufficient capacity for the main back-drains, but of course this will depend upon the number of houses drained into them. These should be trapped at their entrance into the sewers, to prevent the effluvia rising through them from the sewer into the houses. Sinks, water-closets, &c., should also be trapped at the inlets.

We are now arrived at the close of this article; and we are sure that the increasing importance of the subject will excuse the length to which it has been carried.

SEXAGESIMAL, (from the Latin,) the division of a line, first into 60, then each of the parts into 60, and each of these again into 60, and so on, as long as division can be made.

This division is principally employed in dividing the circumference of a circle, and was much used in ancient astronomy. The French have adopted the centesimal division, which is far more convenient for calculation.

SEXAGON, or Hexagon, a six-sided figure.

SHADOWING, in drawing, the art of representing the various degrees of light and shade by means of a dark fluid, or liquid.

The paper intended to be drawn upon, having its rough edges cut off, ought to be wetted, or uniformly moistened, and pasted round its four edges upon a board, observing, in doing this, that no part of the paper ought to be suffered to dry before the edges that are pasted, as the paper will begin to shrink; and, consequently, by its motion towards the centre, will loosen the edges: as soon, therefore, as the middle part appears dry before the edges, it ought to be moistened again with a sponge, and the sponging should be repeated as often as may be found necessary; and, when the paper becomes dry, it will be perfectly flat, and fit for use.

In order to lessen this trouble, some have drawing-boards framed so as to include a panel, which is let into a rebate, on the inner edge of the frame, and fastened, by means of bars, upon the back of the board.

The paper being wetted on the side intended to be drawn upon, the dry side is laid upon the face of the panel, now out of the frame, so that the edges of the paper project alike on all sides, over the edges of the panel; then laying hold of the paper by the edges out of the panel, place it over the aperture in the frame, with the underside reversed, and press it in; after which, bolt the panel to the frame by means of the bars, and the edges of the paper being inserted in the seam, or joint, between the edges of the panel and the adjacent edges of the frame, will prevent the paper, as it contracts in drying, from returning towards the centre, and, when dry, it will be flat and extended; but this method can only be practised in small drawings. The former must, therefore, be considered as the general plan of fixing the paper.

The fluid commonly used in architectural drawings is Indian ink dissolved or mixed in water. The method of doing it is this: fill a small cup with as much water as may be necessary for the quantity of ink intended to be made; then rub the ink upon the tip of the fore-finger, wetted in water, and wash it off in the cup: when the water becomes sufficiently dark, it will be fit for use. This method is, however, too tedious for general use, the more frequent practice is to rub it up as other colours. The stick of ink should be rubbed quite dry, otherwise it will be apt to fall into pieces, and become unfit for use. The liquid thus made is called *ink* or *colour*.

The next thing to be done is to outline the drawing.

Straight lines are drawn with a steel pen, circles by the compass, and curve lines by hand, with camel or sable hair pencils, or with a fine-pointed pen, or with curved ruler and drawing pen.

In drawing very fine lines, the inking-points of the steel pen and compasses ought to be kept very sharp, but not so much as to cut the paper. The outlines being finished, the paper ought to be rubbed clean, and then sponged, or rubbed with a soft brush and water, in order to soften the lines, and to make the paper receive the shadowing more freely. If the paper be even sponged, or brushed, so as to raise the nap in a small degree, it will be the more favourable for producing clear and soft shadows.

In laying the shadowing colour upon the paper, it ought to be spread over the surface uniformly with a camel or sable hair pencil, flowing freely; but not in such quantities as to stand in hollows upon the paper, as, when dry, it becomes cloudy. In making a uniform tint, the first thing to be considered is, the degree of darkness to which the surface is intended to be made. If required to be very light, one tint, or the shade once gone over, will be sufficient; but, if dark, several tints will be necessary. In producing the several degrees of darkness, every tint ought to be nearly dry before the next is laid; the number of repetitions will depend upon the depth of the colour and extension of the surface to be shadowed. It may be observed, that the lightest tint, often repeated, will darken the surface to any degree required. But that too much time may not be dedicated to laying a fine tint, it must also be observed, that the greater the facility with which the tints are laid, the fewer will be required to darken the surface. This facility is to be obtained by sufficient practice.

SHADOWS, *The Doctrine of*, in perspective, is the theory and practice of representing shadows, as projected from a given point at a finite distance, such as a candle; or as projected from the sun, where the distance, though not infinite, is, for the sake of simplicity, considered as such, in order that the rays may be all parallel; or otherwise, for this purpose, the rays may be supposed as proceeding from all points of space in parallel lines.

Definition 1.—A line of shade is the line deprived of light by an opaque point opposed to the luminary.

Definition 2.—A plane of shade is an opaque or dark plane, occasioned by the privation of light from the interposition of a straight line opposed to the luminary; and hence it is evident, that every plane of shade will pass through the luminary.

To find the shadows, upon the surfaces of bodies, occasioned by the privation of the sun's rays.

Proposition I.—*Given the vanishing line of a plane, the vanishing point of the sun's rays, the vanishing point of the seat of a ray on the plane, the representation of a point in space, and the representation of a seat of the point in the plane whose vanishing line is given; to find the representation of the shadow upon the plane of the picture.*

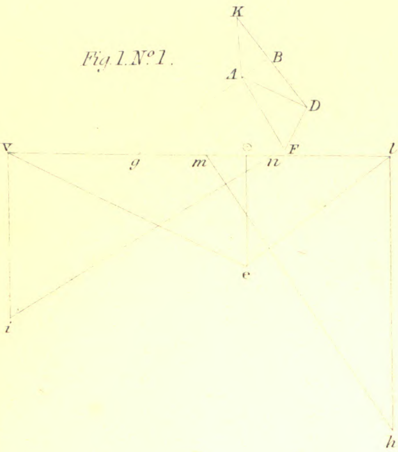


Fig. 1. No. 1.

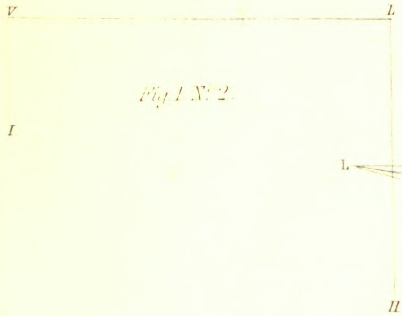


Fig. 1. No. 2.

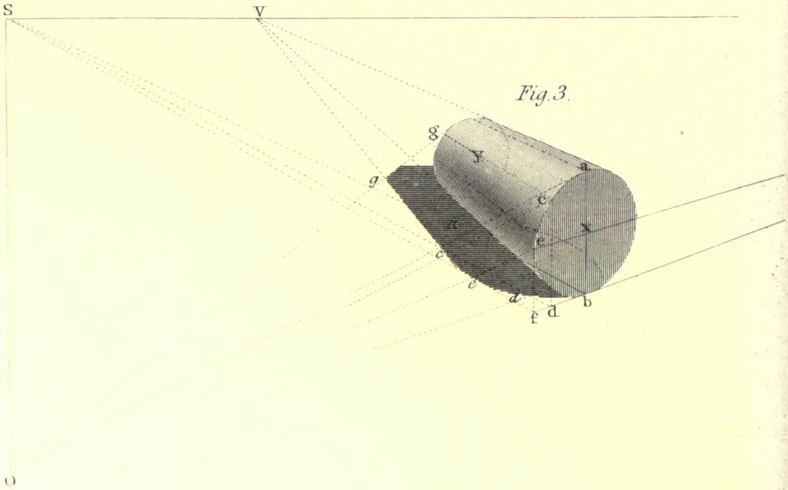


Fig. 3.

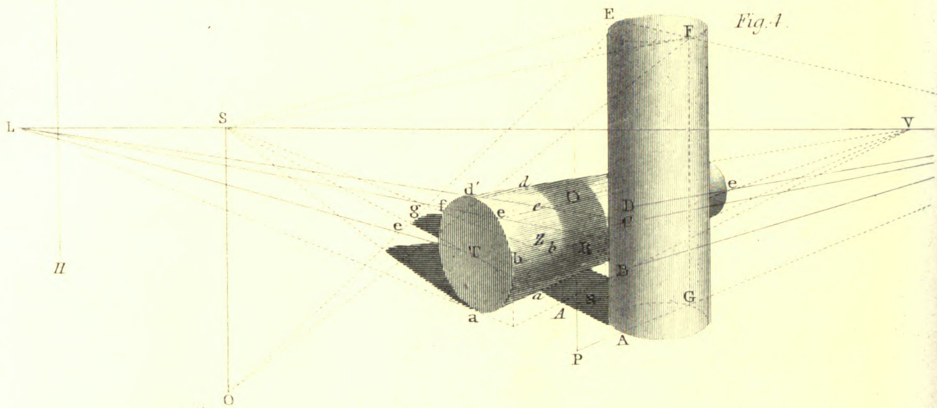


Fig. 4.

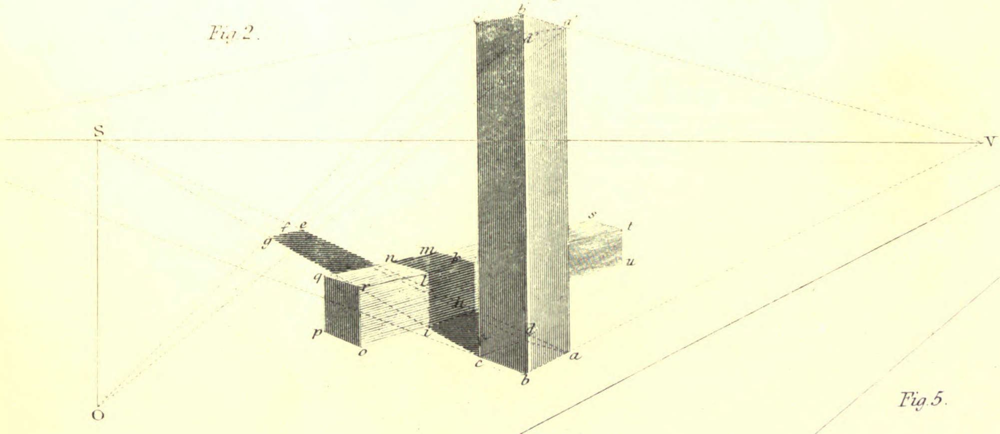


Fig. 2.

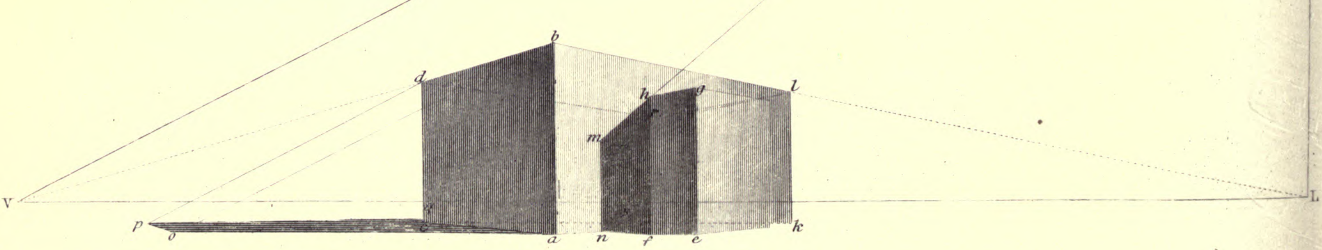


Fig. 5.

Drawn by M.A. Nicholson.

Engraved by

Join the vanishing point of the line to the vanishing point of lines perpendicular to the plane whose vanishing line is given, and the vanishing line of another plane will be obtained, in which is the original of the seat of the point, and the original of the line in projection; and, therefore, the intersection of the vanishing line given of the plane on which the seat of the line required to be drawn, and the vanishing line found, is the vanishing point of the seat of the line. Therefore, draw a straight line through the seat of the point given in projection, to the vanishing point found, and the line thus drawn will be the whole representation of the seat.

This proposition is evident, since the vanishing line of every plane perpendicular to the plane whose vanishing line is given, will pass through the vanishing point of lines perpendicular to that plane; and since the seat of the original line, on the original of the plane given, is formed by a plane passing through the original line perpendicular to the given plane intersecting therewith; therefore the vanishing line of this perpendicular plane will pass through the vanishing point of lines perpendicular to the original of the plane given; but when two points in a vanishing line are given, the whole of the vanishing line is given, being the straight line passing through these points.

A general knowledge of the shadows of lines upon planes in any position ought first to be acquired; but as the relation of lines and planes to the horizon is generally given, it will be necessary to find the relation of these lines and planes to each other; and here it will be proper to observe, that whatever may be the number of planes, the vanishing point of the sun's rays will remain unchangeable, or in the same position in respect of the first vanishing line, and will be common to all the different planes; but every different plane will have its own vanishing point for the seat of the sun's rays in that plane, and that vanishing point will be in the vanishing-line of that plane. As vertical and horizontal planes occur most frequently in practice, these will require particular attention.

Proposition II.—*Given the inclination of a plane to the plane of the picture, both being perpendicular to the original plane, and the seat and inclination of a straight line in the plane of the horizon; to determine the vanishing point of the seat of the line on the vertical plane, and the vanishing point of the line.*

Plate I. *Figure* 1.—Let No. 1, represent the vanishing plane, and No. 2, the plane of the picture. In the vanishing plane, No. 1, let v l be the vanishing line, e the point of sight, or place of the eye, A B the intersection of the original vertical plane, inclined to the plane of the picture in the angle A g l; and let A D be the seat of the line, as given in position, to the horizon: make the angle D A F equal to the inclination of the line to the plane of the horizon; draw D F perpendicular to A D, and D B perpendicular to A B; produce D B to K; make B K equal to D F, and join A K, which is the seat of the line on the vertical plane. Draw e *l* parallel to A B, and draw *l h* perpendicular to v *l*; in v *l* make *l m* equal to *l* e, and make the angle *l m h* equal to B A K; and *h* will be the vanishing point of the seat of the line. Draw e v parallel to D A, and v *i* perpendicular to v *l*; make v *n*, in the vanishing line, equal to v e; make the angle v *n i*, equal to the angle, D A F, which the original line makes with the plane of the horizon; and draw e ⊙ perpendicular to v l, meeting v l in ⊙. In the plane of the picture, No. 2, let V L be the vanishing line answering to v *l*, No. 1: in V L make choice of any convenient point, ⊙, for the centre of the picture: make ⊙ L equal to ⊙ *l*, No. 1, and ⊙ V equal to ⊙ v, No. 1; draw L H and V I perpendicular to V L; then H is the vanishing point of the seat of the line, and I the vanishing-point of the line itself.

The points H and I will be both on the same side of the vanishing line of the horizontal planes.

This problem is the same when the seat and altitude of a ray of the sun are given, with the inclination of a vertical plane to the plane of the picture; to find the vanishing point of a ray of light, and the vanishing point of the seat of the sun's rays.

When the sun is on the same side of the picture with the spectator, the vanishing point of the seat of the rays, and the vanishing point of the rays, will be below the vanishing line, V L; but when on the other side of the picture, the vanishing point of the rays, and the vanishing point of their seat, will be above V L.

Proposition III.—*To find the shadow of a rectangular prism upon the horizon on which it stands, and also upon another rectangular prism; the base of the prism which throws the shadow being in the same horizontal plane with a side of the prism on which the shadow is thrown.*

Figure 2.—Let O be the vanishing-point of the sun's rays, V S the vanishing-line of the horizontal plane on which the two prisms are placed, *a b c d* the base, and *a' b' c' d'* the top of the prism that throws the shadow. Then, because the edges of the prism stand parallel to the picture, they will have no vanishing point but at an infinite distance; thus the line O S, drawn from O, will be parallel to the edges *a a'*, *b b'*, *c c'*, *d d'*, of the erect prism, and will give the vanishing-point, S, of the shadows of *a a'*, *b b'*, *c c'*, *d d'*; therefore, draw *a* S, *d* S, *c* S; and *a'* O, *d'* O, *c'* O, cutting *a* S, *d* S, *c* S, at the points *e*, *f*, *g*; then will *d e f g c* be the shadow on the ground. Let *c* S and *d* S cut the edge of the prism, *o p q r s t u*, at *h* and *i*; draw *i l* and *h k* parallel to O S, cutting the upper edge, *r t*, at *k* and *l*; from the points *k* and *l* draw lines to S, cutting the farther edge, *q s*, at *m* and *n*; then *h k m n l i* will be the shadow upon the recumbent prism, *o p q s t u*.

Proposition IV.—*To find the shadow of a cylinder lying with its convex surface upon a horizontal plane.*

Figure 3.—Let X be one end of the cylinder, Y the other. To find the shadow of the end X upon the horizon, it must be observed, that no line which terminates two surfaces can throw a shadow upon a third, unless one of such two surfaces be in shade. We have, therefore, only to find the shadow of that part of the circumference of the end X, contained between the point of contact on the horizontal plane, and a tangent plane to the surface of the cylinder; and a sufficient number of points will be found by letting fall perpendiculars from as many points in the arc that throws the shadow, to meet the horizontal plane; then find the shadows of the upper extremities of these lines, which will be points in the curve. Or, find the whole ellipsis representing the shadow of the circumference of each end of the cylinder, and draw the line *c g*, to touch these two ellipses; then *d e c g* will be the shadow. To find the shadow of any point, c, in the edge of the end X; draw c d perpendicular to the horizon, meeting the horizon in d; also, draw d O and c S, cutting each other in *c*, then *c* is the shadow of c; in like manner, *e* will be found to be the shadow of e, and so on for as many points as may be necessary.

Proposition V.—*To find the shadow of one cylinder upon another. The cylinder which throws the shadow, and that on which the shadow is thrown, being placed, the former with its end, the latter with its convex surface, upon the same horizontal plane.*

The shadow of the cylinder, which stands upon its end on the horizon, is obtained by finding the shadows of the tops of as many straight lines on the convex surface as may be thought sufficient for the purpose, which will give the points f, g, e. The shadow of the cylinder, which is placed with its convex surface upon the horizon, is found in *Figure* 3. Let A E and G F be the lines of contact with a tangent plane to the point S, then the lines A E and G F will throw the shadow partly upon the horizon and partly upon the convex surface, Z, of the cylinder, which lies on the ground. It is, therefore, only necessary to find the sections of the cylindric surface Z, with the two planes of contact, S A E and S G F; for this purpose, produce the plane A G F E, and the end, T, of the recumbent cylinder, till they meet in P Q. This will be readily done as follows: produce G P, and from the vanishing-point, L, of the end T, of the recumbent cylinder, draw the line L A P, through the point a, and also draw P Q perpendicular to the vanishing-line V L; then P Q is the intersection of the plane passing through G F and A E, with the plane T. Let a *d'* be a vertical diameter from the point of contact, d', of the end T; draw L *d'* Q; then, in P Q take any number of intermediate points, R, S; draw R L, S L; also draw lines from S, R, Q, to the vanishing-point of A G and E F, cutting A E at B, C, D; let the lines from R, S, drawn to L, cut the end T at c, b: draw b V and c V; also draw B L and C L, cutting b V, c V at *b* and c; then *b* and c are points in the shadow. In the same manner, points in the other edge will be found, and the shadow completed.

PROPOSITION VI.—*To find the shadow of a building with a break.*

Figure 5.—Let V L be the vanishing-line of the horizon. V the vanishing-point of the horizontal lines represented by *a c* and *b d*, that form the end of the building, also of *e f*, *g h*, which represent the horizontal lines forming the sides of the break. Let the sun be supposed to be in the plane of the picture, or its rays parallel thereto, and let the planes *a b d c* and *e g h f* be in shade; and the plane *e g h f* will throw a shadow upon the plane *a b l k*, as the plane *a b d c* will also upon the horizon. As the sun's rays are parallel to the picture, they will have no vanishing-point, but still the rule will hold in this case also. Through the vanishing-point L, draw L M perpendicular to V L; then L M is the vanishing-line of the plane *a b l k*, on which the shadow is to be thrown; through V draw V M, parallel to the sun's rays, or make the angle L V M equal to the angle which the sun's rays make with the plane of the horizon. Thus M is the vanishing-point of the shadow of all lines vanishing in V, upon the plane *a b l k:* therefore, to find the shadow of the line *h g*, join M *h*, and produce it to *m;* and draw *g m* parallel to M V; then *m* will be the shadow of the point *g*, and *h m* of *h g*. Draw *m n* parallel to *g e*, and *m n* will be the shadow of *g e:* therefore *h m n f* will be the whole shadow of the plane *h g e f*, upon the plane *a b l k*. To find the shadow of the end *a b c d* upon the plane of the horizon: draw *a o* parallel to L V, and *b o* parallel to M V; then *a o* is the shadow of the vertical line A B: join *o* V, and draw *d p* parallel to M V, and *o p* is the shadow of *b d*: join *p* L, and draw *r q* parallel to M V, and *p q* will be the shadow of the line *d r*, not seen: join *s q*, or draw it parallel to L V; then *a o p q s* will be the shadow of the building upon the plane of the horizon.

Many more examples of shadows might be given; but if the principles here shown are understood, the artist will not be at a loss to find the shadow of any right-lined object whatever: for, to find the shadow of an object constituted by planes, and consequently terminated by straight lines, is no more than to find the shadow of those lines. If a circle be given, the circumference may be divided by parallel lines into parts, and the shadows of the points of division may be obtained by finding the shadows of the intercepted lines, and drawing a curve round their extremities. If it were required to find the shadows upon several planes, first find the shadow in the plane on which the object stands, and observe where the shadow meets the next plane; then, having the vanishing-line of this second plane, observe where the vanishing-line of the plane of shade cuts the vanishing-line of this second plane, and the point of intersection will be the vanishing-point of the shadow on the second plane.

The principles exhibited in the article PROJECTION, will apply equally to the representation of objects in perspective, particularly where the planes which throw the shadow intersect the plane on which the shadow is to be thrown; for by continuing the line that throws the shadow, and the intersection of the planes, to meet each other, the point where the shadow terminates is found; and therefore, if a point be given in the shadow, the direction of the shadow will be known. Thus, in the last example, suppose the line *a o* obtained: since the point *o* is the beginning of the shadow of the line *b d*, produce *a c* and *b d*, to meet in V; join *o* V and draw the ray of the sun, *d p;* then *o p* is the shadow of *b d:* produce *d r* and *c s* to meet in L, and join *p l;* draw the ray *r q* from *r*, and *p q* will be the shadow of *d r*, not seen.

PROPOSITION VII.—*To find the vanishing-line of a pole upon several planes.*

Plate II. *Figure* 1.—Let A B C D E F G H I K be the outline of a building, with a lean-to, or penthouse, D E N P O: V is the vanishing-point of all horizontal lines, in the gable, A B L I K, of the main house, and also of the gable, D M O C, of the penthouse; L^1 is the vanishing-point of all the horizontal lines in the parallel fronts, B F G L and D E N M; and as all vertical planes have vertical vanishing-lines, V R is the vanishing-line of the parallel gables, A B L I K and C D M O; L U the vanishing-line of the fronts, B F G L and D E N M; I L G H is the representation of the roof of the main building, and O M N P that of the penthouse.

Produce L I to meet V R, its vanishing-point, in S: draw S L^1, which will be the vanishing-line of the inclined plane L G H I, for S and L^1 are the vanishing-points of two lines in that plane: produce M O to meet V R in T, and draw T L^1; then T L^1 is the vanishing-line of the inclined plane M N P O of the roof of the penthouse, because T and L^1 are the vanishing-points of two lines in that plane.

Let W X be a pole resting upon the end of the house, in the same plane with the gable, A B L I K; and let Q be the vanishing-point of the sun's rays: produce the pole, X W, to meet V R in R; then R is the vanishing-point of the pole, or of the line that throws the shadow: therefore by drawing Q R, Q R will be the vanishing-line of the plane of shade, and let it cut V L^1, the vanishing-line of the horizon, in Y; and L^1 U, the vanishing-line of the vertical planes, B F G L and D E M N, of the walls, in U; V R, the vanishing-line of the gables, in R; S L^1, the vanishing-line of the main roof, in Z; and T L^1, the vanishing-line of the penthouse, in Z^1: all which does but prepare for drawing the shadow of the pole, W X, upon the horizontal plane and upon the building. Now produce A B to meet W X in X, then X will be the point where the pole rests upon the ground, or horizontal plane: draw X Y, cutting D E in *a;* draw U *a*, cutting D M in *b;* draw *b* R, cutting M O in *c;* draw *c* Z^1, cutting P O in *d;* draw U *d*, cutting G L at L; and draw L Z, cutting the ridge, I H, at *f;* then X *a b c d* L *f* will be the whole shadow of the pole.

For, since the shadow first begins at the foot of the pole, or line, in the plane of the horizon, and since the intersection of the vanishing-line of a plane on which the shadow is to be thrown, with the intersection of the vanishing-line of the plane of shade, gives the vanishing-line of the shadow upon that plane; Y becomes the intersection of the vanishing-line of the plane of shade with the vanishing-line of the horizon; therefore Y is the vanishing-point of the shadow of the line W X upon the plane of the horizon. The next plane on which the shadow is thrown is D E N M; now L U is the vanishing-line of the plane D E N M, and U is the point where the vanishing-line of the plane of shade cuts L^1 U; therefore U is the vanishing point of the shadow upon the plane D E M N. The next plane on which the shadow is projected is the plane C D M O: now V R is the vanishing-line of the plane C D M O, and it intersects the vanishing-line of the plane of shade in R; therefore R is the vanishing-point of the shadow upon the plane C D M O. The next surface on which the shadow is projected is the plane, M N P O, of the roof of the penthouse: now Z^1 is the intersection of the vanishing-line of the plane of shade with the vanishing-line T L^1 of the plane M N P O; therefore Z^1 is the vanishing-point of the shadow on the plane M N P O. The next surface on which the shadow is projected is the plane, B F G L, of the wall; but U has already been shown to be the vanishing-point of the shadow. The plane of the roof is the last surface on which the shadow is projected: now S L^1 is its vanishing-line, and it meets the vanishing-line of the plane of shade in Z, therefore Z is the vanishing-point of the shadow upon the roof.

In carrying the shadow of a line across several planes, it will not be surprising if some little inaccuracy takes place from the obliquity of intersections; it might be a great chance, whether, when the part of the shadow, *d* L, which falls upon the plane B F G L, is drawn from the vanishing-point, U, through the point *d*, it will meet the pole at L, as it ought to do. To remedy this, begin with the shadow, L *d*, and proceed in the reverse order, until it meets the line W X at X, which it must in principle, and will not be liable to vary much in practice.

The points which direct the shadows upon the several planes, might also be found by the methods shown in the article PROJECTION.

The following observations will be useful in the practice of shadows.

When a straight line, that throws a shadow, is parallel to the picture, it is then represented parallel to the original. In this case it has no vanishing-point; or, in other words, the vanishing-point of the line may be said to be at an infinite distance: and, therefore, instead of the vanishing-point of the line being joined to the vanishing-point of the sun's rays, draw a straight line from the vanishing-point of those rays parallel to the projection of the line which throws the shadow, and it will be the vanishing-line of the plane of shade; therefore the intersection of the vanishing-line of the plane of shade with the vanishing-line of the plane on which the shadow is to be thrown, will give the vanishing-point of the shadow on that plane, after the same analogy as lines which are inclined to the picture. This case is similar to that of the sun's rays being parallel to the picture: for here, also, the vanishing-point of the rays is at an infinite distance; but as the plane of shade will still have a vanishing-line, this line will be found by drawing a straight line through the vanishing-point of the line that throws the shadow parallel to the sun's rays, as shown in a former example.

Of shadows projected from a given point; as by the light of a candle or lamp.

It is evident, if the representation of the luminous point be given, with its seat upon any plane, together with the representation of any point in space, and its representation upon that plane, the shadow of the point will be found by drawing a straight line from the luminous point through the point in space, and by drawing another straight line from the seat of the luminous point through the seat of the point in space; and the intersection of the two lines thus drawn will represent the shadow of the point upon the plane. But when the relation of several planes represented in a picture, the representation of the light with its seat, and the representation of a point in space with its seat, are given, to project the shadow of the point on the other planes, other considerations become necessary.

Figure 2.—For this purpose, let A B C D be the inside of a room, consisting internally of the vertical planes A H, E I, F K, G C, and of the horizontal planes A E F G B and D H I K C: also, let L be the luminous point, and M its seat in the plane A E F G B. In order to form an idea of the point L, in respect of the other planes, it is necessary to have the intersection of a line drawn through L, in a given position with one of the planes. Thus, if it is known that the straight line L *a*, parallel to the picture, cuts the plane of the wall, B K, in the point *a*; the position of the point L to any of the other planes may be easily determined, as follows:

Through *a* draw *a b* parallel to the vanishing-line, N O, of the plane B K, cutting B G, the intersection of the planes B K and A G, in *b*; through *b* draw *b* M parallel to P Q, the vanishing-line of the floor, cutting A E, the intersection of the planes A G and A H, in *c*; also F E, the intersection of the planes A G and E I, in *d*. Draw *c* Q parallel to N O, the vanishing-line of the plane A H; and *d f* parallel to R S, the vanishing-line of the plane E I. Then, because the intersecting and vanishing-lines of any plane are parallel to each other, and because a line drawn parallel to the intersecting line is parallel to the picture; therefore the representations of all the lines, *a b*, *b c*, or *b d*, *c* Q, and *d f*, are all parallel to the picture, and in a plane passing through the luminous point L.

Figure 3.—Given the vanishing-lines, A B, C D, E F, of three planes, G H I K, L M N O, and M N I Q R, the common intersection, N O, of the planes G H I K and L M N O; also the intersections, N I, and M N, of the planes G H I K and L M N O with the plane M N I Q R; the representation, *a b*, of a line in the plane L M N O; the point of light, *c*; *c d*, a line parallel to the picture; and *d*, the point where it intersects the plane M N I Q R: to find the shadow of the line on the plane G H I K.

First, find the representation of a ray of light parallel to the picture, thus: draw *d e* parallel to A B, cutting M N at *e*; draw *e f* parallel to E F: then if *a b* be not parallel to *e f*, produce *b a* to *f*, and join *f c*, which is the ray required. Secondly, find the vanishing-line of a plane of shade passing through the line *a b*, and the ray *f c*, thus: produce *a b* to meet C D in D, which is the vanishing-point of *a b*; through D draw D F parallel to *f c*; and D F will be the vanishing-line of the plane required. And, lastly, find the shadow of *a b* upon the plane G H I K, thus: produce O N and *a b* to meet in *g*; from F, through *g*, draw the line F *h i*; and from the point of light, *c*, draw *c b h* and *c a i*; then *h i* will be the shadow of the line, as required.

For *d e* being parallel to A B, the vanishing-line of the plane M N I Q R, *d e* will be parallel to the picture; and since *e f* is drawn parallel to E F, the vanishing-line of the plane L M N O, *e f* will be parallel to the picture; and because *b a* meets *e f* in *f*, *f c* is a ray of light parallel to the picture, meeting the line *a b*; and because C D is the vanishing-line of the plane L M N O, and *a b* is in the plane L M N O, therefore the vanishing-point of *a b* is in C D, and consequently at D, where *a b* produced meets C D: and because D is the vanishing-point of *a b*, the vanishing-line of the plane of shade will pass through D parallel to *f c*; but F is the intersection of the vanishing-line of the plane of shade, with the vanishing-line E F of the plane G H I K, on which the shadow is projected, therefore F is the vanishing-point of the shadow on the plane G H I K; and because g is the intersection of $a\ b$ with the plane G H I K, the shadow will commence at g, and consequently drawing F $g\ h\ i$ gives the direction of the shadow; and, lastly, because c is the luminous point, the rays $c\ a\ i$ and $c\ b\ h$ will terminate the shadow.

As D would be the vanishing-point of all lines parallel to the original of $a\ b$ in the plane represented by L M N O; and as different representations could not meet the line $e\ f$ in the same point, the ray $c\ f$ will have different positions, as will consequently D F, which is drawn parallel thereto; and as the point D is stationary, the point F will be variable.

PROPOSITION VIII.—*Given the representation of three rectangular planes, forming a solid angle, the representation of a point of light, or candle, and the seat of the light on one of the planes; to find the seat of the light on the other two planes.*

Figure 4.—Let the three planes be A B C D, A B G F, A F E D. It is evident that every two adjoining planes have three edges parallel to each other, one common to both, which is their line of concourse; these edges will therefore vanish in a point, or be parallel to each other, according as the original planes are oblique or parallel to the picture; let the original planes be obliquely situated; therefore produce the sides C D, B A, G F, of the two adjoining planes A B C D, A B G F, and they will all meet in V, their vanishing-point; also produce the sides D E, A F, B G, of the two adjoining planes D A F E, F A B G, and they will meet in W, their vanishing-point; likewise produce the sides C B, D A, E F, and they will meet in X, their vanishing-point.

Let I be a luminous point, and S its seat in the plane A B C D: draw S X, cutting A B in a; draw a W, and draw I X, cutting a W, in S^1, then S^1 is the seat of the luminous point in the plane A B G F; draw S V, cutting A D in b; draw b W and I V, cutting each other in S^2, then S^2 is the seat of the luminous point in the plane A D E F.

Because the plane A B C D represents a rectangle, and V is the vanishing-point of the one side, and X that of the other; all the lines drawn to X will represent right angles with the lines which vanish in V; therefore S a and A B represent a right angle in the plane A B C D. For the same reason, $a\ S^1$ represents a right angle in the plane A B G F; and since the planes A B G F and A B C D are at right angles, the angle S a S^1 will represent a right angle; and because a S represents a perpendicular to A B, $a\ S^1$ and S I will represent parallel lines; and since I S^1 and S a have the same vanishing-point, X, the original of I S^1 is parallel to the original of S a; but S a represents a perpendicular to the plane A B G F, therefore I S^1 also represents a perpendicular to the plane A B G F; and because the point S^1 is in the plane A B G F, S^1 is the seat of the luminous point L, in the plane A B G F. In the same manner it may be shown that S^2 is the seat of the luminous point in the plane A D E F.

PROPOSITION IX.—*Given the representation, c d, of a line perpendicular to the original of the plane* A B C D, *and the vanishing-point,* W, *of the line, and the point, d, where the line meets the plane* A B C D, *a luminous point* I, *with its seat* S, *also upon the plane* A B C D; *to find the shadow of the line* C D *upon the said plane.*

Draw S d and I c to meet each other in e, then $d\ e$ will be the shadow of the line $c\ d$, as required. In the same manner, if $f\ g$ represent a line perpendicular to the plane A B G F, and g the point where it meets the plane A B G F, $g\ h$ will be the shadow of the line, by drawing I f and $S^1\ g$ to meet in h.

This method is general for any position of the original planes with respect to the picture; and this position of the planes in respect of each other, is that which most frequently occurs in practice.

Figure 5—Let A B C D be the inside of a room, showing five sides, one, E F G H, being parallel to the picture, and the other four perpendicular to it; C^1 being the centre of the picture.

Let L be the light of a candle, S its seat upon the floor; then to find the seat of the light on all the other four sides: through S draw $a\ b$ parallel to V L^1, the vanishing line of the horizon, cutting B F at a, and C G at b; draw $a\ S^1$ and $b\ S^2$ parallel to Y Z, the vanishing line of the two vertical planes; through L, the point of light, draw $S^1\ S^2$, then S^1 is the seat of the light in the plane A B F E, and S^2 the seat of the light in the plane C D H G. Produce C S to meet B C in c; draw $c\ d$ parallel to Z Y, and join d C^1; draw S S^3 parallel to Y Z; then S^3 is the seat of the light in the plane A E H D; let C S cut the line F G in e; draw $e\ S^4$ parallel to Z Y, cutting L C^1 in S^4, then S^4 will be the seat of the light on the plane E F G H. Then, to project a prism standing perpendicular to any of these planes, suppose that which stands on the floor: from the seat, S, draw S i, meeting C G in o; draw $o\ r$ parallel to Z Y, and draw the ray L $m\ r$; then r will be the shadow of the point m; draw S h, cutting C G in p; draw $p\ s$ parallel to Y Z, and draw L n, cutting $p\ s$ at s; then s is the shadow of the point n; also draw S g, meeting C G in q; draw $q\ t$ parallel to Z Y, and L k, meeting $q\ t$ at t; then t is the shadow of the point k; join $r\ s$ and $s\ t$, which will complete the whole shadow of the prism upon the floor, and on the wall.

The principle of finding the shadows of the prisms on the other sides, is the same, and will be obvious to inspection. The truth of the method has already been shown.

SHAFT, (from the Saxon *sceaft*,) that part of a column which, in the classic examples, may be denominated *the frustrum of a conoid*, situate between the base and capital; it is also called *the fust*, *trunk*, or *body of the column*.

By some architects, columns are diminished from one-third upwards; this occasions a very gouty appearance. Some architects and builders, however, have fallen into the contrary error, by making the sides of columns in a straight line from the base to the capital. Mr. Revely, in his Preface to the third volume of Stewart's *Athens*, expressly says, that all the columns he had seen in Greece were diminished with a gentle curve. The curve is so gentle, that the straight line, which is a tangent at the bottom of the shaft, is not parallel to the axis, but falls nearer to it at the top of the column than at the bottom. For the method of diminishing the shaft of a column, *see* COLUMN.

The method of drawing the shafts of columns upon paper in the most expeditious manner, will be a very useful addition to this article.

Figure 1.—*To represent a fluted column, the height of the column, its diameter at the bottom, and the ratio of the two diameters, being given.*

Let A B represent the height and axis of the column, produce A B to C, make A B + B C to B C in the ratio of the diameter at the base, to its diameter at the capital; draw a line through A, and another through B, at right angles to A B; set half the diameter of the column from A on each side of it, and divide the whole length of this line into parts representing the ratio of the flutes orthographically projected; from the points of division draw lines to C, to meet the line passing through B, and the lines thus drawn will represent the shaft of a column as fluted.

In this example A B + B C is to B C as 4 to 3, therefore the point C will be found by repeating A B four times from A to C.

Figures 1, 2, 3, 4, represent a range of columns, three of which are here supposed to be drawn by this or the fol-

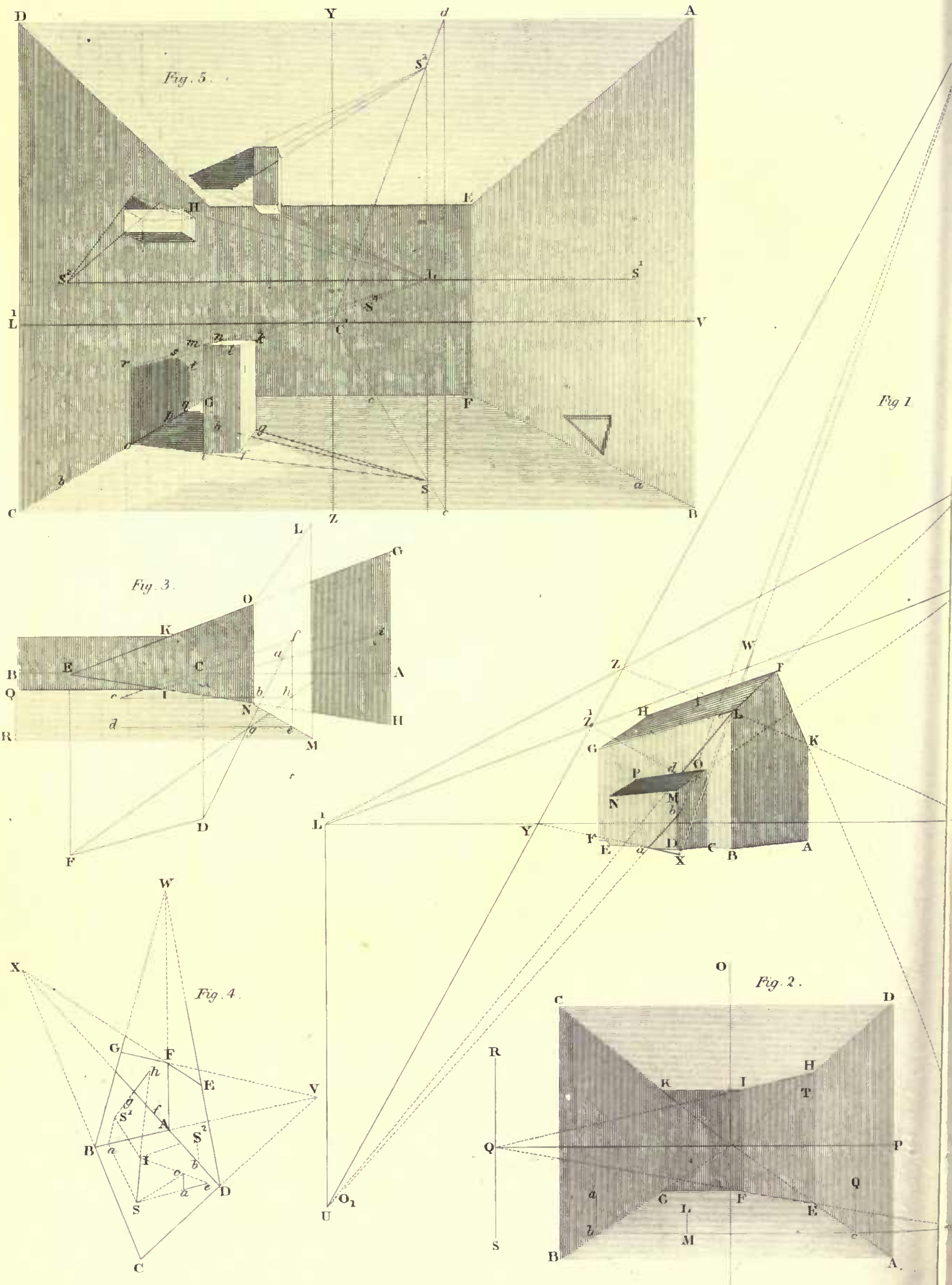
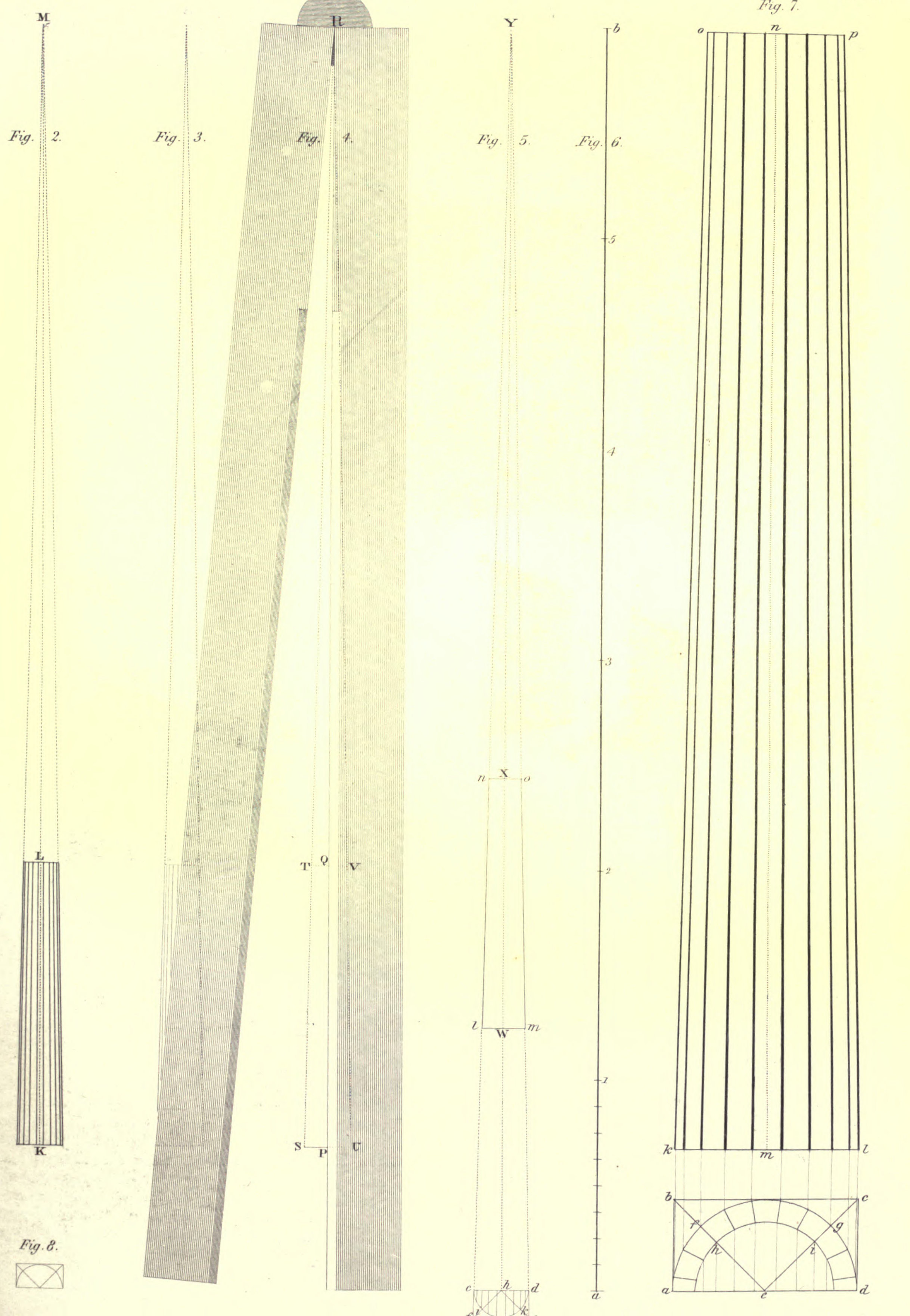


Fig. 5.
Fig. 3.
Fig. 4.
Fig 1
Fig. 2.

SHAFT.

PLATE I.



lowing means, which will be made sufficiently plain by reference to the plate:—

Suppose a compass joint-rule, as in *Figure* 4, bevelled on the upper sides of the inner edges; from R, the centre of the joint, set on the inner edge R P as many times the height of the shaft, P Q, as the diameter at the bottom contains the difference of the two diameters; lay the edge of the rule upon the axis, with the point P on the middle of the bottom diameter, S U; draw the other leg of the rule out to any convenient distance, while the marked leg is kept fast upon the axis; then pressing down the leg which is not over the work, move the marked leg to any point in S U, and draw a line by it, which will represent a flute; and all the other flutes may be drawn by repeating the operation. If the two lines which terminate the breadth of the column be continued downwards to D and G (*Figure* 1) at the waste edge of the paper, and also the axal line A B, the fluting may be projected by means of the semicircle D H I G; the line D G being supposed at right angles to A B. On D G describe a semicircle, and draw the tangent line E F parallel to D G, cutting C D and C G at E and F; then from E and F draw lines to the centre, cutting the circumference at H and I; divide the arc H I into five equal parts, set two on the arc H D, and two on the arc I G, which will be the points for the angles on the semi-circumference; and from these points draw lines to C between the diameters at A and B.

Figures 1, 2, 3, 4, are four equal shafts of columns, placed at equal distances, and supposed to constitute a part of the drawing of a Doric portico. The method of drawing the flutes to a point is most expeditiously performed by means of a joint-rule in the following manner:—Whatever be the intended height of the drawing of the shafts, set as many times that height from the centre of the joint on the inner edge of the rule, as the diameter of the column at the bottom contains the excess of that diameter above the upper diameters. Let us suppose that the upper diameter is to the lower as 3 to 4, as in the plate, then P Q being the representation of the height of the shaft, make R P on the edge of the rule equal to four times P Q; and lay the edge R P on the line representing the axis of the column; while R P is in this position, move the other leg out to any distance, and press upon it so as to make it stationary; then revolve the leg that was first stationary, and the point R will still keep its situation in the axis of the column, so that the moveable leg of the rule, moving round the centre of the joint, will answer the same purpose as a straight-edge moving round a pin; but it is much handier, for if the point falls on the paper, we shall have no occasion to prick it; and if the point extends beyond the surface of the board, we can still use the joint-rule with as much correctness as if the point were in the drawing board. *Figures* 5 and 6 exhibit a very correct modification of the principle just explained. Find the point V as above, extend the axal line V W to the bottom of the board at *h*, where the paper is intended to be cut off when the drawing is finished; then if the upper diameter is to be one-sixth less than the lower diameter, divide *a b*, *Figure* 6, of the same length into six equal parts, and if the column be eight diameters in height, divide the lower sixth part into eight equal parts; then on the point *h* describe the semicircle *c, i, k, d;* with a radius equal to one of these parts, circumscribe the rectangle *c, f, e, d*, and divide the flutes as before.

Figure 7 is the method of drawing the flutes by dividing both diameters in the same ratio as shown by the plan at the bottom.

SHAFT OF A CHIMNEY, the stone or brick turret above the roof. *See* CHIMNEY.

SHAFT OF A KING-POST, the prismatic part between the joggles.

SHAFTED IMPOST, an impost which has horizontal mouldings separating the archivolt from the pier, and where the section of the archivolt is different from that of the pier. Imposts are termed *shafted*, to distinguish them from *banded* imposts, in which the sections above and below the impost-moulding are alike, the shaft or pier seeming to pass through its capital.

SHAKE, or SHAKEN, a term applied to timber that is rent by drying too suddenly; in which the fissure, occasioned by too great a heat, is called *a shake*.

SHAKY, or SHAKEN, a natural defect in timber when full of splits, or clefts.

SHAM DOOR, in joinery, a panel of frame-work, that appears like a door, but does not open. Sham doors are necessary where corresponding symmetry is wanted; they are only wrought and moulded on the side next to the room. *See* DOOR.

SHANK, (from the Saxon *sceanca*,) a name given to the interstitial spaces between the channels of the triglyph, in the Doric frieze; they are sometimes called *the legs of the triglyph*, and by Vitruvius, *femur*.

SHEERS, a machine employed for lifting heavy and cumbrous materials, consisting of two lofty beams or legs of wood, placed vertically, united at the top, and set apart at the feet; a capstan rope passes over a pulley at the top, by means of which the weight is raised.

SHEET LEAD. *See* PLUMBERY.

SHELVES, (from the Saxon *cylf*,) boards fixed against a wall by their edges, and with their sides horizontally disposed, for the purpose of setting articles upon them. Shelves are supported below by brackets, which are either solid pieces, or small trusses; they are also supported at the ends with vertical pieces, called *standards*, or *cut standards*, where they are let in, and moulded on the edge.

SHIDES, or SHINGLES. *See* SHINGLES.

SHINGLES, (from the German *schindel*,) small boards, similar to slates, prepared for covering a building. They are of oak, either sawn or cleft, about an inch thick at one end, thinned off towards the nail or pin; about 4 inches broad, and from 8 to 12 inches in length. This kind of covering is very dear, and seldom used but for the roofs of churches and pyramidal steeples. Nevertheless, when a light covering is required, shingles may be employed with propriety. Before they are used, they should be well seasoned, by steeping them in water, and drying them in the sun. When made of good cleft oak, this covering is preferable to thatch.

SHINGLING, the act of covering a roof with shingles. In this operation, the building must be first covered all over with boards, after which the rest of the process is similar to that of slating. *See* SLATING.

SHOAR, or SHORE (from the Saxon *score*,) among builders, a prop, or oblique timber, acting as a brace upon the sides of a building, the wall itself performing the office of a post, and the ground that of a beam; so that the wall and ground are ties, while the post is a straining-piece. The upper ends of shores should always rest against that part of the wall into which a floor is inserted, in order to make a counter-resistance to its action. Both ends of shoars should rest upon plates, or beams, which, if firmly fixed, will form a much stronger resistance than could be obtained without them. They should be tightly trimmed between the plates, by driving wedges under their lower ends.

SHOAR, *Dead*, an upright piece of wood, built up in a wall, which has been cut or broken through in order to make some alteration in the building. The piece of wood thus enclosed, being necessary for the support of the superincumbent part during the making good of the wall, and left for the security of the work, which would otherwise be in danger of shrinking, and thereby occasion a fracture in the building.

SHOARING, *See* Shoar.

SHOE (from the Saxon *sceo* or *scoe*,) the part at the bottom of a water-trunk, or leaden pipe, for turning the course of the water.

SHOOT, a term expressive of the act of planing the edge of a board straight, and out of winding.

SHOOTING-BOARD, two boards fixed together, with their sides lapped upon each other, so as to form a rebate, for the purpose of making short joints, either oblique to the fibres, or in their direction. By this instrument, the joints of the panels of framing are made, as also those of the mitres of architraves, or the like.

SHOULDER OF A TENON, the transverse plane to the length of a piece of timber, from which the tenon projects. The shoulder should always be at right angles to the length; though it does not always lie in the same plane as here defined, but sometimes in different planes; as, in the binding-joists of a floor, the shoulder consists of two parallel planes, and one oblique plane. As this compound shoulder seldom or never takes place in anything else, it is simply defined, as above, by its form, in order that the meaning may be more easily comprehended; however, it may be generally defined thus: a shoulder is that which can only be resisted when the piece is pushed forwards in the same direction, supposing the piece, and that which resists it, to be polished.

SHOULDERING PIECES, *See* Brackets.

SHREAD HEAD, or Jerkin Head, *See* Jerkin Head.

SHREDINGS, (from the Saxon *screadan*.) In the roofs of many old buildings, the rafters were formed with a knee, or an obtuse exterior angle from the outside, at the bottom, the upper part, above the knee, being straight to the ridge; and the lower part, which rested upon the wall, either plumb, or nearly so: in order to support the slating between the knee and the face of the building, short slight pieces, as bearers, were fixed below, forming a straight line with the upper part of the rafters; these were called *shredings*, or *furring*, of which, the latter term is most commonly used. *See* Furrings.

SHRINE, a tomb in which the remains or relics of some saintly or noble persons were deposited. They are usually of a highly decorative character; fine examples exist in many of our cathedrals; there is one of Edward the Confessor in Westminster Abbey; it is of stone, and measures 15 feet in height; there is another of St. Frideswide at Oxford, but this is of wood, date about 1480.

The term is also applied to small caskets to contain relics, usually in the shape of rectangular boxes with coped coverings; they are mostly of metal, or overlaid with metal, and enriched with precious stones and other valuables.

SHRINKING, the contracting of a piece of timber in its breadth, by seasoning, hot weather, &c. The shrinking of a piece of timber is proportioned to its breadth. The length of timber is unalterable by seasoning, or any kind of weather; and hence it is, that, in unseasoned timber, mitred together, such as the architraves of doors and windows, the mitres are always close on the outside, and open towards the door, forming a wedge-like hollow on each side of the frame. It is to avoid the shrinking of timber, that narrow boards, called *battens*, are used in floors; and when the panels of a piece of framing are very broad, they will shrink so much as to fall out of the grooves.

SHUTTERS, the boards, or framed joinery, by which the aperture of a window is closed. *See* Joinery.

When shutters are made like boards, they are generally clamped, to keep them from warping; in this case they are seldom less than three-fourths of an inch thick. Framed shutters are either square, or moulded on one or both sides: in the latter case, the mouldings on the outside are made to correspond with the doors in the same room. Framed shutters are seldom less than $1\frac{1}{4}$ inch thick. The thickness of shutters generally depends upon the mouldings, which will occasion the panels to be more or less sunk, according as they are placed on one or both sides. Shutters are sometimes cut, that they may fold more readily together; in this case, they have usually a bead attached to one of them, most commonly to the upper one, by which means the ends of the styles are completely covered. Shutters should not be cut for wide windows, such as those of the Venetian kind; for, in consequence of the cutting, the hinges have less power to support them, and they become liable to go wrong. In shutters, the parts that are hinged together are called *folds*; and those folds that appear when the others are depressed within the boxings, are called *front shutters*; while those that are only seen when the aperture is shut, are called *back flaps*, or simply *flaps*: these, in ordinary works, are generally made thinner than the front shutters, and are mostly clamped, or square-framed. *See* Boxings of a Window, and Sash-Frame.

SIDE POSTS, a kind of truss-posts, placed in pairs, each particular post being disposed at the same distance as the rest from the middle of the truss. Their use is not only for the support of the principal-rafters, braces, crown or camber-beams, but also to hang the tie beam below. In extended roofs, two or three pairs of side-posts are employed, with frequently a middle-post, king-post, or crown-post besides, as the whole stress of the roof must be thrown either to the middle-post, or, in case there is no middle-post, to the two side-posts next the centre; these posts must then act upon each other by the intervention of struts. Posts of a roof are most commonly cut into joggles, which are butments, against which the shoulders of the tenons of the struts rest, and then the butments are at right-angles to the length of the struts. The side-posts of a truss, where the principal-rafters meet, sustain as many points, both in the principal-rafter and in the tie-beam, as they are themselves in number.

Side Timbers, a term used in Somersetshire for purlins. *See* Purlins.

Side Wavers, a term used in Lincolnshire for purlins. *See* Purlins.

SILL, or Cill, (from the Saxon *syl*,) in carpentry, a beam disposed in the lower part of walls, or upon the tops of joists, or under apertures. *Ground-sills* are those upon which the posts and superstructure of a timber building are raised. *Door* and *window sills*, sufficiently indicate their place by their names. The bottom pieces, on which quarter and truss partitions are raised, are called *sills*. Sills are either supported throughout their whole length, as in ground and window sills; or in many points, as those of partitions by joists.

SIMA. *See* Mouldings.

Sima-Inversa, *See* Mouldings.

Sima-Recta, *See* Mouldings.

Sima-Reversa, *See* Mouldings.

SIMILAR FIGURES, those of which the several angles are respectively equal, with the sides about the equal angles proportionate.

SINGLE FLOOR, *See* Naked Flooring.

Single Frame and Naked Floor, a floor with only one tier of joists.

Single-Hung, an expression applied to window-sashes, when only one of them is moveable in the same vertical plane.

Single-joist Floor, a floor without binding-joists.

Single Joists, those which are employed singly in a floor.

Single Measure, a term applied to a door that is square on both sides. It stands opposed to *double measure*, or moulded on both sides. When doors are moulded on one side, and square on the other, they are accounted measure and half.

SITE, the situation or locality of a building, &c.; the plot of ground on which it stands.

SKEW ARCH, an arch, the face of which stands obliquely with reference to the inner faces of the piers. *See* a description of a Skew Bridge in the article Stone Bridge.

SKEW-TABLE, a stone built at the bottom of a gable, to carry the raking coping above. The term is of rather doubtful application; and is employed also to signify the coping itself, consisting of either slabs or solid blocks, toothed into the masonry of the walls. It may be, perhaps, further applied to the sloping projecting rib of masonry frequently seen over gable-ends of roofs, where they abut against vertical walls of greater height than the apex of the roof; as when the roof of the nave of a church abuts against the side of a tower.

SKIRTINGS, or Skirting Boards, the narrow boards round the margin of a floor, forming a plinth for the base of the dado, or simply a plinth for the room itself, should there be no dado. The skirting is either scribed close to the floor, or let into it by a groove; in the former case, a fillet is put at the back of the skirting, to keep it firm.

SKIRTS, (from the Swedish *skiorte*,) one or more superficies, laid in plano, but which would cover a body without leaving any interstice, or without any one part lapping upon another. The four sides of a room, when laid out in this manner, are called *skirts;* as are also the sides of a roof laid out upon a plane.

SKREEN, (from the French *escran*) the instrument used by labourers in sifting earth, lime, &c., for making mortar.

SKYLIGHTS, glass frames placed in a roof with one or more inclined planes of glass. Skylights are either in one plane, as when placed in the inclined side of a roof, or pyramidal, conical, conoidal, spherical, or ellipsoidal, when they are placed above the roof; in which last cases the axis is perpendicular, with the vertex, of course, above. Plane skylights, the most common of all, are sometimes made to slide: the pyramidal have a more grand appearance; but the most dignified is the conical and conoidal, particularly when the ceiling below forms a dome. The spherical and ellipsoidal are less graceful than the conical or conoidal, and much more troublesome to execute. In all skylights, it is necessary that the joint between the bottom and the curb on which they rest, should be so secured as to prevent water running through. Plane skylights, not intended to open, are fixed in the following manner: the upper side of the skylight is bevelled all round the edge of the frame; a row of slates is fixed at the bottom of the aperture; the skylight is then fixed, and the other three sides covered in the process of slating.

SLAB, an outside plank, or board, sawn from the sides of a timber tree, and frequently of very unequal thickness.

The word is also employed to express a thin piece of marble, consisting of right angles and plane surfaces.

SLATE, a bluish fossil stone, very soft when dug out of the quarry, and thereby easily cut or sawed into long thin squares, to serve instead of tiles for the covering of houses, making tables, &c.

SLATING, is employed, in architecture, in sundry ways, the principal of which refers to the covering of the roofs of buildings, but such has been lately the perfection of working in slate, that it is now wrought and fitted into many useful utensils, as well as made up into balconies, chimney-pieces, casings to walls, skirtings, staircases, &c.

The slate principally used in London is brought from Wales, taken from quarries on Lord Penrhyn's estate at Bangor, Caernarvonshire, whence it is forwarded to all parts of the United Kingdom. There are also some other kinds of slate in use, the best sort of which is brought from Kendal, in Westmoreland, and is called *Westmoreland slate.* These are of a fine pale bluish-green colour, and are most esteemed by architects. They are not of a large size, but of good substance, and well calculated to give a neat appearance to a roof. The Scottish slate is nearly similar in size and quality to a slate from Wales called *ladies*, but they are very little sought after.

French slates, which were very much in use many years since, are small in size, most commonly not larger than the Welsh doubles, extremely thin, and, consequently, light; but their composition has been found to be not well adapted to this climate, where the atmosphere contains an excess of moisture. By analysis, this slate is ascertained to contain $\frac{1}{30}$ of manganese, besides other matters, such as iron, &c., the excessive affinity of which for oxygen soon shivers the stony portion of the slate, when employed as a covering, in this country.

Slaters class the Welsh slates after the following order and designations, *viz.*

	Ft.	Inch.		Ft.	Inch.
Doubles, average size,	1	1	by	0	6
Ladies,	1	3	by	0	8
Countesses,	1	8	by	0	10
Duchesses,	2	0	by	0	12
Welsh rags,	3	0	by	2	0
Queens,	3	0	by	2	0
Imperials,	2	6	by	2	0
Patent slate,	2	6	by	2	0

The *doubles*, so called from the smallness of their size, are made from fragments of the larger qualities as they are sorted.

The *ladies* are similarly obtained, but in pieces that will square up to the size of such description of slate.

Countesses are a gradation above *ladies;* and *duchesses* still larger.

The slate is extracted from the quarries, as other stony substances usually are, that is, by making perforations between its beds, into which gunpowder is placed and fused. This opens and divides the beds of the slate, which the quarrymen remove in blocks of very considerable size. These blocks are aftewards split by driving iron wedges between their layers, which separates them into scantlings of from four to nine inches in thickness, and as long and wide as may be required. Such of the scantling as is intended for exportation is sawn to the sizes ordered.

For the purpose of sawing the slate, the works in Wales are provided with abundance of ingenious machinery, some of which are put in motion by steam, and others by water, which keep in action a vast number of saws, all cutting the scantlings into pieces adapted to their several purposes.

The *imperial slating* for roofs is uncommonly neat; and is known by having its lower edge sawn, whereas all the other slates, used for covering, are chipped square on their edges only.

The *patent slate* is so called, among the slaters, from the mode adopted to lay it on roofs, as no patent was ever obtained for such a mode of slating. It was first brought into use by Mr. Wyatt, the architect. It allows of being laid on a rafter of much less elevation than any other kind of slate, and is considerably lighter by reason of the laps being less than is necessary for the common sort of slating. This slating was originally made from that description of slates known as *Welsh rags.* The slaters now frequently make it of imperials, which renders it still lighter, and somewhat neater in its appearance. Experiments have been instituted on the Westmoreland slate by the Bishop of Llandaff, from which there appears very little difference in its natural composition from that obtained from Wales.

Thirteen loads of the finest sort of Westmoreland slate will cover 42 square yards of roofing, and 18 loads of the coarsest will cover the same quantity; so that there is half a ton less weight put upon 42 square yards of roof when the finest sort of slate is used, than if it were covered with the coarsest kind, and the difference of expense is very trifling. It must be remarked, that it owes its lightness, not so much to any diversity in the component parts of the stone from which it is split, as to the thinness to which the workmen reduce it; it is therefore not so well calculated to resist violent winds as that which is heavier.

All the kinds before named partake of a similar mode of laying, in as far as refers to the *bonding* or *lap* of one portion of the slate over another. The lap of each joint is generally equal to *one-third* of the length of the slate, and the slater selects all the largest of the description about to be used, to be put on nearest the eaves. When the slates are brought from the quarry, they are not so square as to be immediately fit for use, but are prepared by cutting and sorting. The slater, to effect this, picks and examines the slate, observing which is its strongest and squarest end. He then, by holding the slate a little slanting upon, and projecting about an inch over the edge of a small block of wood, seating himself at the same time on something which is equal to it in height, cuts away straight one of its edges: next, with a slip of wood, he gauges the other edge parallel to the same, and cuts off that also; after which he turns it round and squares the end. The slate is so far prepared, excepting it be the turning of his tool round and pecking through it, on its opposite end, two small holes, which are made for the nails to enter when he lays it on the roof. All the quarry slates require this preparation from the slater. All slates are put on with nails or screws, and two, at least, are assigned to each slate. The copper and zinc nails, or iron nails tinned, are esteemed the best, as being less susceptible of oxidation than those of bare iron.

The preparation necessary for laying slates on roofs, consists in forming a base or floor for the slates to lie compactly and safely upon. For the *doubles* and *ladies*, boarding is essential, if it be expected to have a good water-proof covering. All that is required in the boarding for such slates is, that it be laid very even, with the joints close, the boards being properly secured by nailing them on the rafters.

When the boarding is ready, the slater examines it, and provides himself with several slips of wood, called *tilting fillets.* A tilting fillet is made about two inches and a half wide, three-quarters of an inch thick on one edge, and chamfered away to an arris on the other. These fillets he carefully lays and nails down all round the extreme edges of the roof, beginning with the hips, if any, and, if not, with the sides, eaves, and ridge. When these are all done, he prepares for laying the slates, and begins at the eaves first. For these he picks out all the largest slates, and places them regularly throughout, setting their lower edges to a line; after which, he secures them by nailing them down to the boarding. He then selects such slates as will form the bond to the under sides of the eaves. This part of the work consists in placing another row of slates under those which he has previously laid, so as to cross and cover all their joints; such slates are pushed up lightly under those which are above them, and are seldom nailed, but left dependent for their support on the weight of those above them, and their own weight on the boarding. The *countesses*, and all other descriptions of slates, when intended to be laid in the best manner, are also laid on boards. When the slater has finished the eaves, he strains a line on the face of its upper slates parallel to its outer edge, and as far from it as he deems sufficient for the lap of those slates which he intends shall form the next course, which is laid and nailed even with the line, and crossing the joints of the upper slates of the eaves. This lining and laying of the slates is continued till the slater gets up close to the ridge of the roof, observing throughout to cross the different joints by the slates he lays on, one above another. This method is uniformly followed in laying all the different kinds of slates, excepting what are called *the patent* slates, as will be hereafter explained. All the larger kinds of slate are found to lie firmly on what are called *battens*, in consequence of which they are frequently made use of for the sake of economy, being cheaper than the smaller slates laid on boarding. A batten consists of a narrow portion of deal wood, about two inches and a half, or three inches wide; three of which are commonly taken out of a deal. When *countesses* are to be laid on, battens of three-quarters of an inch in thickness will be an adequate substance for them; but for the larger and heavier kind of slates, inch battens will be necessary. When a roof is to be battened for slates, the slater himself is the best person to fix them, as they are not placed at a uniform distance from each other, but so as to suit the lengths of the slates; and as these vary as they approach the apex or ridge of the roof, it follows that the slater himself becomes the best judge where to fix the batten so as best to support the slates.

The patent slating, as it is called, consists in selecting the largest slates, and those also of uniform thickness. A roof to be covered with this kind of slate, requires that its *common* rafters be left loose upon their purlins, as they must be placed so as to suit the widths of the slates, it being necessary to have a rafter under every one of their meeting joints. Neither battening nor boarding is required for these slates, and the number of rafters will depend on the width of the slates; hence if they are of a large size, very few will be required, and of course a great saving in the timber takes place, besides giving much less weight upon the roof. The work of covering by this kind of slating is commenced, as before, at the eaves, but no crossing or bonding is wanted, the slates being uniformly laid, with each end reaching to the centre of a rafter, and they are all butted up to each other throughout the length of the roof; the rafters being so placed as to come regularly under the ends of two of the slates. When the eaves course is laid, the slates composing it are all screwed down by two or three strong inch-and-a-half screws at each of their ends into the rafters. A line is then strained about two inches below their upper edge, this being allowed as a lap for the next course of slates, which is laid on above, with its edges straight with the line; and this lining, laying with a lap, and screwing down, is continued till the roof is finally covered. The joints are then to be secured by filleting, which consists in covering all the meeting joints with fillets of slate, bedded in glazier's putty, and screwed down through the whole into the rafters. The fillets are usually about three inches wide, and as long as the slate they are intended to cover. They are solidly bedded in the putty and their intersecting joints are lapped as those of the slates; one screw is put in each lap, and one in the middle of the fillet. The fillets, being so laid, are neatly pointed up all round their edges with more putty; and are lastly painted over the colour of the slate. The hips and ridges of such slating are frequently covered by fillets in a similar way, and have a very neat effect. But lead is the best covering for *all* hips and ridges of roofs, and it is not much dearer than covering them by this mode.

The patent slating may be laid so as to be perfectly water-tight, with an elevation of the rafters considerably less than for any other slate or tile covering; a rise of two inches in each foot of the length of the rafter being deemed sufficient; and this, for a rafter of fifteen feet, would be only two feet six inches, a rise in the pitch of a roof, which, on any height from the ground, would be hardly perceived.

Slating is done also in several other ways, but the principles before explained embrace the most of them. Some workmen shape and lay their slates in a lozenge-form. This kind of work consists in getting all the slates to a uniform size, and the shape of a geometrical square; when laid on the roof, (which is always boarded for this work,) they are bonded and lapped as in common slating; observing only to let the elbow, or half of the square, appear above each slate that is under it, and to be regular in the courses all over the roof. One nail or screw only can be used for such slating, hence it soon becomes dilapidated. It is commonly employed in places near to the eye, or where particular neatness is required.

Slaters' tools consist of a few only, which are sometimes found by the master, and sometimes by the men. The tool, called the *saixe*, is composed of tempered iron, about sixteen inches in length, and two inches in width, somewhat bent at one end, with a beech handle at the other.—This instrument is not unlike a large knife, except that it has on its back a projecting piece of iron, about three inches in length, and drawn to a sharp point. With this tool, ground sharp, the slater chips or cuts all his slates to the required sizes.

The *ripper* is of iron, about the same length as the saixe, and very thin in its blade, which is one inch and three-quarters wide, tapered somewhat towards its top, where it has a round head projecting over the blade about half an inch on each side, and having also two little round notches in the two internal angles, at their intersection. At the handle-end of this tool there is a shoulder, which raises it up above the blade, and enables the workman to hold it firmly in his hand. The use of this tool is in repairs of old slating, as by forcing up its blade under the slates, the projecting head catches the nail in the little notch at its intersection, and enables the workman to pull it out, at the same time that it loosens the slate, and allows him to remove it, and insert another in its place.

The *slater's hammer* is somewhat different in shape from the common tool of that description; it is on the hammer, or driving part, about five inches in height, bent on the top a little back, and ground to a tolerably sharp point; its lower or flat end being about three-quarters of an inch in diameter, and quite round. On the side of the driving part is a small projection, with a notch in its centre, which is used as a claw to extract such nails as do not drive satisfactorily.

The *shaving-tool* is used for getting the slates to a smooth face for skirtings, floors of balconies, &c. It consists of an iron blade, sharpened at one of its ends like a chisel, and mortised through the centre of two round wooden handles, one of which is fixed at one end, and the other about the middle of the blade. The blade is about eleven inches long, and two inches wide; the handles are about ten inches long, so that they project four inches on each side of the blade. In using this tool the workman takes it in both his hands, placing one hand to each side of the handle in the middle of the blade, and allowing the other to press against both his wrists; in this manner he works away all the uneven parts from off the surface of the slate, and gets it to a smooth face.

The slater's other working tools consist of numerous *chisels* and *gouges*, together with *files* of all sizes, with which he finishes his slates for the better parts of his work into mouldings, and other forms.

The strength of slate is very great in comparison of any kind of freestone, as it is ascertained that a slate of one inch in thickness will support, in an horizontal position, as much in weight as five inches of Portland stone, similarly suspended. Hence, slates are now wrought and used for galleries and other purposes, where strength and lightness combined are essential.

Slates are also fashioned into chimney-pieces, partaking of the different varieties of labour applied to marble; but it is incapable of receiving a polish like it, except by japanning. It makes excellent skirtings of all descriptions, as well as casings to walls where dilapidations, or great wear and tear, are to be anticipated. It is capable of being fixed, for these purposes, with joints equally neat with wood, and may be painted over if required, to appear like it. Staircases may be executed in slate, and will have an effect not unlike to black marble.

Slaters' work is measured by the surveyors, as most artificers' work now usually is, and is afterwards reduced into squares, each square containing 100 feet superficial.

Slaters are allowed, in addition to the nett dimensions of their work, (when taking the measure of roofs,) six inches for all the eaves, and four inches for the hips; this allowance is made in consequence of the slates being used double in the former case, and for the waste in cutting away the sides of the slates to fit into the latter. Some of these eaves, for instance, when *rags* or *imperial slates* are used, require an additional allowance of nine inches for the eaves, such kind of slates being so much larger than the size of most of the other kinds now in use. All faced work in slate skirtings, staircases, galleries, &c. is charged by the foot superficial, without any addition. Chimney-pieces are made up and sold at per piece, by the masons.

The following Table of Comparisons will be found useful:

	Average gauge when laid	1200 will cover squares.	Weight per thousand of 1200 in tons.	Nails required to a square.	
				Iron, cast or wrought at per huudred.	Copper at per lb.
	Inches.				
Doubles	$5\frac{1}{2}$	$2\frac{1}{4}$	$\frac{3}{4}$	480	5
Ladies	7	$4\frac{1}{2}$	$1\frac{1}{4}$	280	3
Countesses........	10	$7\frac{1}{2}$	2	320	$3\frac{3}{4}$
Duchesses	11	10	3	254	$2\frac{3}{4}$

SLEEPERS, a row of horizontal timbers, disposed in a building, next to the ground, transversely, under walls, ground joists, or the boarding of a floor.

In bad foundations, sleepers are laid upon piles, and planked over, in order to support the incumbent walls. Sleepers under ground-joists, either lie upon the solid earth, or are supported in several places of their length by prop-stones: when in the former position, having no rows of timbers below, these ground-joists are themselves called *sleepers.* Old writers of practical architecture call those rafters which lie in the valley of a roof by the name of *sleepers;* but the word, applied in this sense, is quite antiquated: such rafters take the name of the place under which they are disposed, that is, they are called *valley rafters*, or, more simply, *valleys*.

SLIDING-RULE, a rule constructed with logarithmic lines, formed upon a slip of wood, brass, or ivory, inserted in a groove, in a rule, made to slide longitudinally therein, so that by means of another scale upon the rule itself, the contents of a surface, or solid, may be known. This rule has already been described under the article CARPENTER'S RULE: but as no examples of its use are given under that head, we shall here supply them. To make the matter more intelligible, we shall here state that all squares are to be found upon C, the side, and all roots upon D, the scale adjoining the slide next to the folding-joint; then, whatever value is put on the 10 on D, the value on C will be the square of that on D. A mean proportional, or root, or given side, is to be found on D. The line C contains squares, lengths, and contents of solids. In finding a mean proportional, set the least number on C to the same on D, then against the greater, on the side, stands the mean on D.

EXAMPLE 1. *To multiply numbers together, as* 12 *and* 16.—Set 1 on B, to the Multiplier (12) on A; then against the multiplicand (16) on B, stands the product (192) on A.

EXAMPLE 2. *To find the product of* 35 *and* 19.—Set 1 on B, to the multiplicand (35) on A; then, because 19 on B runs beyond the rule, I look for 1.9 on B, and against it, on A, I find 66.5; but the real multiplier was divided by 10, therefore the product 66.5 must be multiplied by 10, which is done by taking away the decimal point, so the product is 665.

EXAMPLE 3. *To divide one number by another, as* 360 *by* 12.—Set the divisor (12) on A, to 1 on B; then against the dividend (360) on A, stands the quotient (30) on B.

EXAMPLE 4. *To divide* 7680 *by* 24.—Set the divisor (24) on A, to 1 on B; then because 7680 is not contained on A I look for 768 on A, and against it I find 32 on B, the quotient; but because one-tenth of the dividend was taken to make it fall within the compass of the scale A, the quotient must be multiplied by 10, which gives 320.

EXAMPLE 5. *To square any number, as* 25.—Set 1 upon C to 10 upon D. Then observe, that if you call the 10 upon D 1, the 1 on C will be 1; if the 10 on D be called 10, then the 1 on C will be 100; if the 10 on D be called 100, then the 1 on C will be 10,000, &c. This being well understood, it cannot escape notice, that against every number on D stands its square on C.

Thus, against 25 stands 625
against 30 stands 900
against 35 stands 1225
against 40 stands 1600

Reckoning the 10 on D to be 10.

EXAMPLE 6. *To extract the square root of a number.*—Fix the slider exactly as in the preceding example, and estimate the value of the lines D and C in the same manner; then against every number found on C, stands its square root on D.

EXAMPLE 7. *To find a mean proportional between two given numbers, as* 9 *and* 25.—Set the one number (9) on C, to the same (9) on D; then against 25 on C, stands 15 on D, the mean proportional sought.

For, 1 : 15 : : 15 : 25.

EXAMPLE 7. *To find the mean proportional between* 29 *and* 430.—Set 29 on C to 29 on D; and then 430 on C will either fall beyond the scale D, or it will not be contained on C. Therefore take the 100th part of it, and look for 4.3 on C, and against it on D stands 11.2, which being multiplied by 10, will be 112, the mean proportional required.

SLIT DEAL, a name for inch-and-quarter-inch deal cut into two leaves, or made into two boards.

SMOOTHING PLANE. *See* PLANE.

SNACKET, a local term for a kind of hasp for a casement.

SNIPE'S-BILL, a plane with a sharp arris for getting out the quirks of mouldings.

SOCKET-CHISEL, a strong chisel, used by carpenters, for mortising; used by the percussive blows of a mallet.

SOCLE, or ZOCLE, (from the Latin, *soccus*) a square piece, of less height than its horizontal dimension, serving to raise pedestals, or to support vases, and other ornaments. The socle is sometimes continued round a building, or an entire part of a building. It has neither base nor cornice.

SOFFITA, SOFFIT, or SOFIT, in architecture, any timber ceiling formed of cross-beams, or flying cornices, the square compartments, or panels of which, are enriched with sculpture, painting, or gilding.

The word is Italian, and signifies the same with the Latin *lacunar* and *laquear;* with this difference, that *lacunar* is used for any ceiling with square hollow panels, called *lacus;* and *laquear* for compartments interlaced with platbands, after the manner of *knots*, or *laquei.* Such are those in the basilicas and palaces of Italy, and in the apartments of the Luxemburg at Paris.

SOFFITA, or SOFFIT, is also used for the underside of the corona, or larmier, which the ancients called *lacunar*, the French denominate *plafond*, and we, usually, *the drip*.

SOFFITS, the under sides of the heads of apertures, or the parts of mouldings which may be projected upon a horizontal plane, by lines perpendicular from all points of the mouldings upon that plane. Several methods have already been described, under the article ENVELOPE. What is proposed under the present head, is to show the methods adopted by early writers, not with a view of exposing their errors, but in order to guard the student against erroneous principles.

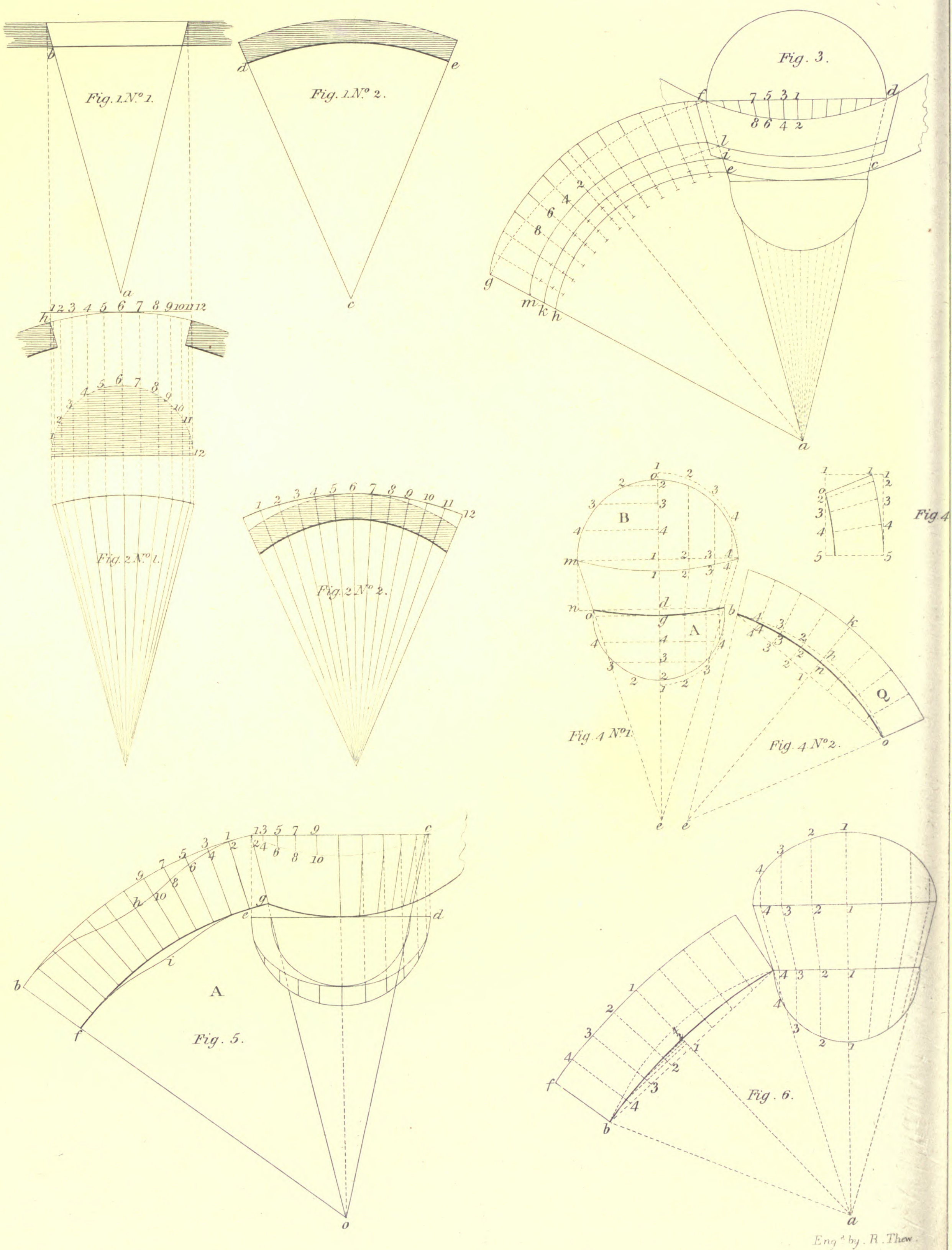
Figure 1, No. 1 and 2, as also *Figure* 2, No. 1 and 2, are from Swan's *British Architect, Plate* I.—"*Figure* 1 shows the opening of a window in a straight wall: draw the lines, ranging with the splay of the jambs; where these meet, s at *a*, is the length of the radius for drawing the curvature of the soffit; then take the distance *a b*, transfer it from *c* to *d*, in *Figure* 2; then set your compasses in *c*, and draw the circular line *e d;* then set on the width of your soffit, and draw the external line; this, when bent to a semicircle, will range along with each part of the straight wall.

"*Figure* 2 represents the opening of a window, of the same width as the former, in a circular wall. The shadowed semicircle above (*Figure* 2, No. 1) shows the opening of the arch. The arch-line may be divided into any number of parts, as here, into twelve. Draw lines perpendicular from the base-line, through all these divisions of the line *h;* then, in *Figure* 2, No. 2, draw a circular line, as for a straight wall; and divide it into the same number of parts as the arch-line above *Figure* 2; then take the distances from the line *h* to the circular wall, and set them from the outside line in *Figure* 2, No. 2, as at 1, 2, 3, &c. to 12; then you will have the true curvature of your soffit, which, when bent to a semicircle, will, in every part, agree with a circular wall."

The following are from the *Carpenters' and Joiners' Repository*, by William Pain:

"*Figure* 3 is a circular soffit in flewing jambs. Draw the flewing of the jambs, *c d* and *e f*, to meet at the point *a;* then draw the arch *d f*, and divide the said arch into any

SOFFITS.



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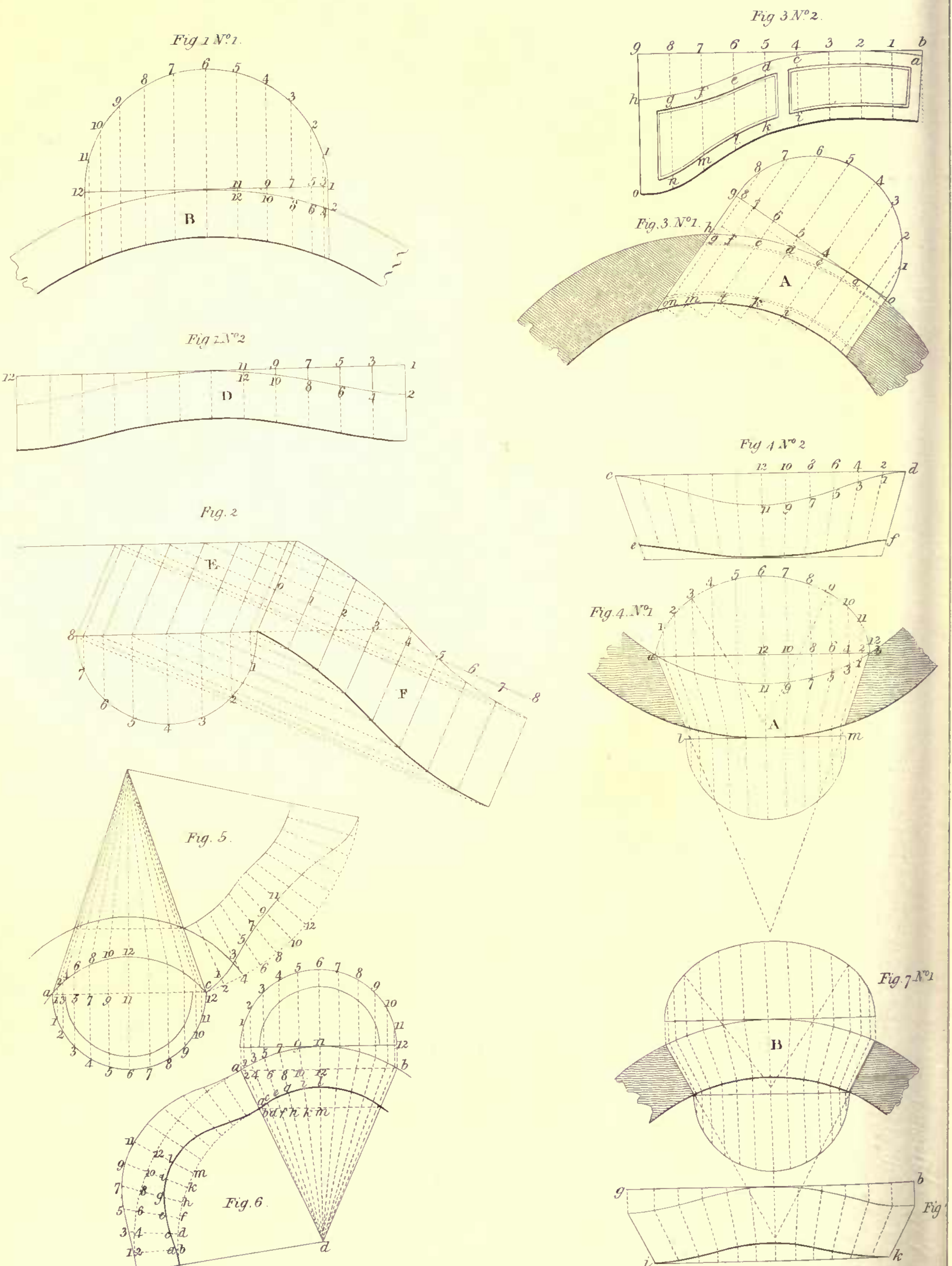
SOFFITS



Eng^d by. R. Thew.

number of equal parts, the more the truer the work, and run these parts on the dotted arch-line figure; then draw a line from *a* to *g*, which is the soffit stretched out; then draw a dotted line from the centre, *a*, the parts of the arch-line, stretched out far enough to receive the parts taken from the chord-line to the inside of the wall, and set them on the soffit, stretched out, as 1, 2, 3, 4, 5, 6, 7, 8, and so on; which will give the edge of the soffit.

"*Figure* 5.—A is a circular soffit in a circular wall, which is flewing on the jambs, and square at top; which makes the soffit winding as well as flewing. Draw the flewing of the jambs till they meet at *o*. The outside-arch is a semicircle, the inside-arch a semi-ellipsis. On the transverse diameter draw the plan of the wall, and the chord-line *e d*, equal to the opening on the inside 1 *c;* then, on the chord-line, *e d*, draw the semicircle, whose diameter is equal to *e d;* then, on the same chord-line, draw the lesser semicircle to the outside opening; then draw the ellipsis, *e d*, whose height is exactly equal to the height of the lesser semicircle; then divide the greater semicircle into a number of equal parts, and draw dotted lines from these parts to the inside curve of the wall; then apply a rule from the point *o*, to where those lines meet the inside of the wall, and draw the black lines across the plan of the wall, which will give the width of the soffit at those places; then draw, with the centre *o*, the two arch-lines 1 *b*, *f g*, and on the arch 1 *b*, run the parts on the great circle; and, from the centre, *o*, to these parts, draw the black lines across the soffit, stretched out, as 1, 3, 5, 7, 9; then take off the parts between the great semicircle and the ellipsis, and set them on the lines drawn across the soffit, stretched out, as 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and trace through these points, which will give the inside of the soffit; then take the width of the plan on those black lines, and set it on the soffit, stretched out, will give the line *g i f*, which is the width of the soffit."

The following are taken from the *British Palladio:*—

"*Figure* 4 is a circular flewing soffit, in a circular wall: continue the flewing of the jambs, till they meet at *e;* then take the radius, *e o*, and draw the arch-line *b o;* then divide the greater and lesser arch into the same number of parts, as here into 8; this will do for a straight wall: as this plan flews circular, take half the distance of the chord-line of the lesser arch in the compasses, and strike the dotted arch which divide into four parts; then set them on the chord-line of *b o*, as 1, 2, 3, 4, and draw lines from them to the arch-line stretched out parallel to *e* 1; then take *d g*, the distance of the chord-line of the plan and the curve, and set it from *h* to *n*, on the line *k e;* then set the distances, 2, 3, 4, of the chord-line and curve-line, and set from the arch-line stretched out on the parallel lines, 2, 3, 4; trace through those points from *b* to *n*, and you have half the edge of the soffit. To get the breadth, make a section of the arch, as on the right of *Figure* 4, No. 1; draw the perpendicular lines, 1 5, 1 5, the distances of *m o* on the plan; then take the distances *o*, 2, 3, 4, set them on the perpendicular line to the right, as marked from 1 to 2, 3, 4, 5, at right angles, the distances from the chord-line of the great arch, 1 1, 2 2, 3 3, 4 4, trace through them, and you have one side of this section; for the smaller arch, proceed as before, and on the other perpendicular line, 5 1, of the distances, as figured, 5, 4, 3, 2, 0; from 0 to 1 draw the flewing line of the arch, at the crown; take that distance, and set it from *n* to *k* on the soffit; also, to the perpendicular line on the side of the plan, *m*, *n*, set the compasses in *m*, and strike out the side of the flew to *n;* divide the difference of the line 0 1, from the section to *n*, into as many parts as the great arch; then set off those parts with a small curve, respectively, from 2, 3, 4, 6, on the soffit; then with the parts 1, 2, 3, 4, on the greater dotted arch, cross them from *k;* trace through them, and you have half the soffit; mark them to the other side, and the soffit is complete.

"*Figure* 6 is a circular flewing and winding soffit, in a straight wall. Continue the flewing of the jambs till they meet at *a;* then draw the arch-line *b c*, and make the chords equal to the circumference of the lesser arch, on which set the parts it is divided into, 1, 2, 3, 4; divide the distance of the chord from the arch into five parts; draw a line from 3 to *b*, and mark where it cuts the perpendicular 4 at *d;* draw a line from *d* to 1, parallel to the chord-line; divide 1 2 into four parts; from two of them draw a line parallel to 1 *d;* mark where it cuts the perpendicular of 3, on the chord-line at *e;* draw another parallel line from the third mark, and mark its crossing the perpendicular of 2, on the chord-line at *h;* trace through the points *b*, *d*, *e*, *h*, 2, this gives one side of the soffit, then take the ordinates across the plan, 1 1, 2 2, 3 3, 4 4, and the side of the flew *a f*, and set them from 2, *h*, *e*, *d*, *b;* then take the parts 1, 2, 3, 4, of the greater arch, and set them from 1 to 2, 3, 4, *f;* trace through them, and get the other side; set off these; measure to the other half, and complete the soffit."

Plate II. *Figure* 1.—A soffit, from the *Practical House Carpenter*. No. 1, is the plan and section of the centre. No. 2, is the covering extended in plano. The author describes it thus: "*Figure* B the plan of a circular wall, wherein a circular door, or window, is to be fixed; to make a soffit to fit or stand on the plan, as *Figure* D; draw the base-line of the arch, or soffit, to touch the bow of the wall; divide the arch-line into twelve parts, and drop them down to the plan across it; then stretch out the arch, as 1 to 12, and draw the divisions at right angles from it; then take them from the base-line to the wall, as 1, 2, 3, 4, &c., and transfer them on the parts of the line stretched out, will give the edge of the soffit D."

Figure 2.—A cylindrical soffit, cutting obliquely through a straight wall, from the *Practical House Carpenter*. The author describes it thus: "*Figure* E is a soffit in a straight wall on flewing jambs: F the soffit stretched out; stretch out the arch, as *o* to 8, and draw lines from those divisions parallel with the jambs; then draw the lines from the divisions on each side of the plan; the angle of meeting will give the edge of the soffit." This description is imperfect: for the true method, see the article ENVELOPE.

Figure 3.—A cylindrical soffit in a circular wall, from Pain's *Practical Builder*. The author describes it thus: "*Figure* A is a circular wall, which has a door or window, that stands flewing. Because the jambs do not stand at right angles with the diameter of the circle, find the curve-line of the soffit in this case; draw the chord-line or base-line, of the arch, *o* 9, at right angles with the jambs *o*, *h*, to touch the arch of the wall at *a*, and divide the arch into equal parts, and drop them to the wall; then take off the distances *h g*, 8, 9, 7, *f*, 6, *e*, &c., and put them on the arch stretched out, gives the edge of the soffit." It is singular, that this method should be true, while the former, which is more simple, is false.

Figure 4.—A cono-euneoidal soffit in a circular wall. No. 1 is the plan and sections of the centre: No. 2, the soffit stretched out.

Figure 5.—A conical soffit in a cylindrical wall, where the aperture expands towards the concave surface of the wall.

Figure 6.—A conical soffit in a circular wall, where the aperture expands towards the convex surface of the wall.

Figure 7.—A cono-euneoidal soffit in a circular wall, where the aperture expands towards the convex surface of the wall.

These *Figures*, viz., 4, 5, 6, 7, are from Pain's *Golden Rule*. The principles upon which they are founded are erroneous: see the article ENVELOPE; where are given correct methods for *Figures* 5 and 6, and very near approximations for *Figures* 4 and 7.

SOILS, an obsolete pronunciation for the sills of a window. *See* SILL.

SOILS, in roofing, in Westmoreland, are what are generally denominated in London, PRINCIPAL RAFTERS, which see.

SOLDERING, the method of uniting two or more metals by partial fusion. The union is effected by an alloy or solder, of greater fusibility than the metals to be united.

SOLID, (from the Latin, *solidus*, compact,) in geometry, a magnitude of three dimensions, extended in length, breadth, and thickness.

A solid is terminated, or contained, under one or more plain surfaces, as a surface is under one or more lines. From the circumstances of the terminating lines, solids are divided into *regular* and *irregular*.

Regular solids are terminated by equal and similar planes, so that the apex of their solid angles may be inscribed in a sphere. Under this class come the DODECAHEDRON, the ICOSAHEDRON, the OCTAHEDRON, and the TETRAHEDRON, or CUBE. See those articles.

SOLID ANGLE, an angle formed by three or more plane angles meeting in a point.

The sum of all the plane angles constituting a solid angle, is always less than 360°; otherwise they would constitute the plane of a circle, and not a solid.

If the apex of a solid angle be supposed in the centre of a sphere, the measure of the solid angle is the space intercepted upon the surface of the sphere by the planes of such angle.

Hence the comparison of solid angles is easily effected: for since the areas of spherical triangles are measured by the excess of the sums of their angles, each above two right angles, and the areas of spherical polygons of n sides by the excess of the sum of their angles above $(2\,n—4)$ right angles; it follows, that the magnitude of a trilateral solid angle will be measured by the excess of the sum of three angles above $(2.3—4=2)$ above two right angles; and the magnitude of solid angles, formed by n bounding planes, will be measured by the excess of the sum of the angles of inclination of the several planes above $(2\,n—4)$ right angles.

In all cases, the maximum limit of solid angles will be the plane, towards which various planes determining such angles approach, as they diverge farther from each other about the same summit; the same as a right line is the maximum limit of plane angles, being formed by the two boundary lines, when they make an angle of 180°. The maximum limit of solid angles is measured by the surface of the hemisphere, in like manner as the maximum limit of plane angles is measured by the arc of a semicircle.

The solid right angle is $\frac{1}{4}=(\frac{1}{2})^3$ of the maximum solid angle; while the plane right angle is half the maximum plane angle.

SOLID SHOOT. *See* WATER SHOOT.

SOLIVE, (French,) among carpenters, a joist, rafter, or piece of wood, either slit or sawed, with which the builders lay their ceilings. This word, though generally found in builders' dictionaries, is not used by English carpenters.

SORTANT ANGLE, the same as SALIENT ANGLE, which see.

SOSTRATUS, in biography, the most eminent architect of his time, was a native of Cnidos, in Lesser Asia, the son of Dexiphanes, also an architect, who flourished in the third century before the Christian æra. The high patronage he met with, caused him to be denominated *the friend of kings*. He was particularly in favour with Ptolemy Philadelphus, sovereign of Egypt, and is celebrated in history for the terraces, supported on arcades, with which he adorned his native city. He also built the celebrated lighthouse on the island of Pharos, opposite to Alexandria, which was reckoned among the wonders of the world; and, by a crafty device, he transmitted his name to posterity, in lieu of that of his patron. Being ordered to engrave upon the tower an inscription to the following effect: "King Ptolemy to the gods, the saviours, for the benefit of sailors;" instead of the king's name, he substituted his own, and then filling up the letters with mortar, he painted upon it as he had been directed; but in process of time, the mortar wearing out, the original engraving appeared, and the inscription ran, "Sostratus, of Cnidos, the son of Dexiphanes, to the gods, the saviours, for the benefit of sailors;" which remained as long as the tower stood.

SOUFFLOT, JAMES GERMAIN, an eminent architect, born, in 1714, at Irancy, near Auxerre. His father, an *avocat* of the parliament, destined him for his own profession, and sent him, while very young, to Paris for education; but preferring the science of architecture, he was for some time employed in that art at Lyons, whence he repaired to Italy, for improvement, and, on his return to France, was admitted one of the king's pensioners. It being resolved that several public buildings should be erected at Lyons, he was recommended to undertake part of the work, by the director of the French academy at Rome; and the construction of the Exchange and the Hospital was committed to him. The noble simplicity of the Hospital, together with its excellent adaptation to the object for which it was intended, were universally admired, and raised his reputation as an artist. After this, he was employed to build the Concert-Room and Theatre of the same city. He next travelled again into Italy, and on his return, settled at Paris, where he was successively made comptroller of the buildings at Marly and the Tuilleries, member of the academies of architecture and painting, knight of St. Michael, and intendant of the royal buildings. In 1757, he laid the foundation of the church of St. Geneviève, of which he only finished the portal, the nave, and the towers. In this business, he subjected himself to some severe criticism, especially with respect to the possibility of erecting the intended dome upon the basis designed for it; though some exact calculations justified his plan. The criticisms and unfriendly remarks of his rivals were more than his temper, naturally irritable, could bear; and he died partly of chagrin, in the year 1780, at the age of 67. Besides the public works already mentioned, he executed many others, which display the powers of a great genius; and after his death, M. Dumont, professor of architecture, published a book of designs, which he had left behind him, under the title of *Elévations et Coupes de quelques Edifices de France et d'Italie, désignées par feu M. Soufflot, Architect du Roi, et gravées.*

Though Soufflot was rough and hasty in his manners, he was kind and friendly, whence he obtained the name of *Le Bourru Bienfaisant.*

SOUND-BOARD, the same as a canopy or type over a pulpit, used for the purpose of increasing the sound by reflection.

SOUND-BOARDING, in floors, short boards placed transversely between the joists, and supported by fillets, fixed to the sides of the latter, for holding the pugging, which is any substance that will prevent the transmission of sound from one story to another. The narrower the sound-boards, the better. The fillets, on which the sound-boards rest, may be about three-quarters of an inch thick, and

SPANDREL BRACKETING

ANGLE BRACKETS

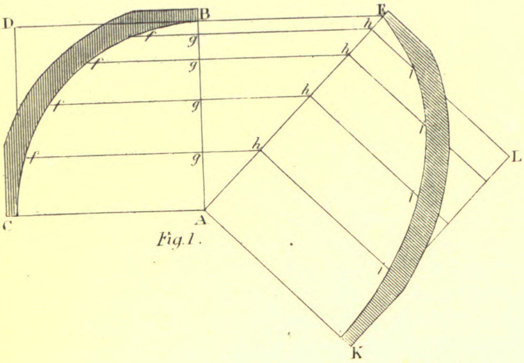


Fig. 1.

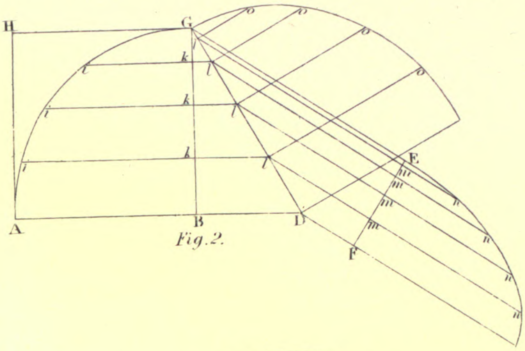


Fig. 2.

SPANDREL BRACKETS

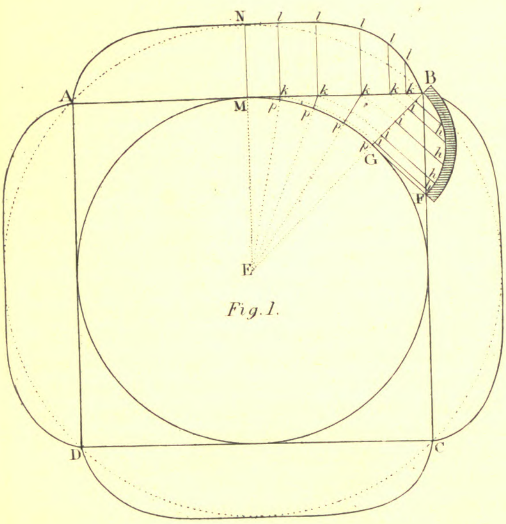
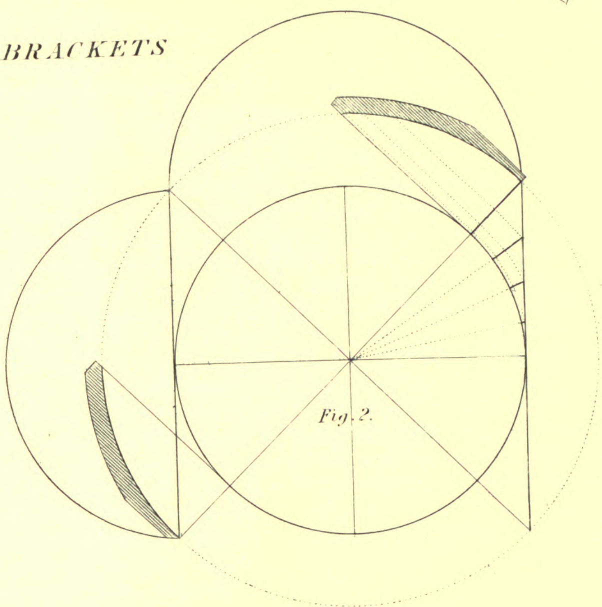


Fig. 1.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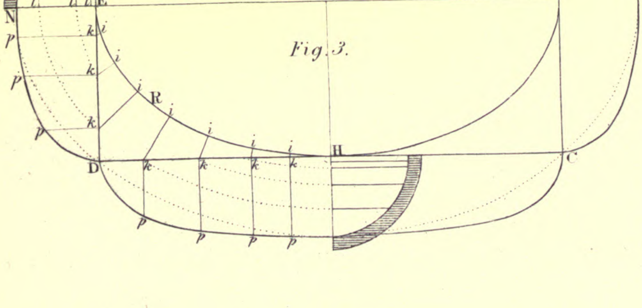


Fig. 3.

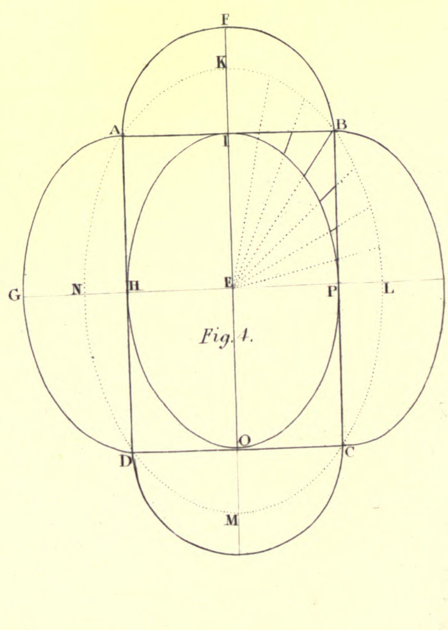


Fig. 4.

Drawn by P. Nicholson

Engraved by J.C. Bu

about an inch broad, nailed to the joists at intervals of one foot each.

SPAN, the width of an arch; the distance between the piers, or the length of an imaginary line extending between its springing on either side; the same as *chord.*

SPANDREL, an irregular triangular space, bounded on one side by the outer or convex curve of an arch, and on the other two by two straight lines touching the curve, and meeting each other at right angles. It is commonly formed in Gothic architecture by an arch with a rectangular hood-mould, the spandrel so formed being frequently enriched with carving or sculpture, sometimes with foliage, at others with quatrefoils, shields of arms, and various devices.

The term is further applied to any surface of a similar form, or formed under similar circumstances.

SPANDREL BRACKETING, a cradling of brackets fixed between one or more curves, each in a vertical plane, and in the circumference of a circle, whose plane is horizontal.

PROPOSITION I.—*Given the plan of a square room to be covered or vaulted with spandrel bracketing, and the vertical section of the cove, whose plane passes through the axis of the room, and through the intersection of two adjoining walls; to find the figure of the springing on the walls, so that the faces of the brackets may be in the surface of a solid, formed by revolving the given section from its place in the angle, round the axis of the room, until it makes a revolution.*

In the given square inscribe a circle, which will represent the ceiling-line, from any angle of the square draw a line to the centre: apply the given section upon this line as a base, to its place at the angle. Take any number of points in the curve, and draw lines perpendicular to the base to cut it. Upon the centre of the square, and with the distance of the several points of section, describe arcs cutting any side of the square. From these points draw perpendiculars to that side, from which make the several lengths of the perpendiculars equal to those of the section; through the extremities draw a curve, which will be the figure of the springing.

Example 1. *Figure* 1.—Let the given square be A B C D, and let E be its centre; join E B; apply the given section, B F, to E B, as a base, so that when turned perpendicular round E B upon the square, it will then be in its place. In the curve, F B, take any number of points, *h*, and draw the lines *h i*, perpendicular to E B, meeting it at the point *i*. On the centre, E, with the radii E *i*, describe arcs, *i k*, meeting A B in the points *k*. From the points *k*, draw the lines, *k l*, perpendicular to A B; and also from M, the points of contact, draw M N. Make the perpendiculars M N, *k l*, *k l*, &c. equal to the lines *i h*: through the points B, *l*, *l*, *l*, &c., to N, draw a curve, which will be half the springing line required. But if the points *p* are taken in the arc, M O, equidistantly, and the points *p* be the upper ends of the brackets, it will be much more convenient to draw the lines E *p k*. On the centre, E, with the radii E *k*, describe the arcs *k i*; draw the perpendiculars *i h* and *k l*, and proceed as before, to complete the curve, as the points *l* will give the spring of the foot of the brackets. In this example, the section here given is a quadrant; but it may be any geometrical curve, or any other line, that fancy may suggest, the same method extending to all.

Example 2. *Figure* 2.—In this example, the section given is a part of a circle, the radius of which is half the diagonal of the square, therefore, the quadrant, one of whose radii is the axis, and the other the half of the diagonal, will generate a hemisphere. It is evident, that if a square be inscribed in its base, and cut by planes through the sides of the square at right angles to the base, the sections will be semicircles; therefore, upon any side, as a diameter, describe a semicircle, and it will give the springing required. The places or springing-points of the brackets, may be found as before.

PROPOSITION II.—*Given the plan of an oblong room, to be coved or vaulted with spandrel bracketing, the ceiling-line an ellipsis inscribed in the plan, and a section of the cove, through the diagonal perpendicular to the ceiling-line; to find the spandrels of the bracketing, such that they may be the intersections made by the planes of the four walls, with the curved surface of a solid, generated by the given section, moving always perpendicular to the ceiling-line, which passes through the upper extremity of the curve of the generating section, and the lower extremity, always in a horizontal plane.*

Figure 3.—Let the oblong, A B C D, be the plan of the walls, and E F G H, the inscribed ellipsis; E G being the greater axis, and F H the lesser, parallel to the sides of the rectangle; consequently, E, F, G, H, the points of contact. In any quadrant, E H, take any number of equidistant points, *i*, or rather in a ratio, in which every succeeding two towards E, the extremity of the longer axis, will be nearer and nearer together, by the property of the ellipsis. Draw the lines, *i k*, perpendicular to the curve, cutting the two sides, D A, D C, in the points *k*. Let N E O be the given section, N E its base, which is a prolongation of G E, the line drawn from D, perpendicular to the curve, meeting it at R; from the point E, on E N, make the distances E *l* respectfully equal to the lines *i k*. Draw the lines *l m* perpendicular to N E, cutting the curve N O in the points *m*, and the lines *k p* perpendicular to A D and D C: make all the lines *k p* equal to the lines *l m*, and through the points *p* draw curves, which will be half the springing line on the two adjacent sides, and the points *p* will be the places for the springing of the brackets. The reader must here observe, that though the points *l* would describe parallel curves on the horizontal plane, yet none of these curves would be ellipses.

PROPOSITION III.—*Given the plan of a rectangular room to be coved with spandrel bracketing, supposing the surface of the solid with which the faces of the brackets are to coincide, to be an ellipsoid, the base of the spandrel solid, a section passing through its axis, given the springing-line of one of the ends, which is a section perpendicular to the fixed axis; to find the springing-line upon the sides, so that they may be of the same height with that upon the ends, and also the curves of the ribs.*

Figure 4.—Let A B C D be the rectangular plan, and let A F B be the section given, which is necessarily semicircular; upon A D, as a transverse axis, and with one-half of A B, as a semi-conjugate, describe the semi-ellipsis A G D, and it will be the springing required for the other two sides. Produce I O and H P, the two axes of the inscribed ellipsis, in all the four directions. Through any point, A, in one of the angular points of the plane, describe an ellipsis, N K L M, whose two axes shall be on the lines H P and O I, and also in the same ratio as those lines, the transverse axis being M K, and the conjugate N L; this ellipsis would be the base of the ellipsoid. Now, as every section passing through the shorter axis of this ellipsoid, viz., all the vertical ellipses passing through E, have the same conjugate axis, it will be very easy to describe the ribs over any given seat, as this seat is the transverse axis, and the radius of the greatest circle is the semi-conjugate.

Two diagrams illustrative of the method of obtaining the projection of angle-brackets are added.

Figure 1, a cove bracket; B A E the plan of the angle-rib; the ordinates *h i*, are taken from the ordinates *g f*.

Figure 2.—Another cove-bracket, of which one side has less projection than the other. B G D, the plan of the angle, as before; the bracket A G B, the angle B G D, and the position of the line, G E, are given; H G E, being an obtuse angle, viz., the angle of the room. The ordinates, *m n*, of one side of the room, are taken from the ordinates, *k i*, of the given bracket, A B G.

SPAN-PIECE, a provincial term in Lincolnshire, and perhaps in other counties, for COLLAR-BEAM, which see.

SPAN-ROOF, a roof consisting of two inclined sides. The term is used in contradistinction to *shed-roofing*. Span-roofing may have simple rafters, with or without a collar-beam; or the roof may be trussed; in which latter case, the term applies only to the external construction.

SPECIES OF TEMPLES: these are determined by the number of columns in the front of the portico; which, with their distance from each other, is regulated by the diameter of the columns at the bottom. *See* TEMPLE.

SPECIFICATION, a detailed and formal description of an edifice to be erected, the materials to be used therein, and the particular uses to which they are to be applied. Specifications are provided for the guidance of the builder in making his tender for work, and are appended to the contract. They are usually divided into several heads, according to the different trades employed in the work, and ought to be made out with great accuracy and precision; the more simple they are, the better.

SPECIFIC GRAVITY, a comparison of every solid, or fluid, with the weight of the same magnitude of rain-water. Rain-water is chosen as the standard of comparison, on account of its being less subject to variation in different circumstances of time, place, &c., than any other body, whether solid or fluid. And by a very fortunate coincidence, at least to English philosophers, it happens, that a cubic foot of rain-water weighs 1,000 ounces avoirdupoise; and consequently, assuming this as the specific gravity of rain-water, and comparing all other bodies with this, the same numbers that express the specific gravity of bodies, will at the same time denote the weight of a cubic foot of each in avoirdupoise ounces, which is a great convenience in numerical computations.

From the preceding definition, we readily draw the following laws of the specific gravity of bodies, viz.,

1. In bodies of equal magnitudes, the specific gravities are directly as the weights, or as their densities.

2. In bodies of the same specific gravities, the weights will be as the magnitudes.

3. In bodies of equal weights, the specific gravities are inversely as the magnitudes.

4. The weights of different bodies are to each other in the compound ratio of their magnitudes and specific gravities.

Hence it is obvious, that if in the magnitude, weight, and specific gravity of a body, any two be given, the third may be found; and we may thus find the magnitude of bodies, which are too irregular to admit of the application of the common rules of mensuration; or we may, by knowing the specific gravity and magnitude, find the weight of bodies which are too ponderous to be submitted to the action of the balance or steel-yard; or, lastly, the magnitude and weight being given, we may ascertain their specific gravities.

Example 1.—*The weight of a marble statue being* 748*lb. avoirdupoise, required the number of cubic feet, &c., which it contains; the specific gravity of marble being* 2742.

Since a cubic foot weighs 2742 ounces, we have
as $2742 : 748 \times 16 :: 1 : 4.36$ feet.

Example 2.—*Required the weight of a block of granite whose length is* 63 *feet, and breadth and thickness each* 12 *feet; the specific gravity of granite being* 3500.

Here $63 \times 12 \times 12 = 9072$ feet: then again
as $1 : 9072 :: 3500 : 31752000$ ounces:
or 885 tons, 18¾ cwt. The above are said to be the dimensions of one of the stones in the walls of Balbec.

Other properties relating to the specific gravity of bodies are as follows, *viz.*

1. A body immersed in a fluid will sink, if its specific gravity be greater than that of the fluid; if it be less, the body will rise to the top, and be only partly immersed; and if the specific gravity of the solid and fluid be equal, it will remain at rest in any part of the fluid in which it may be placed.

2. When a body is heavier than a fluid, it loses as much of its weight when immersed, as is equal to a quantity of the fluid of the same bulk or magnitude.

3. If the specific gravity of the fluid be greater than that of the body, then the quantity of the fluid displaced by the part immersed, is equal to the weight of the whole body. And hence, as the specific gravity of the fluid is to that of the body, so is the whole magnitude of the body to the part immersed.

4. The specific gravities of equal solids are as their parts immersed in the same fluid.

5. The specific gravities of fluids are as the weights lost by the same immersed solid.

Hence are drawn the following rules for ascertaining the specific gravities of both solids and fluids.

To find the specific gravity of a body.—This may be done generally by means of the hydrostatic balance, which is contrived for the easy and exact determination of the weights of bodies, either in air, or when immersed in water, or other fluid, from the difference of which the specific gravity of both the solid and fluid may be computed.

1. *When the body is heavier than water.*—Weigh it both out of water and in water; then say,

As the weight lost in water
Is to the whole or absolute weight,
So is the specific gravity of water
To that of the body.

2. *When the body is lighter than water.*—In this case attach to it a piece of another body heavier than water, so that the mass compounded of the two may sink together. Weigh the denser body and the compound body separately, both out of the water and in it; and find how much each loses in the water by subtracting its weight in water from its weight in air; and subtract the less of these remainders from the greater. Then use the following proportion:

As the last remainder
Is to the weight of the light body in air,
So is the specific gravity of water
To the specific gravity of the body.

3. *When the specific gravity of the fluid is required.*—Take a piece of some body of known specific gravity; weigh it both in and out of the fluid, and find the loss of weight by taking the difference of these two; then say,

As the whole or absolute weight
Is to the loss of weight,
So is the specific gravity of the solid
To the specific gravity of the fluid.

The following table exhibits the specific gravity of several of the most common bodies; it is extracted from a more extensive one given in Gregory's *Mechanics;* and other tables of a similar kind will be found in the works of Emerson, Muschenbroeck, Ward, Cotes, Martin, &c.

Table of Specific Gravities of Bodies.

METALS.

Brass, cast, not hammered	8396	Mercury, solid or congealed	15632
——, cast, common	7824	——, fluent	13568
Copper, not hammered	7788	Nickel, molten	7807
Gold, pure, melted, not hammered	19258	Platina, crude, in grains	15602
——, the same hammered	19362	——, purified, not hammered	19500
——, guinea	17629	——, ditto hammered	20337
Iron, cast	7207	Silver, virgin, not hammered	10477
Iron rod	7700	——, ditto, hammered	10511
Steel, neither tempered nor hardened	7833	——, shilling	10534
——, hardened, but not tempered	7840	Tin, pure Cornish melted, and not hardened	7291
Iron ore, prismatic	7355	——, hardened	7299
Lead, molten	11352	Zinc, molten	7191
——, ore of, cubic	7587		

STONES.

Beryl	3549	Spar	2595
Chrysolite, of the jewellers	2782	Topaz	4011
Crystal	2653	Agate onyx	2638
Diamond	3521	Flint	2594
Emerald	2775	Jasper	2816
Garnet	4189	Opal	2114
Ruby	4283	Pearl	2684
Sapphire	3994	Pebble	2664
		Stone, paving	2416

VARIOUS STONES, EARTHS, &c.

Alabaster	2730	Glass, white	2892
Amber	1078	——, bottle	2733
Ambergris	926	Granite, red Egyptian	2654
Basalts, from Giant's Causeway	2864	Hone, white razor	2876
Bath Stone	1975	Limestone	3179
Brick	2000	Marble	2742
Chalk	2784	Phosphorus	1714
Clay	2000	Portland stone	2013
Coal	1269	Porphyry	2765
Earth, common	1520	Pyrites	4954
Gypsum, opaque	2168	Slate	2672
Glass, green	2642	Stone, common	2520
		Sulphur	2033

LIQUORS, OILS, &c.

Alcohol, commercial	837	Oil of turpentine	870
——, highly rectified	829	——, whale	923
Ether	720	Water, rain	1000
Beer	1034	——, distilled	1000
Milk, woman's	1020	——, sea	1026
——, cow's	1032	Wine, Port	997

RESINS, GUMS, &c.

Bees-wax	965	Honey	1456
Bone of an ox	1659	Ivory	1822
Camphor	989	Tallow	945
Gunpowder	930	Wax	897

WOODS.

Alder	800	Beech	852
Ash, the trunk of	845	Box, French	912
Cedar	596	Mahogany	1063
Cherry-tree	715	Maple	750
Cork	240	Oak, heart of, 60 years	1170
Ebony	1331	Pine, American yellow	460
Elder-tree	695	Poplar	383
Elm, trunk of	671	Vine	1327
Fir, red or yellow	550	Walnut	671
Fir, white	470	Willow	585
Larch	560	Yew, Dutch	788
Lignum-vitæ	1333	——, Spanish	807
Logwood	913		

GASES.

Atmospheric air	1.000	Light gas	986
Carbonic air	1.524	Nitrogen	672
Carbonic oxyde	967	Oxygen	1.106
Hydrogen	69	Pit gas	558

SPERE, a screen across the lower end of ancient halls.

SPHERE, (from the Greek, *σφαιρα, a ball*,) a solid, whose surface is everywhere equally distant from a certain point within the solid; which point is called *the centre of the sphere.*

Every sphere is equal to two-thirds of its circumscribing cylinder; that is, it is equal to a cylinder, whose ends are circles, equal to a great circle of the sphere, and whose height is equal to the diameter of the same. Therefore,

To find the solidity of a sphere. Multiply the square of the diameter by .7854, and this product by the diameter of the sphere, and take two-thirds of the last product; or,—Multiply the cube of the diameter by .5236, and the product is the solid content.

To find the superficies of a sphere.—Multiply the area of the great circle by .4, and the project is the superficies.

Example.—To find the solidity of a sphere, whose diameter is 23 *feet,* 3 *inches.*

Here 23 : 3=23.25 in decimals.

```
     23.25
     23.25
    ------
    11625
    4650
   6975
  4650
  --------
  540.5625
     23.25
  --------
  27028125
 10811250
16216875
10811250
-------------
12568.078125
       .5236
-------------
  75408468750
 37704234375
25136156250
62840390625
-----------------
6580.6457062500
```

The superficial content of the same sphere is 540.5625 + 4=2162.2500.

SPHERICAL BRACKETING, the forming of brackets to support lath-and-plaster-work, so that the surface of the plaster shall form the surface of a sphere. *See* PLASTERING.

The form of the bracketing depends upon the planes in which they are disposed, within the surface of a sphere: but, in all cases, the edges are circular, because the section of a sphere is a circle, according to any position of the cutting plane: the edges of the bracketing will be equal circles, when their planes intersect each other in the centre of the sphere; in this case, the edges require no bevelling: but if the planes of the brackets are disposed in a parallel way, the edges are all unequal circles, and the edges, which receive the lath, will be more oblique, as the planes of the circles are more remote from the centre of the sphere: therefore, the quantity of labour, and the waste of timber, will entirely depend on the disposition of the planes of the bracketing.

SPHEROIDAL BRACKETING, the bracketing prepared for a plaster-ceiling, whose surface is to form that of a spheroid.

As all the sections of a spheroid are either circles or ellipses, the edges of the bracketing are either circles or ellipses.

As a spheroid may be supposed to be generated by the revolution of a semi-ellipsis upon one of its axes; therefore, if the planes of the bracketing be disposed in parallel planes, perpendicular to the axis of the generating circle, the edges of the bracketing must be circles.

If the planes of the bracket be disposed in planes passing through the axis of rotation, the edges of the bracketing will be portions of an ellipsis, equal and similar to the generating semi-ellipsis.

If the planes of the bracketing be so disposed as to pass through a diameter of the great circle of the spheroid, viz., that circle perpendicular to and bisecting the generating axis; then all the ribs of the bracketing will be elliptic quadrants, bounded by two semi-axes and the quadrantal curve; one of the semi-axes will be equal to the radius of the great circle, and the other will be found upon the plane of the generating ellipsis.

SPHINX, a sculptured figure frequently found in Egyptian temples, and their approaches, representing a monster with the head and breasts of a woman, the wings of a bird, the claws of a lion, and the other parts of the body like a dog.

SPIRAL, (from the Latin, *spira*, involved,) a curve which makes one or more revolutions round a fixed point, and which does not return to itself. *See* VOLUTE.

SPIRE, a pyramidal acutely-pointed covering or roof, most usually found on towers of churches and on turrets. Spires are constructed either of stone or of wood, covered with lead, slate, or oak shingles. They were probably not introduced into England till some time after the Norman conquest. In the earliest examples, they are usually of the same plan as the tower, either square, circular, or octagonal, and are of no very great height. In early English examples of later date, they are sometimes of the same plans, but more frequently octagonal, and also of much loftier proportions; where an octagonal spire stands on a square tower, the angular spaces left unoccupied are covered by pinnacles, or by semi-pyramidal masses of masonry sloping against the spire. The outline is frequently broken by one or more tiers of small open windows, termed spire-lights, the faces of which are vertical, and therefore project out at the top from the sloping face of the spire; they are usually covered with gablets or sharp pediments, which in the later and more ornamented styles are often enriched with crockets, finials, pinnacles, &c. Spire-lights are frequently placed on the alternate faces of the spire in alternate tiers. Early English spires are usually what are termed *broach-spires;* that is to say, they spring directly from the edge of the tower, without the intervention of a parapet, whereas, in the later styles, the parapet is seldom omitted. In the Decorated and Perpendicular styles, the spire is more enriched, usually having angular pinnacles, and often flying-buttresses from the pinnacle to the spire; crockets sometimes adorn the angles of the spire, and ornamental bands divide it into several stages. Spires are terminated at the apex either with a finial or metal cross or vane, the latter being frequently in form of a cock, as an emblem of prayer and watchfulness. Spires of open work are not unfrequent in the larger continental churches.

SPITAL, an hospital.

SPLAYED, (from the old French, *disployer*, to spread abroad,) a term, in architecture, applied to whatever has one side making an oblique angle with the other: thus, the heading-joints of a boarded floor are frequently splayed in their thickness, as are also the jambs, or sides, of a window; in the latter case, the room may be lighted to the greatest advantage. The word *fluing* is sometimes applied to an aperture in the same sense as *splayed.*

SPRING BEVEL OF A RAIL, the angle made by the top of the plank, with a vertical plane touching the ends of the rail-piece, which terminates the concave side.

SPRINGED, in boarding a roof, the art of setting the boards together with bevel-joints, so as to keep out the rain.

SPRINGING COURSE, the horizontal course of stones from which an arch begins to spring; or the row of stones upon which the first arch-stones are laid.

The term is also applied to the bottom stone of the coping of a gable.

SQUARE, (from the Latin, *quadratus*, having four corners,) a term among workmen, applied to any material, when two of the sides stand perpendicular to each other. In joinery, the work is said to be *square-framed*, or *framed square*, when the framing has all the angles of its styles, rails, and mountings, square, without being moulded.

SQUARE, an instrument for trying whether an angle be a right angle, generally consisting of an outer and inner square, parallel to each other; the former for trying interior angles, the latter for exterior ones.

SQUARE-SHOOT. *See* WATER-SHOOT.

SQUARE-STAFF, a piece of wood, used for fortifying the angles of plaster-work intended to be papered over.

SQUARING HAND-RAILS, the method of cutting a plank to the form of a rail for a staircase, so that all the vertical sections may be rectangles. The squaring is the most difficult part in the execution of hand-rails, as the moulding and finishing must be regulated by it. To perform it accurately, the plank must be shot to the proper bevel, or edge; then, supposing it to be set to the pitch, a vertical line must be drawn on the edge, and the face-mould must be applied, first on one side of the plank, so that the two points may come close to the edge that is shot, and, one of them coinciding with the vertical face, lines are to be drawn by the edges of the mould on the surface of the plank. The mould is then to be applied to the other side, in the same manner, and lines drawn as before; after which, the plank is to be cut out between the lines thus drawn on both sides, great care being taken to keep the teeth of the saw perpendicular. The edges will then only want smoothing, and the top and bottom of the rail-piece will be brought to a level by the falling mould. *See* HAND-RAILING.

SQUARING OF A PIECE OF STUFF, the act of trying it up by the square, in order to make the angles right angles.

SQUINCH, a small arch thrown across the angles of square towers to support octagonal spires. The same object is sometimes effected by corbelling out at the angles, which has this advantage over the arch, that it does not tend to thrust apart the walls of the tower; this latter plan is termed the straight squinch.

SQUINT, an opening often found in the walls of churches, passing through them in an oblique direction, usually on one or both sides of the chancel-arch, so as to enable persons sitting in the aisles or transept to see the elevation of the host: where there are no chancel-aisles, there is often a projection on the exterior of the church through which the aperture is pierced. In Bridgewater church, Somersetshire, the perforation is carried through three walls in an oblique line, so as to enable persons in the porch to view the altar.

Some of these openings extend from the ground to a height of ten feet, or thereabouts, but they are usually two or three feet above the ground, and two or three feet high, by two wide; they are frequently plain, but sometimes highly enriched. They are more correctly termed *hagioscopes*.

STABLE, a house or shed for horses and cattle generally.

STADIUM, a Roman measure of length, nearly equivalent to an English furlong. Also an enclosed area in which the various athletic exercises were exhibited.

STAFF-BEAD, a vertical piece of timber placed on the exterior angles of the walls of apartments to preserve the arris, which, if made up of plaster, is liable to be broken; it is frequently moulded with a bead on the outer edge.

STAINED GLASS, pieces of glass stained of various colours, and arranged so as to form a variety of patterns or devices, and sometimes of pictorial representations.

The ancient Egyptians are said to have made and coloured small ornaments of glass, but glass does not seem to have been much used by any of the ancients; small pieces are found in Roman mosaics, and some larger plates have been discovered at Herculaneum, which some have supposed to have been used as window glass. According to Bede, glass was employed in the windows of Bishop's Wearmouth church, but it did not come into general use for some time afterwards, and was not used in private houses till A. D. 1180. Stained glass for windows, was probably in use as early as the ninth century, but no example exists in England of earlier date than the twelfth century, to which period belong the remains at Canterbury. These consist of panels of various forms, containing subjects on a deep blue or ruby ground, the spaces between the panels being filled up with mosaic patterns in which ruby and blue are the prevalent colours; the whole is surrounded with a border of foliage and scroll-work.

During the Early English period, the glazing consists of panels, circles, quatrefoils, and other forms, including that of the vesica piscis, and these contain subjects; the spaces between are filled with coloured mosaic patterns, and the whole contained in a border of leaves and scroll-work. Sometimes the entire space within the border is filled with scrolls, and foliage, on a deep blue or ruby ground, the scrolls, &c., being either of coloured glass, or only in black outline in plain glass; in the latter case, panels formed by strips of coloured glass are sometimes inserted. Quarry glazing, in which the windows are formed by lozenge-shaped pieces of glass, with a small pattern upon each, is first used in this style.

In the Decorated style, quarry glazing becomes of frequent use, and the panel system loses ground; where panels occur, the ground is covered with patterns of foliage of a more flowing and natural character than in the preceding style; the vine and ivy leaves are favourites. Sometimes the entire window is filled with such foliage, which is often only in outline, and frequently only some portions of the pattern are stained yellow. Quarries contain small patterns of leaves, rosettes, &c., sometimes in plain outline, but frequently coloured yellow; in foliage patterns, in which the vine and ivy leaves predominate, the stalks of the leaves are often so arranged, as to form one continuous flowing pattern throughout the window, and at other times, one edge of each quarry had a coloured stripe, so that when put together they each appeared surrounded with a coloured border. The entire design is surrounded, in most cases, with a running border of foliage and flowers. At this period, single figures surmounted by canopies, begin to appear, at first of small size, two or more being contained in one light, but afterwards they become larger, and were disposed one in each light.

In the Perpendicular period, this practice begins to increase, the figures and canopies are of a larger size, more than one being seldom contained in one light; at last whole windows containing several lights were filled with one large grouped subject. Quarries still continue in use, but the devices do not flow one into the other, consisting mostly of rosettes, flowers, fleurs de lis, and heraldic devices, the latter being very frequently and generally adopted in this style. Coloured inscriptions on bands or scrolls are frequently seen running diagonally, and at regular intervals, across windows, from top to bottom.

With the decline of Gothic architecture, stained windows fell into disuse; and with its revival, it is now occupying a great deal of attention, and is executed with considerable taste and skill.

STAIRCASE, a term applied to the whole set of stairs, with the walls supporting the steps, leading from one story to another. The same staircase frequently conducts to the top of the building, and thus consists of as many stories as the building itself.

When the height of the story is considerable, resting-places become necessary, which go under the name of *quarter-paces* and *half-paces*, according as the passenger has to pass a right angle, or two right angles; that is, as he has to describe a quadrant or a semicircle. In very high stories that admit of sufficient head room, and where the space allowed for the staircase is confined, the staircase may have two revolutions in the height of one story, which will lessen the height of the steps; but in grand staircases only one revolution can be admitted, the length and breadth of the space on the plan being always proportioned to the height of the building, so as to admit of fixed proportions.

In contriving a grand edifice, particular attention must be paid to the situation of the space occupied by the stairs, so as to give them the most easy command of the rooms.

With regard to the lighting of a grand staircase, a skylight, or rather lantern, is the most appropriate; for the light, thus admitted, is powerful, and the design admits of greater elegance; indeed, where the staircase does not adjoin the exterior walls, this is the only method by which light can be admitted.

In small buildings, the position of the staircase is indicated by the general distribution of the plan; but in larger edifices, this is not so obvious, but must at last be determined by considering maturely its connection with the other apartments.

STAIRS, (from the Saxon, *stæger*,) in a building, the steps whereby to ascend and descend from one story to another.

The breadth of the steps of stairs in general use in common dwelling-houses, is from 9 to 12 inches, or about 10 inches at the medium. In the best staircases of noblemen's houses, or public edifices, the breadth ought never to be less than 12 inches, nor more than 18. It is a general maxim, that the greater breadth of a step requires less height than one of less breadth: thus, a step of 12 inches in breadth will require a rise of $5\frac{1}{2}$ inches, which may be taken as a standard by which to regulate those of other dimensions; so that multiplying 12 inches by $5\frac{1}{2}$, we shall have 66; then supposing a step to be 10 inches in breadth, the height should be $\frac{66}{10}=6\frac{3}{5}$ inches, which is nearly, if not exactly, what common practice would allow. The proportions of steps being thus regulated, the next consideration is, the number requisite between two floors or stories, which will be ascertained by supposing the breadth of the steps given, say 10 inches each, as depending on the space allowed for the staircase, and this, according to the rule laid down, will require a rise of 7 inches nearly; suppose, then, the distance from floor to floor to be 13 feet 4 inches, or 160 inches: $\frac{160}{7}=22\frac{6}{7}$, which would be the number required; but as all the steps must be of equal heights, we should rather take 23 rises, provided the staircase-room would allow it, and so make the height of each somewhat less than 7 inches.

The most certain method of erecting a staircase is, to provide a rod of sufficient length to reach from one floor to the other, divided into as many equal parts as the intended number of rises; and try every step as it is set, to its exact height. The breadth of the staircase may be from 6 to 20 feet, according to the use or occupier of the building, or the form and proportions of the plan. If the steps be less than three feet in length, the staircase becomes inconvenient for the passing of furniture, as is frequently the case in small houses.

Though it is desirable to have such rules as are here laid down for regulating the proportions of the heights, breadths, and lengths of steps, architects and workmen cannot be so strictly tied to them, but that they may vary them as circumstances may demand.

Stairs, *Straight*, such as ascend in a straight line, and consist only of plane surfaces.

Stairs, *Winding*, those which turn round a solid newel, or circular well-hole; the latter either enclosed in a complete cylindric case, or semi-cylinder, at one end, adjoined to two parallel walls, which terminate upon an opposite wall.

In winding stairs the steps are formed narrower next to the well-hole than at the other end, where they adjoin the wall; these are termed *winders*.

Those steps which continue of the same breadth are termed *flyers*, in contradistinction to the winders.

A series, or number of flyers, connected together, is termed *a flight of steps*.

STALK, an ornament in the Corinthian capital, similar to the stalk of a plant, from which spring the volutes and helices; it is sometimes plain, and at others fluted.

STALL, (from the Saxon, *steal*, a shed,) a place, or division of a stable, for a single horse to stand and feed in. According to the number of these divisions, a stable is denominated a *one-stall*, *two-stall*, &c. *stable*.

Stall, a fixed seat, enclosed entirely or partially at back and sides, and frequently in an elevated position; to be seen at the sides of the choir, or chancel of parish and cathedral churches, in the latter of which, they are frequently covered with a lofty and rich canopy, with tabernacle-work, and richly carved on the sides and back, as also on the desk in front. They are appropriated to the officials and dignitaries of the church.

STANCHION, a term applied to any perpendicular support, such as the mullions of windows, &c.; also to the upright iron bar between the mullions, which is frequently terminated by a finial, or other ornamental top.

Stanchions, or Puncheons. *See* Studs.

STANDARDS, (from the Saxon, *standan*, to be on the feet,) the upright poles used by bricklayers in scaffolding.

Standards, in joinery, the upright pieces of a plate-rack, commonly placed above a dresser. When the edges of standards are cut into mouldings across the fibres of the wood, they are called *cut standards*.

Standards: the term is applied generally to upright supports, or upright pieces which are used to keep other pieces together; thus the upright ends of stalls or benches, into which the back and seat are fixed, are termed standards.

STAPLE, (Dutch,) a small bar of iron, pointed at each end, and bent so that the two ends may be parallel to each other, and of equal lengths; to be driven into wood, or into a wall, so as to form a loop for fastening a hasp, or bolt.

STARLINGS, in bridges and similar works, are the projections in front of the piers, usually pointed or rounded off at the ends, and employed to break the force of the current, and protect the piers from iniury.

STAVES, (from the Saxon, *stæf*, a staff) in joinery, the boards that are joined together laterally, in order to form a hollow cylinder, cylindroid, cone, or conoid, or any frustum of these bodies. The shafts of columns, in joinery, are frequently glued up in staves.

Staves are also small cylinders sometimes called *rounds*, for forming a rack to contain the hay in stables, out of which the horses eat.

STAY BAR, the horizontal iron bar placed across windows, to strengthen the mullions.

STEEL, (from the Saxon *stal*,) is made of the purest malleable iron by an operation called *cementation*, by which it acquires a small addition to its weight, amounting to about the hundred and fiftieth, or two hundredth part. In this state it is much more brittle and fusible than before. It may be welded like bar-iron, if it has not been fused or over cemented: but its most useful and advantageous property is, that of becoming extremely hard when heated and plunged into cold water; the hardness which it thus acquires is greater, as the steel is hotter and the water colder. The sign that should direct the mechanic in the tempering of steel, is the variation of colour which appears on its surface. If the steel be slowly heated, it exhibits a yellowish white, yellow, or gold colour, purple, violet, or deep blue. If the steel be too hard, it will not be proper for tools intended to have a fine edge, as it will be so brittle that the edge will soon become notched: and if too soft the edge will soon turn aside, even by very slight use. Some artists heat their tools, plunge them into cold water, and then brighten the surface of the steel upon a stone; the steel being then laid upon hot charcoal, or upon the surface of melted lead, or on a bar or piece of hot iron, it gradually acquires the desired colour, and must at that instant be plunged into water. If a hard temper be required, as soon as the yellow tinge appears, the piece is dipped again, and stirred about in the cold water.

In tempering tools for working upon metals, it will be proper to bring them to a purple tinge before the dipping. Springs are tempered by bringing the surface to a blue tinge. This temperature is also desirable for tools employed in cutting soft substances, such as cork, leather, and the like; but if the steel be plunged into water when its surface has acquired a deep blue, its hardness will scarcely exceed the temperature of iron. When soft steel is heated to any one of these colours, and then plunged into water, it does not acquire so great a degree of hardness as if previously made quite hard. The degree of heat required to harden steel varies in the different kinds. The best require only a low red heat; the harder the steel, the more coarse and granulated will its fracture be. Hardened steel has less specific gravity than the soft. The texture of steel is rendered more uniform by fusing it before it is made into bars, and in this state it is called *cast steel*, which is wrought with more difficulty than common steel, because it is more fusible, and will disperse under the hammer if heated to a white heat.

Every species of iron is convertible into steel by cementation; but the best steel can be made only from iron of the best quality, which possesses stiffness and hardness as well as malleability. Swedish iron has been long remarked as the best for this purpose.

The *cast steel* of England is made as follows: a crucible, about ten inches high, and seven in diameter, is filled with ends and fragments of the crude steel of the manufactories and the filings and fragments of steel works; they add a flux, the component parts of which are usually concealed. It is probable, however, that the success does not much depend upon the flux. This crucible is placed in a wind furnace, like that of the founders, but smaller, being intended to contain only one pot, and surmounted by a cover and chimney to increase the draught of air; the furnace is then entirely filled with coke, or charred pit-coal. Five hours are required for the perfect fusion of the steel. It is then poured into long, square, or octagonal moulds, each composed of two pieces of cast-iron fitted together. The ingots, when taken out of the mould, have the appearance of cast iron. It is then forged in the same manner as other steel, but with less heat and more precaution. Cast steel is almost twice as dear as other good steel; it is excellent for razors, knives, joiners' chisels, and all kinds of small work requiring an exquisite polish: its texture is more uniform than that of common steel, which is an invaluable advantage. It is daily more and more used in England, but it cannot be employed in works of great magnitude, on account of the facility with which it is degraded in the fire, and the difficulty of welding it.

STEEPLE, a spire or lantern; the pyramidal roof of a tower. By some the term is made to include both tower and spire, and by others is used indifferently for any lofty tower, with or without a spire.

STENCH TRAP, a valve to prevent the emission of effluvia from drains and sewers; they are of various forms.

STEPS, (from the Saxon, *stæp*,) the degrees of a staircase, by which we rise, consisting of two parts, one horizontal, called *treads*, the other vertical, called *risers*. When steps are placed round the circumference of a circle, or of an ellipsis, or any segments of them, they are called *winders:* but when the sides are straight, they are called *flyers*. The first or lower step, with a scroll wrought upon its end, according to the plan of the hand-rail, is called *the curtail step*.

STEREOBATA, or STEREOBATES, (from ςερεοβατης, *solid prop*,) in ancient architecture, the basis, or foundation, whereon a column, wall, or other piece of building, is raised. This answers pretty well to the continued socle, or basement of the moderns. Some confound it with the ancient *stylobata*, or *pedestal*; but, in effect, the stereobata is to the stylobata, what the stylobata is to the spire, or base of the column.

STEREOGRAPHIC PROJECTION OF THE SPHERE, that in which the eye is supposed to be placed in the surface of the sphere.

STEREOGRAPHY, (from ςερεος, *solid*, and γραφω, *to describe*,) that branch of solid geometry which demonstrates the properties, and shows the construction, of all solids which are regularly defined. It explains the methods for constructing the surfaces in plains, so as to form the entire body, or to cover the surface of a given solid; or, when a solid is bounded by plain surfaces, the inclination of the planes is determined by the rules of stereography. The sections of solids are also a branch of stereography; but this we shall refer to the article STEREOTOMY, with which it is more intimately connected.

Mr. Hamilton has denominated the principles of perspective by the name of *stereography;* but in this sense the term is too limited, as perspective is only a branch of the doctrine of solids, and extends only to the sections of pyramids and cones, and the representations of solids.

The eleventh and twelfth books of Euclid, which treat of the properties of solids, may be looked upon as the elements of this branch of geometry; and to them we shall refer our readers for the first elements to be acquired.

It is somewhat singular, that though the first principles of solids have long been demonstrated, no practical application to mechanical constructions has been made of them. The knowledge of solids is of the greatest importance in the constructive parts of architecture, as in masonry, bricklaying, carpentry, &c.

To be proficient in the art of construction, this branch of geometry is indispensable, and contains the very essence and foundation of the whole in abstract.

Definition 1.—*A solid* is that which has length, breadth, and thickness.

Definition 2.—The exterior surface of a solid is called its *superficies.*

Definition 3.—*A straight line* is perpendicular, or at right angles to a plane, when it makes right angles with every straight line meeting it in that plane.

Definition 4.—*A plane* is *perpendicular to a plane*, when the straight lines drawn in one of the planes, perpendicularly to the common section of the two planes, are perpendicular to the other plane.

Definition 5.—*The inclination of a straight line to a plane* is the acute angle contained by that straight line, and another drawn from the point in which the first line meets the plane, to the point in which a perpendicular to the plane drawn from any point of the first line above the plane meets the same plane.

Definition 6.—*The inclination of a plane to a plane* is the acute angle contained by two straight lines, drawn from any, the same point of their common section at right angles to it, one upon one plane, and the other upon the other plane.

Definition 7.—Two planes are said to have the *like inclination* to each other, which two other planes have, when the said angles of inclination are equal to one another.

Definition 8.—*Parallel planes* are such as do not meet each other, though produced.

Definition 9.—*A solid angle* is that which is made by the meeting of more than two plane angles, which are not in the same plane, in one point.

Definition 10.—*Similar solid figures* are such as have all their solid angles equal each to each, and contained by the same number of similar planes.

Definition 11.—*A prism* is a solid, of which the ends are similar and equal plane figures, and the sides parallelograms.

Definition 12.—When the ends of the prism are perpendicular to the sides, it is called *a right prism;* but if otherwise, it is termed *oblique.*

Definition 13.—A prism, whose sides and ends are equal squares, is called *a cube.*

Definition 14.—When the ends are parallelograms, the prism is called *a parallelopiped;* and when the planes of the parallelopiped are at right angles to each other, the prism is called *a rectangular prism.*

Definition 15.—When the ends of the prism are circles, it is called *a cylinder ;* but if the ends are ellipses, and alike situated, it is called *a cylindroid.*

Definition 16.—The straight line extended between the centres of the two bases is called *the axis.*

Definition 17.—A solid having any plane figure for its base, and its sides plain triangles terminating in the same point, is called *a pyramid.*

Definition 18.—A solid having a circle for its base, and terminating in a point, such that a straight line extended from any part of the circumference of the base to the terminating point may be in the surface of the solid, is called *a cone ;* and the surface which lies between the circumference of the base and the terminating point, is called *the conic surface.*

Definition 19.—If the plane of a circle be supposed perpendicular to a given plane, with its circumference or edge upon that plane ; and if there be a straight line standing on any other point perpendicular to the said plane; and if another straight line be made to move parallel to the plane on which the circle stands, so as always to touch the circumference and the straight line, beginning at any given point, and proceeding entirely round until it arrives at the same point; then the solid bounded by the circle, and the surface passed over by the straight line contained between the circumference of the circle and the straight line is called *a conoid;* and the surface generated by the straight line is called *a conoidal surface.*

Definition 20.—*A sphere* is a solid formed by the revolution of a semicircle upon its diameter.

Definition 21.—*The centre of a sphere* is the same with that of the semicircle.

Definition 22.—*The diameter of a sphere* is any straight line which passes through the centre, and is terminated both ways by the superficies of the sphere.

Definition 23.—*A cube* is a solid figure contained by six equal squares.

Definition 24.—*A tetrahedron* is a solid figure contained by four equal and equilateral triangles.

Definition 25.—*An octahedron* is a solid contained by eight equal and equilateral triangles.

Definition 26.—*A dodecahedron* is a solid contained by twelve equal pentagons, which are equilateral and equiangular.

Definition 27.—*An icosahedron* is a solid contained by twenty equal and equilateral triangles.

The solids defined in the last five definitions are called *the five regular solids.*

STEREOMETRY (from ϛερεομετρια, formed of ϛερεος, *solid,* and μετρον, *measure,*) that part of geometry which teaches to measure solid bodies, *i. e.*, to find the solidity, or solid content of bodies; as globes, cylinders, cubes, vessels, ships, &c. The methods see under the respective bodies; CYLINDER, GLOBE, SPHERE, &c.

STEREOTOMY, (from ϛερεος, *solid,* and τομη, *section,*) the science and art of cutting solids under certain specified conditions.

Stereotomy may be regarded as a branch of stereography, which is the science of solids in general. Mr. Hamilton has intitled his complete body of perspective, *Stereography,* which perhaps would have been more properly called *Stereotomy,* as the perspective representation of every object in nature is the section of a pyramid or cone of rays. But as it has not been the object of writers on perspective to show the rules for finding the sections of solids in general, under certain specified conditions of the cutting plane, nor of finding any other sections besides those of cones and pyramids, it is the express intention of this article to explain the general principles of the science for any given law, by which the surface of the solid may be constituted of straight lines, or that the surface may agree with the common section of two planes disposed in given positions. And as nothing of the kind has yet appeared, perhaps this attempt may be the more acceptable, particularly as in its principles the whole art of dialing is included, and the mechanical arts of masonry and carpentry. The art of stone-cutting, the squaring and cutting of timbers, and the formation of hand-rails, depend entirely upon the sections of solids.

Properties of Planes and Solids demonstrated in the eleventh book of Euclid's Elements, useful in Stereotomy.

Proposition I.—One part of a straight line cannot be in a plane, and another part above it.

Proposition II.—Two straight lines which cut each other are in one plane, and three straight lines which meet each other are in one plane.

Proposition III.—If two planes cut each other, their common section is a straight line.

Proposition IV.—If a straight line stand at right angles to each of two straight lines in the point of their intersection, it shall also be at right angles to the plane which passes through them.

Proposition V.—If three straight lines meet all in one point, and a straight line stands at right angles to each of them in that point, these three first straight lines are in one and the same plane.

Proposition VI.—If two straight lines be at right angles to the same plane, they shall be parallel to each other.

Proposition VII.—If two straight lines be parallel, the straight line drawn from any point in one to any point in the other, is in the same plane with the parallels.

Proposition VIII.—If two straight lines be parallel, and one of them at right angles to a plane, the other shall also be at right angles to the same plane.

Proposition IX.—Two straight lines which are each of them parallel to the same straight line, and not in the same plane with it, are parallel to each other.

Proposition X.—If two straight lines meeting each other be parallel to two others that also meet, but are not in the same plane with the first two, both couples will contain equal angles.

Proposition XI.—PROBLEM.—*To draw a straight line perpendicular to a plane, from a given point in space above the plane.*

Draw any straight line in the plane, and from the given point above the plane draw a second straight line at right angles to the first; from the point where the perpendicular meets the first line, draw a third straight line in the plane, at right angles to the first; and, lastly, from the given point in space draw a fourth line at right angles to the third; and the fourth straight line, thus drawn, will be perpendicular to the plane.

Proposition XII.—PROBLEM.—*To erect a straight line at right angles to a given plane from a given point in the plane.*

From any given point above the plane draw a straight line perpendicular to the plane, and through the given point in the plane draw a second line parallel to the first; which second line will be the perpendicular required.

Proposition XIII.—From the same point in a given plane there cannot be two straight lines at right angles to the plane upon the same side of it; and there can be but one perpendicular to a plane from a point above.

Proposition XIV.—Planes to which the same straight line is perpendicular, are parallel to each other.

Proposition XV.—If two straight lines, meeting each other, be parallel to two other straight lines, which also meet but are not in the same plane with the first two; the plane which passes through the latter is parallel to the plane which passes through the former two lines.

Proposition XVI.—If two parallel planes be cut by another plane, their common sections with it are parallels.

Proposition XVII.—If two straight lines be cut by parallel planes, they will be cut in the same ratio.

Proposition XVIII.—If a straight line be at right angles to a plane, every plane which passes through it will be at right angles to that plane.

Proposition XIX.—If two planes cutting each other be each of them perpendicular to a third plane, their common section will also be perpendicular to it.

Proposition XX.—If a solid angle be contained by three plane angles, any two of them are greater than the third.

Proposition XXI.—Every solid angle is contained by plane angles, which together are less than four right angles.

Proposition XXII.—If every two of three plane angles be greater than the third, and if the straight lines which contain them be all equal, a triangle may be made of the straight lines that join the extremities of those equal straight lines.

Properties of Solids.

In a prism, all parallel sections which cut the sides, are similar and equal figures; or, all parallel sections which would cut the plane of the base, if produced, are similar and equal figures.

In a pyramid, all the parallel sections which are not parallel to the plane of the base, are unequal similar figures.

The properties of a cone are numerous and interesting. If cut parallel to the plane of the base, the section is *a circle;* if in any direction through the apex, the section is *a plane right-lined triangle;* if the cone be cut by a plane inclined to the plane of the base, at any given angle, the section is *an ellipsis;* if cut by a plane parallel to any straight line within the solid passing through the apex, the section is denominated *an hyperbola;* and if cut by a plane parallel to another plane which touches the curved surface, the section, formed by this position of the cutting plane, is called *a parabola.*

For the purposes of stereotomy, we shall suppose the cone a right one; and consequently the abscissa of the curves, or sections, will bisect all the double ordinates at right angles.

Definition 1.—If any semi-conic section be supposed to revolve upon its abscissa, so as to perform an entire revolution, the surface generated by the curve-line is called *a conoid,* and the abscissa *the axis.*

Definition 2.—If the semi-conic section be a semi-ellipsis, the solid generated is called *an ellipsoid.*

Definition 3.—If the generating figure be a semi-parabola, the solid is called *a paraboloid.*

Definition 4.—If the generating figure be a semi-hyperbola, the solid is called *an hyberboloid.*

Definition 5.—All solids whatever, generated by revolving plane figures upon an axis, are called *solids of revolution.*

Definition 6.—All parallel sections of conoids are *similar figures.*

General Principles of Construction.

Definition.—Solid angles, which consist of three plane angles, are called *trihedrals.*

In the construction of trihedrals, besides the three plane angles which form the boundaries of the solid, there are the three inclinations. These inclinations are, by way of distinction, called *the angles;* the three boundaries are called *the sides;* and the sides and angles are indifferently called *parts;* any three of which, excepting the three angles, may be found by the following constructions:

Problem I.—*In a right-angled trihedral are given the two sides containing the right angle; to find the acute angles, and the side or hypothenuse which subtends the right angle.*

Figure 1.—Make the angle E B H equal to one of the given sides, and the angle E B F equal to the other; draw E H perpendicular to E B, and E I perpendicular to B F, cutting B F at F; from B, with the radius B H, describe an arc, cutting E I at I, and join B I; then B I is the hypothenuse: from E, with the radius E F, describe an arc, cutting E B in G, and join G H; then E G H is the angle contained by the hypothenuse and the side E B F, or the angle opposite the side E B H: or, make F I equal to G H, and join B I.

In the same manner the angle opposite the side of E B F may be found.

The reason will appear thus: raise the plane of the triangle B E F upon B E, so as to be perpendicular to the plane B E H; raise the triangle E G H upon E H, until E G fall upon E F; then the plane E G H will become perpendicular to B F; revolve the plane B I F upon B F, and F I will describe a circle, whose plane is also perpendicular to B F, from the point F; therefore, the plane of the circle and the plane E G H will be both in the same plane: therefore, since the point F coincides with G, the straight line F I may be made to coincide with G H; let this coincidence take place; and because F I is equal to G H, and the point G falls upon F, the point I will fall upon H; therefore, the straight line B I will fall upon B H; and the angle F B I, joining F B and B H, is the hypothenuse.

Again, it is evident from the planes thus raised, that the angle, E G H, contained by the planes F B E and F B I, and perpendicular to F B, their common intersection, is the measure of the angle contained by the planes F B E and F B I.

Problem II.—*Given one of the sides containing the right angle and the angle opposite; to find the remaining side which contains the right angle.*

Figure 2.—Let the given side be H B E: in B E take any point, F, and make E F H equal to the angle required; draw H E perpendicular to E B; from E, with the radius E F, describe an arc, F G; draw B G a tangent at G; and E B G is the side required. The demonstration is evident from the last.

Problem III.—*Given one of the sides containing the right angle and the inclination or angle adjacent; to find the remaining side which contains the right angle.*

Figure 2.—Make A B D equal to the given side; in A B take any point, E; draw E G perpendicular to B D, cutting it in G, and E H perpendicular to A B; make E F equal to E G, and E F H equal to the given angle; draw B H C, and A B C will be the measure of the plane angle opposite.

The following propositions show the construction of all the cases of trihedrals or spherical triangles, which are represented by right-lined angles. In each of the cases it will be found, that two of the sides of the spherical triangle are represented by the tangents of the arcs drawn from the same angle; and the angle included by these tangents is the measure of the spherical angle. The representation of the third side is a line joining the extremities of the tangents; the other two angles are measured by this proposition. If each of the three plane angles be denominated *a side,* and each of the three inclinations *an angle,* the geometrical construction will be the same as that of a spherical triangle, and the manner of expressing the data of the one is the same as expressing those of the other. The sides are always measured by the three plane angles of the solid angle.

Problem IV.—*Given two sides and the contained angle; to find the other parts.*

Figure 3.—Make the angle A B C equal to the contained angle; draw B D perpendicular to A B, and B E to B C; make B D and B E equal to each other, the angle B D A equal to one of the containing sides, and B E C equal to the other;

upon C, as a centre, with the distance C E, describe an arc, F; and upon A, as a centre, with the distance A B, describe another arc, cutting the former at F; join F A and F C; then the angle A F C will be the measure of the third side. Now if the triangle A B D be turned round the line A B, the triangle C B E round C B, and the triangle A C F round A C, until the points D, E, F, coincide, each of the two planes, A B D and C B E, will be perpendicular to the plane A B C; therefore, two of the sides of a solid angle will be given, one perpendicular to the other, to find the inclination of the vertical plane with that of the hypothenusal. Proceed, therefore, as in the last problem, and find the angle G H K, which will be the inclination of the two planes C B E and C A F. In the same manner may the inclination of the planes A B D and A C F be found.

Note.—The triangle A B C represents the spherical triangle, of which A B and B C are the tangents of two arcs; and the angle A B C is the spherical angle contained by the arcs, of which A B and B C are tangents.

PROBLEM V.—*The three sides of a spherical triangle being given; to find the angles.*

Figure 4. No 1 and 2.—Make the three angles, A B C, C B E, and E B F, equal to the three sides of the spherical triangle, that is, to contain the same number of degrees. On B, as a centre, with any radius, A B, describe an arc, A F; draw A C and F E tangents at A and F; join C E; draw the straight line G H equal to C E; on the centre G, with the tangent A C, describe an arc at I; and on the centre H, with the tangent F E, describe another arc, cutting the former at I. Join G I and H I; draw I K and I L perpendicular to I G and I H, making them equal to A B or B F; join K G and L H. Now if the triangles, G I K and H I L, be raised on the lines G I and H I, until the points K and L coincide; then each of the triangles, G I K and H I L, will be perpendicular to the triangle G I H. Proceed, therefore, as in the first Proposition, to find the angles, which, in the representation of the spherical triangle I G H, are represented by G and H.

Scholium.—Since each of the extreme angles may be made the middle angle in No. 1, the triangle G H I, No. 2, may be laid down in three different figures, each of which will have as many angles included by each pair of tangents. These three angles, made in each separate triangle, are the measures of the three spherical triangles; but this mode requires more lines than what are described in the above Proposition.

There is another method of finding the angles of a spherical triangle, when the three sides are given, pointed out by Bishop Horsley, at page 215 of his *Elementary Treatises.* The substance of it is as follows: Draw a right angle; make one of the legs equal to the difference of the cosines of the sides containing the required angle; the hypothenuse being equal to the chord of the third side. Upon the remaining perpendicular side, as a base, construct a triangle, whose two other sides are equal to the sines of the sides containing the required angle; then the angle contained by the sines will be the measure of the spherical angle. This may be very easily accomplished by means of a scale of sines and chords from Gunter's scale.

PROBLEM VI.—*Two angles and a side opposite to one of them, being given; to find the other two sides and the remaining angle.*

Figure 5.—Make the angle A B C equal to the spherical angle next to the given side; draw B D and B E perpendicular to B A and B C; make B D of any length, and B E equal to it; and make the angle B D A equal to the measure of the given side; draw A F perpendicular to B C, cutting it in F; make the angle F A G equal to the complement of the other given angle; on the centre F, with the distance F G, describe an arc, G H I; draw C H E a tangent to the arc at H, the same as in the second Proposition; join A C; and the angle C E B will be the measure of the included side. On the centre C, with the distance C E, describe an arc at K; and on the centre A, with the distance A D, describe another arc, cutting the former at K; join A K and K C; then will A K C be the measure of the third side of the spherical triangle.

PROBLEM VII.—*Given two angles, and the contained side; to find the other three parts.*

Make A B C, *Figure* 3, one of the given angles; draw B E perpendicular to B C; make D E C equal to the number of degrees contained in the given side; in B C take any point, G; draw G I perpendicular to C E, cutting it at I, and G K perpendicular on the other side of it; make G H equal to G I, and the angle G H K equal to the other given angle; draw C K A, as in Proposition III., and A B C will be a plane triangle representing the spherical one.

Now, because A B C is the angle included by the tangents, draw B D perpendicular to B A, and equal to B E, and join D A; then B D A is the measure of the side, of which A B is the tangent. On the centre A, with the distance A D, describe an arc at F; and on the centre C, with the distance C E, describe another arc, cutting the former at F. Join F A and F C; then A F C will be the measure of the third side.

PROBLEM VIII.—*Two sides, and an angle opposite to one of them, being given; to find the three remaining parts.*

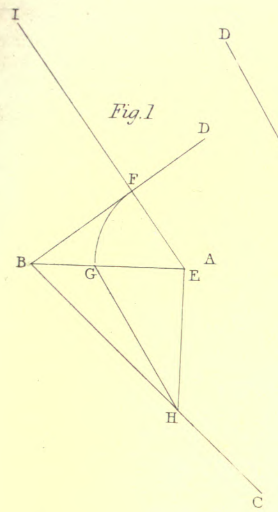
Figure 6.—Draw A C, representing the side adjoining the given angle, and A B perpendicular to it; make the angle A B C equal to the given side; in A C take any point, E; draw E D perpendicular to B C, cutting it in D, and E G perpendicular to A C; make E F equal to E D; and the angle E F G equal to the given angle; draw the line C G H; on A, as a centre, with the tangent of the other given side, describe an arc, K H; and if it cut the straight line C H in two points, H and K, join A K and A H; draw A I perpendicular to A H, and equal to A B; join I H; on the centre H, with the distance H I, describe an arc at M; and on the centre C, with the distance C B, describe another arc, cutting the former at M; join H M, K M, C M; then the angle C A K, or C A H, will be the measure of the spherical angle included by the tangents. The measure of the angle A H C, or A K C, representing the spherical angle opposite the given side, shown by the tangent A C, is found by Proposition I. The angle C M H, or C M K, is the measure of the remaining side, viz., that opposite the angle included by the tangents.

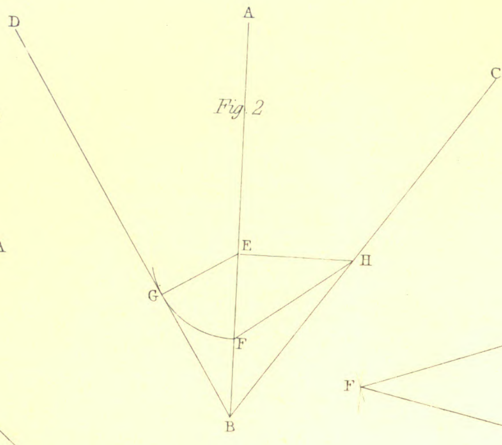
Note.—This case is not always ambiguous; for if A H be equal to, or greater than A C, the arc K H will only cut H C in one point; and, therefore, there can only be one triangle; or, if the angle A H C be a right angle, A H will only touch H C: and in this case also there can be only one.

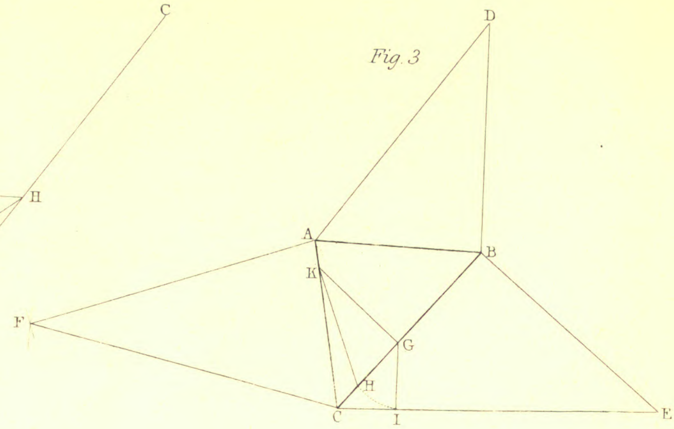
PROBLEM IX.—*The three angles of a spherical triangle being given; to find the three sides.*

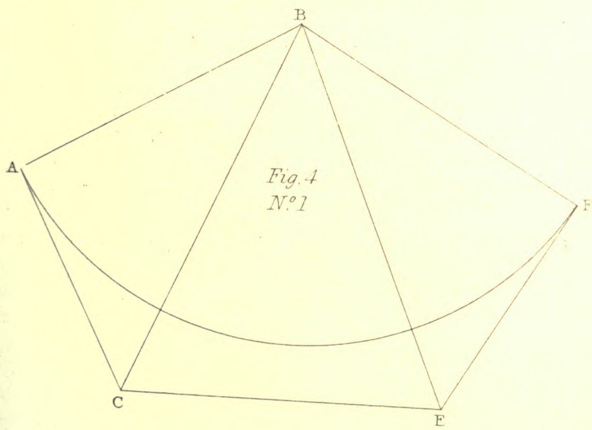
Take the supplements of each of the angles, and describe a triangle, by Proposition V., whose sides are equal to such supplements; and the measure of its angles will be the supplements of the sides of the triangle sought. This is demonstrated by writers on spherical trigonometry.

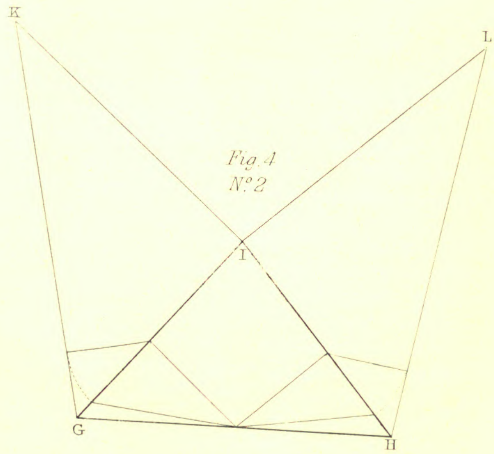
Though the author of this Dictionary has not given formal demonstrations of the preceding Propositions relating to the geometrical construction of spherical triangles, as it would have swelled the article too far, he hopes that enough has been said to enable any one, who has a clear conception of the parts of a spherical triangle, to describe the representation of it, and to find the measure of its parts in the most easy manner, without having recourse to the projection of the sphere, which frequently runs into conic sections, and, from their difficulty of description, renders the projection

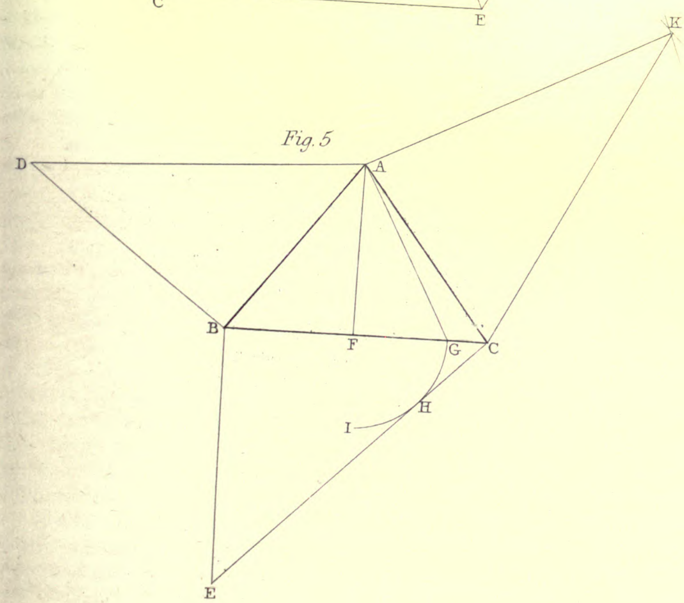


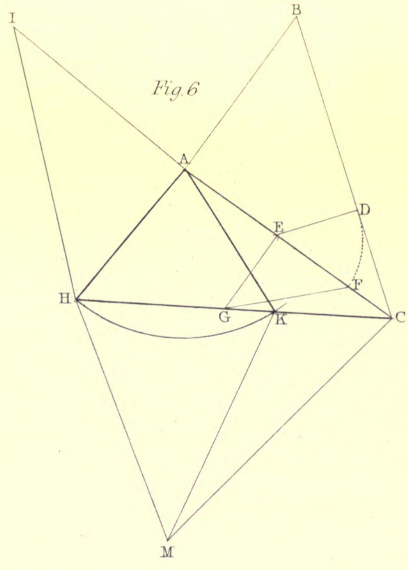












awn by P. Nicholson.

very inaccurate. The representation of the spherical triangle belonging to the preceding Propositions, is nothing else than a plane triangle, which is a tangent to the sphere at one of the spherical angles, and whose sides are bounded by the intersections of the planes of the three great circles of the sides of the spherical triangle; consequently, two of the sides of the representative triangle are always two tangents from the same spherical angle. The included angle by these tangents in the representative triangle is the measure of the spherical angle contained by the sides which the tangents represent. And the third side in the representative triangle is a line joining the extremities of the tangents, as has been already mentioned. In another point of view, the whole may be conceived to be a pyramid, whose sides are planes from the centre of the sphere, passing through the three arcs of the spherical triangle; and its base a triangle, a tangent to the sphere at one of the angles, which meets the sides. The vertical angles of the sides of this pyramid are the measures of the sides of the spherical triangle: the angles of the pyramid are the measures of the spherical angles: and the base of the pyramid is the representative triangle. Consequently, one of the angles of the pryamid is always perpendicular to the base. The angle intercepted by the two planes upon the base is equal to the inclination of the planes.

The triangle belonging to the preceding Propositions is such, that when all the parts are completed, the sides may be turned up upon the base, which is the representative triangle, until the edges of all the triangles forming the sides are united in one common vertex. A pyramid will then be formed, equal, similar, and situated like that above.

The Rev. George Walker, in his ingenious doctrine of the sphere, Proposition I. p. 258, shows, that "if there be a spherical triangle, and a plane quadrilateral figure be formed, two of whose sides are the secants, the other two the tangents of two of the sides of the spherical triangle, and the angle comprehended by the secants be measured by the spherical base, the angle comprehended by the tangents shall be the measure of the spherical angle opposite the base; the diagonals of the quadrilateral shall intersect each other at right angles; the segments of the diagonal joining the angle of the secants, and the angle of the tangents shall be the secant and tangent of the spherical perpendicular, drawn from the vertical angle to the base; the angle which this diagonal makes with the secants, shall be measured by the spherical segments of the base; and the angles which this diagonal makes with the tangents, shall be the measures of the spherical angles which the perpendicular makes with the sides." This theorem is very analogous to Problem V.; but the properties shown by it do not apply to the construction from any given data, nor can all the parts be found from any one datum; they may be very well applied when two sides and the contained angle are given, or when the three sides are given, by varying the triangle, as has been here shown, in order to find the other two angles; but this is both troublesome and inelegant. From what has been said, it will be easy to construct any solid similar to any other solid given, whose sides are planes, by constructing each solid angle, that is, by dividing it into as many solid angles, each consisting of three plane angles, wanting two, as the number of plane angles bounding the whole solid angle; then constructing the figure of any side, of which a plane angle of the described solid angle is one similar to the side of the solid given. From the several angles of this figure construct other solid angles in the same manner.

Problem X.—*Given the seat,* A B, *of the intersection in space of two planes, having a given inclination, and the intersection,* A C, *of one of them in a given plane,* Y; *also the inclination of the common intersection of the two planes to the plane* Y; *to find the intersection of the other plane with* Y.

Figure 7.—Make B A D equal to the inclination of the intersection of the two planes; from any point, D, draw D E perpendicular to A D, cutting A B at E; make E B equal to E D; draw E C perpendicular to A B; make the angle C B F equal to the inclination of the planes, of which the seat of their intersection is A B; let B F meet E C in F; and join A F; then will A F be the intersection required.

Or thus: Through any point, E, in A B, draw C E perpendicular to A B; make E A D equal to the inclination of the intersection; draw E D perpendicular to A D; make E B equal to E D; join B C; make the angle C B F equal to the inclination of the planes, which have A B for the seat of their intersection; let B F meet C E in F; and join A F; then will A F be the intersection required.

Demonstration.—Imagine the triangle A D E to be turned upon A E, until it becomes perpendicular to the plane, Y; let the plane Z be turned upon C E, until E B fall upon E D; that E B will fall upon E D is evident, since E B, in revolving upon E C, will always be in a plane passing through E perpendicular to C E; and E D is also in a plane passing through E perpendicular to C E; and since E B is equal to E D, E B must fall upon E D, and the point B upon D; and the plane A E D will be perpendicular to the two planes C E A and C E B; therefore A D will be perpendicular to the plane C E B; whence it is manifest, that C B F is in a plane perpendicular to the common intersection, and is the measure of the inclination of the planes.

Problem XI.—*Given,* I N, *the intersection of a plane,* W, *with another plane,* X, *and their inclination, the seat,* A B, *in the plane,* X, *of a line in space insisting at* A, *and the inclination of the line to the plane* X; *to find the section of the line in the plane* W.

Figure 8.—Through any point, B, in A B, draw B S perpendicular to I N, cutting I N at E; make the angle B E F equal to the inclination of the plane; draw B G perpendicular to B S; make B G the tangent of inclination to the radius A B; draw G F parallel to B S; through A, draw any two lines, A J and A K, cutting I N at J and K; make E S equal to E F; through S, draw V L parallel to I N; produce B S to P; make S P equal to F G; draw P V parallel to A K, and P L parallel to A J; and join K V and J L, cutting each other at *a;* and *a* will be the section of the line in the plane W, as required.

For, imagine the triangles B E C and C G F in the same plane to be turned upon B E, so that their plane may be perpendicular to the plane X; then B G will be perpendicular to the plane X, and the point G will fall in the line in space: imagine also the plane W to be revolved upon I N, until E S falls upon E F, as is evident for the same reasons as given in the first Problem, and the point S will fall upon F; then the line V L will become parallel to the plane. In revolving the plane W upon I N, imagine the plane Y to revolve upon V L at the same time, so that the plane Y may always continue parallel to the plane X, then V P will continue parallel to A K, and L P parallel to A J; then, as in perspective, X is the original plane, W the plane of the picture, Y the vanishing-plane, G or P the place of the eye coinciding therewith, I N the intersecting line, V L the vanishing-line, J, K, the intersecting points, V L the vanishing-point, and the original line would be a visual ray; therefore, by the theory of perspective, *a* is the representation of the point A.

Problem XII.—*The same things being given, and the constructive lines remaining as in the preceding Problem, as also the point a, the section of the line in space; to find* *the seat of the line in the plane* W, *and its inclination to the said plane.*

Figure 9.—Draw G Q perpendicular to E F, meeting E F in Q; in E P, make E T equal to E Q, and join T *a;* draw T R perpendicular to *a* T; make T R equal to Q G, and join R *a;* then will T *a* be the seat of the line in the plane W, and T *a* R its inclination to the said plane.

Demonstration.—For when E S is made to coincide with E F, as in the last Problem, the plane F C G will be perpendicular to the plane of the section W; but the line F C being now in the plane W, and Q G being perpendicular to F C, Q G will also be perpendicular to the plane W; but the point G, that is R, is a point in the line, whose seat is A B, and the point *a* is another point in the line, whose seat is A B; therefore, R and *a* are two points in the line, whose seat is A B; then join *a* R, which will be the part of the line in space on the other side of the plane W, and *a* T its seat.

Scholium.—This amounts to the same as when the seat and distance of the eye are given with respect to the original plane, and the position of a point in the said plane; to determine the seat and inclination of the visual ray.

PROBLEM XIII.—*Two straight lines,* A B *and* C D, *tending to an inaccessible point, being given; through a given point,* E, *to draw a third straight line, to tend to the same inaccessible point.*

Figure 10.—From any point, A, in A B, draw a straight line, A E, from A to the given point E, cutting C D in C; and through any other convenient point, B, draw B F parallel to A E, cutting C D in D; find D F, a fourth proportional to A C, C E, B D, and join E F; then will the lines A B, C D, and E F, tend to the same point of concourse.

Scholium.—It sometimes happens, that a number of lines radiate from the same point, and that from a given point it is required to radiate other straight lines so as to meet the radiations given in a given straight line: some, or many, of these radiations, according to their number, will be inaccessible; and though they may be all found by this Problem, yet if the several operations are combined in one, much trouble will be saved.

Figure 11.—Thus, let the radiations be A B, A C, A D, A E, A F, tending to the straight line B C; and let *a* be a given point, from which it is required to radiate other straight lines to meet or tend to the same points in B C, with those drawn from A. Join A *a*, cutting B C in G; and through any convenient point, C, in B C, draw F *f* parallel to A *a;* make C P equal to G A, and C Q in B C, produced to *o*, equal to G *a;* join P Q; let A D, A E, meet C F in D and E; draw D *m*, E *n*, F *o*, parallel to P Q, cutting R *o* at *m*, *n*, *o;* make C *d* equal to C *m*, C *e* equal to C *n*, C *f* equal to C *o;* draw *d a*, *e a*, *f a*, which are the lines required.

Example 1.—*Given the meridian,* A B, *in the plane of the horizon,* X, *the latitude of the place, the intersection,* I N, *of the plane,* W, *with the horizontal plane,* X, *and the inclination of the plane,* W, *to that of the horizon* X; *to construct a dial in the plane* W.

Figure 12.—In A B, take any point, A, for the foot of the style; then A B will be the seat of the style, or of the line tending to the pole; the latitude of the place is its inclination. Find *a*, the representation of A, that is, the section of the style of the dial in the plane W, by the eleventh Problem; produce A B to meet I N in D; draw D *a* in the dial plane W; then, by the twelfth Problem, find *a* T, the seat of the style in the plane W, and the angle of elevation T *a* R: and by the tenth Problem, find the intersections, U *a*, Y *a*, Z *a*, &c., of planes passing through the style, making angles respectively of 15°, 30°, 45°, 60°, &c., with the vertical plane passing through the meridian, A B; that is, with the plane whose intersection is T *a:* the inaccessible lines are also found by the last Problem; and the dial is constructed as required: *a* T is the seat of the style, whose intersection is T *a;* T *a* R its inclination; *a* D is the 12 o'clock line; and U *a*, Y *a*, Z *a*, &c., are the hour-lines.

Another method of finding the sub-style is thus: produce G Q to meet P E in H; join H A, which produce to N; and draw N *a*, the sub-styler line. Thus, upon one common principle, the sections of lines, planes, and solids, may be found. The sections of solids are found by means of the sections of planes; and the construction of a dial is only finding the sections of planes, whose positions are given. This method is, perhaps, of all others the easiest to consider and to construct.

Example II.—*Given the base,* A N Q R, *of a pyramid, in the plane* X, *and the whole seat,* A B, *of one of its angular lines, the intersection,* I N, *of the cutting plane* W, *and the inclination of the planes* W *and* X; *to find the section of the pyramid.*

Figure 13.—Find the vanishing line, V L, of the plane X, and the vanishing points, V and L, of the lines A R, N Q, A N, R Q; produce A R to K, N Q to M, A N to J, and R Q to L, to meet the intersecting-line I N; join K V and M V, also J L and L L; then *a n q r* will be the section of the pyramid insisting upon A N Q R.

Example III.—*To find the section of a prism, the same things as before being given.*

Figure 14.—Find the vanishing-points, V and L, of the lines A J and A K, and the representations, K V and J L, as before; draw L *r* parallel to J L, and M *n* parallel to K V; and *q n a r* will be the section of the prism required.

Plate 3. *Figure* I.—*To find the section of a right pyramid.* Suppose a trahedral, or solid angle, consisting of three plane angles, two of which are at right angles to each other; let the base of the solid be disposed in one of the planes which form the right angle, and let the cutting plane be the plane angle which subtends the right angle; let *x*, or G P F be the plane angle on which the base of the solid is to be placed; Y, or *g* P G, the other plane angle, standing perpendicular to the plane X; and *g* P *f*, or Z, the hypothenusal plane angle; the three angles being developed, or unfolded upon one plane. Here P F will be the intersection of the cutting plane with the plane of the base. In the plane X, let A B C D be the base of the pyramid parallel to the intersection, E P; find the centre, E; produce A D from each extremity, to meet P F in F, and P G in P; through E draw H parallel to A D, or B C, meeting P F at H, and P G at I; produce B C both ways, to meet P F at K, and P G at L; draw E N parallel to A D, meeting P G at N; produce A B to meet P G at M, and D C to meet P G at O; draw I Q and N R, each perpendicular to P G, and in length equal to the height of the pyramid; join G Q at L Q; also O R and M R; let P *g* be cut by G Q in *g*, I Q in *i*, L Q in *l*, O R in *o*, N R in *n*, and M R in *m*; transfer P F, P H and P K, to P *f*, P *h*, and P *k;* join *f g h k l;* parallel to P *f*, draw *m a* and *o d*, cutting *f g* at *a* and and *k l* at *b* and *c;* then the quadrilateral *a b c d* will be the section required.

Figure 2.—*To find the section when the base of the pyramid is oblique.*

Let A B C D be the base; find the points *g*, *i*, *l*, and F, H, as before; produce A B and D C to meet O F at M and N; transfer O F, O H, O K, O M, and O N, to O *f*, O *h*, O *k*, O *m*, O *n*, draw the diagonal B D, and produce it till it meet O F in T; transfer O T to O *t*, and produce O G and B D to meet each other; from the point of section draw a line, in the plane Y, perpendicular to O G, cutting O *g* produced; join *t* with the point of section; also join *g f*, *i h*, and *l k*, and let *g f* and *l k* cut

Fig. 7

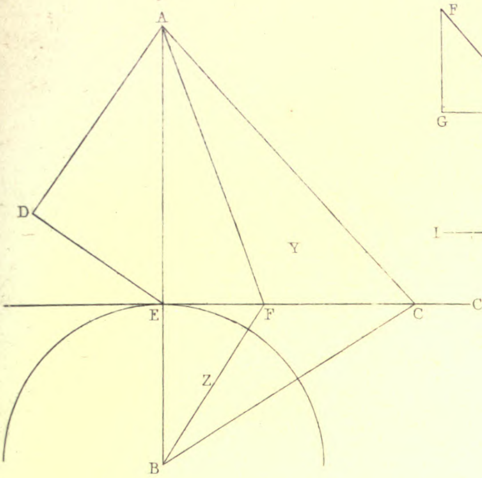


Fig. 8

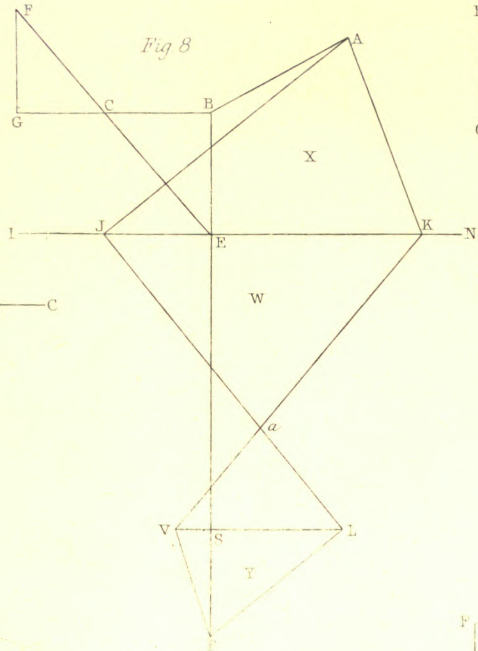


Fig. 9

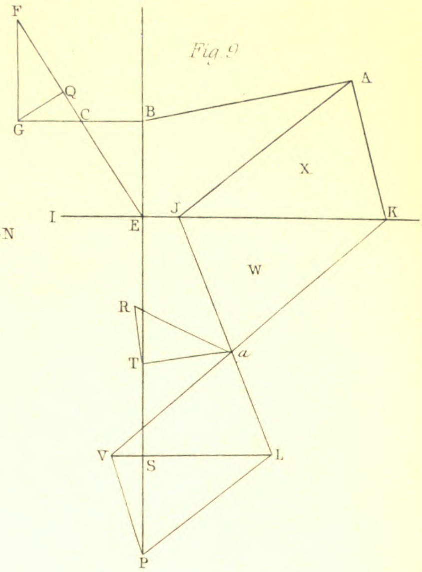


Fig. 10

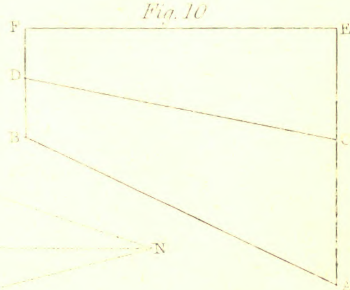


Fig. 12

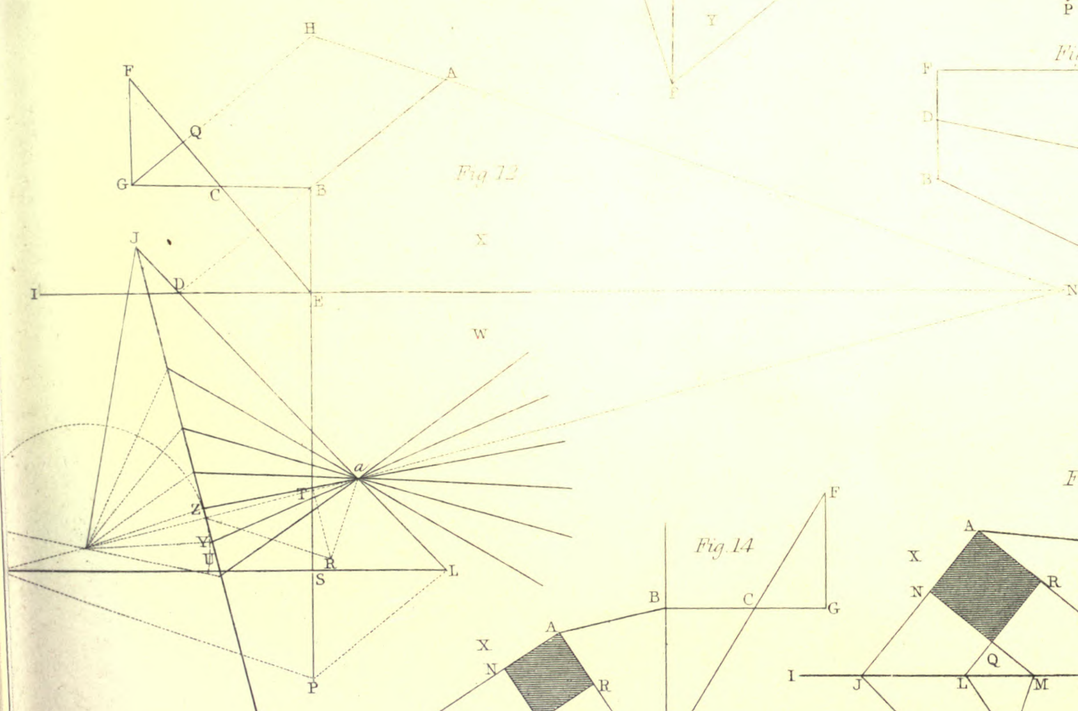


Fig. 13

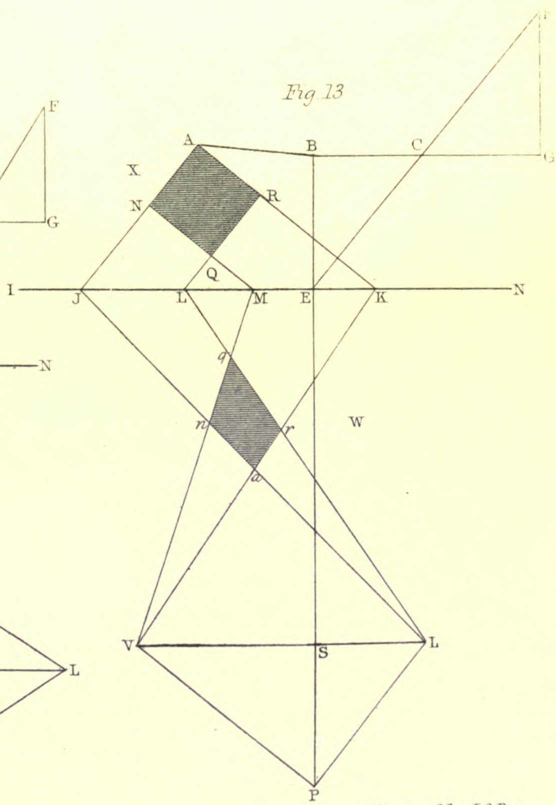


Fig. 14

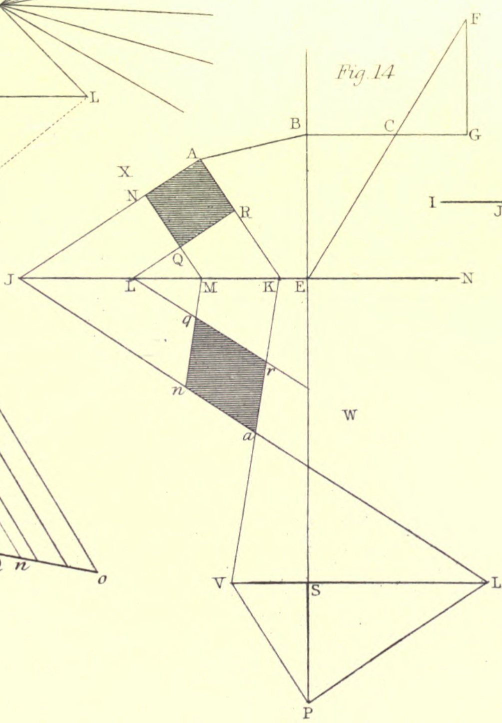
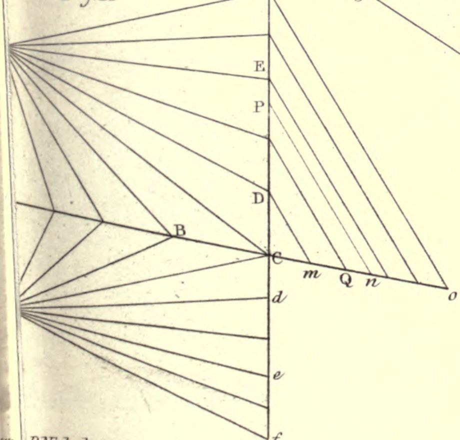
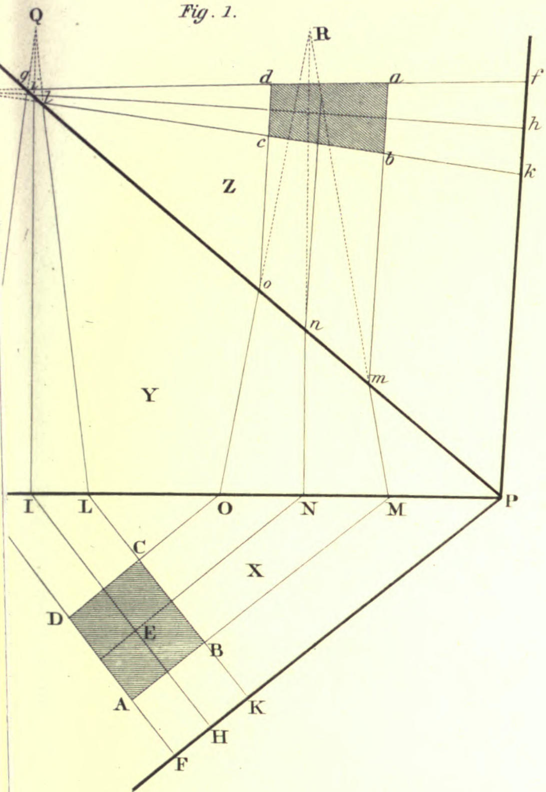


Fig. 11





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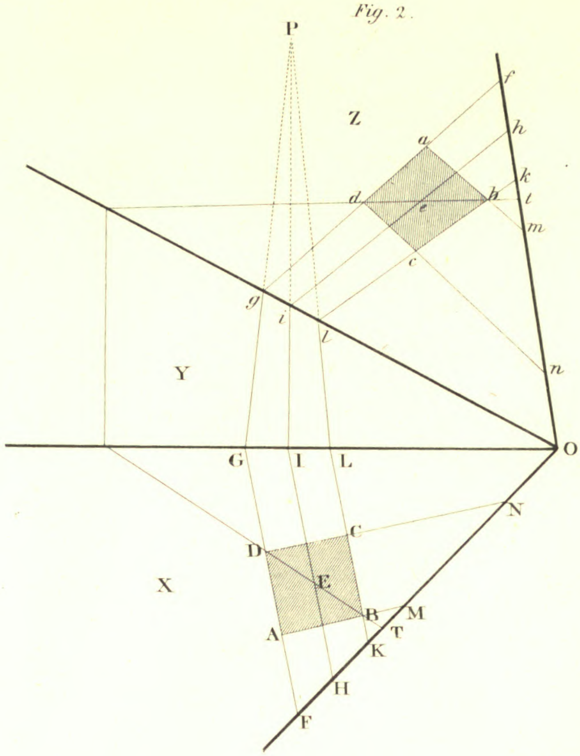

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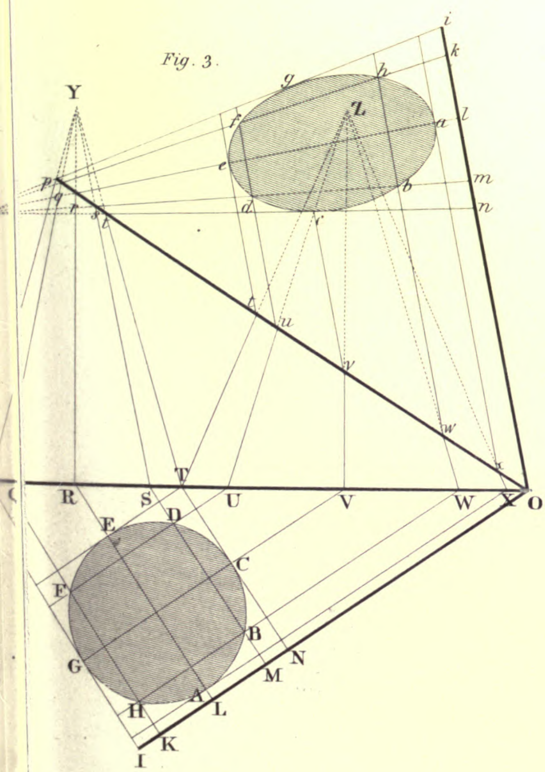

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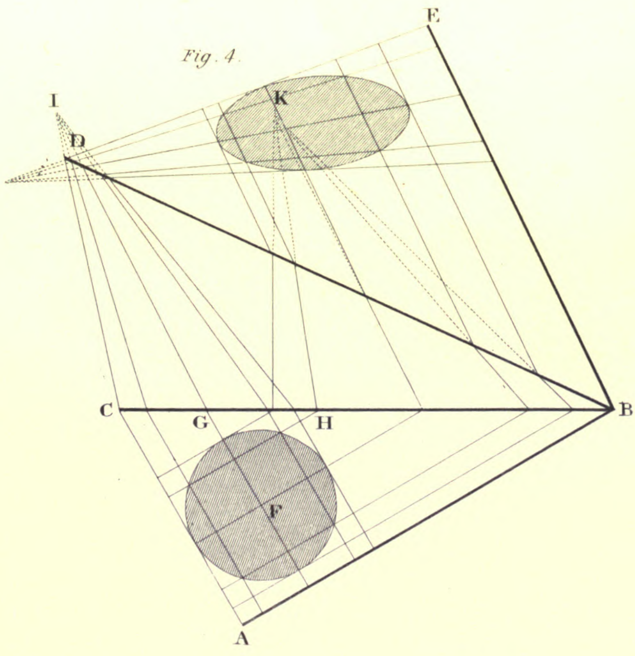

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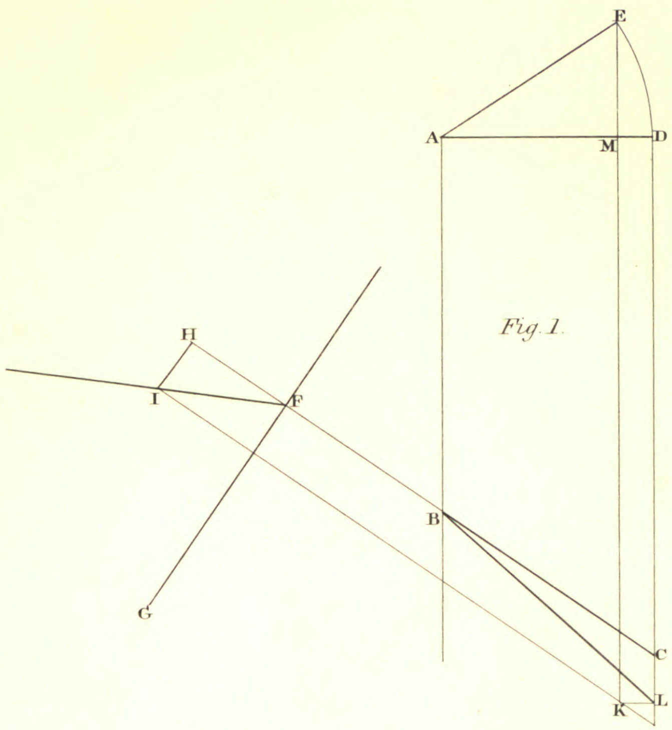

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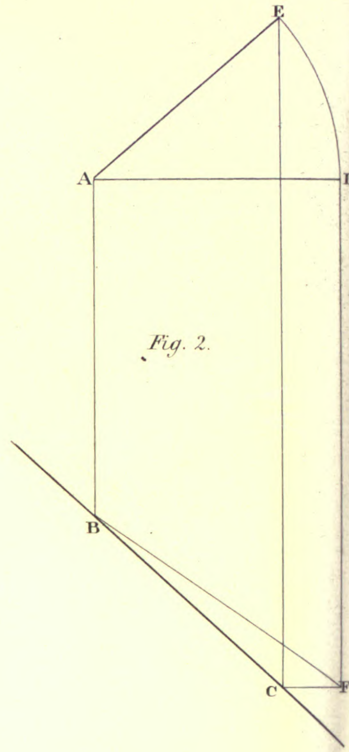

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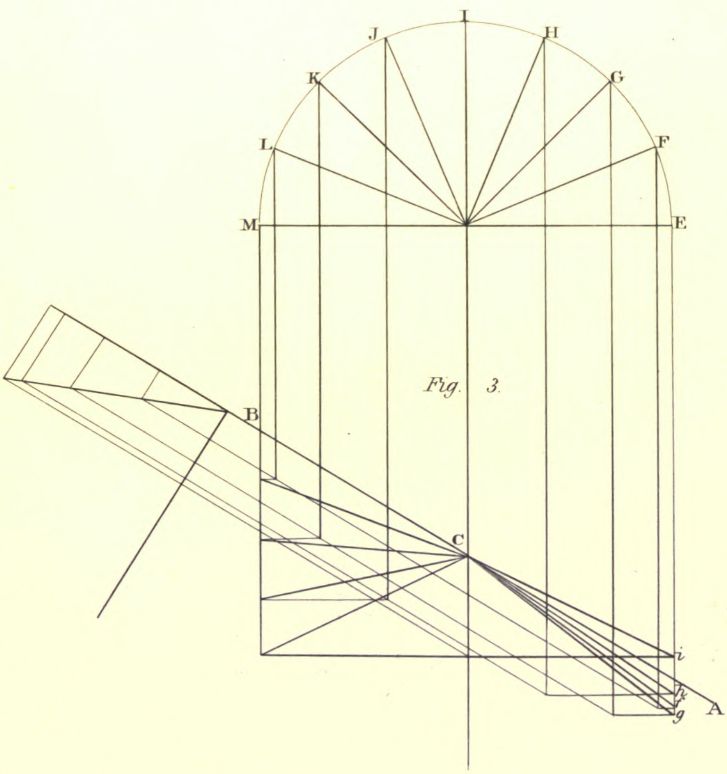

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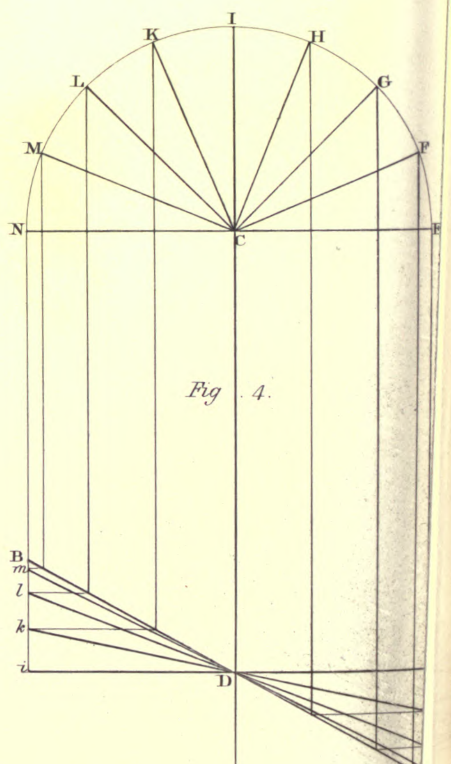
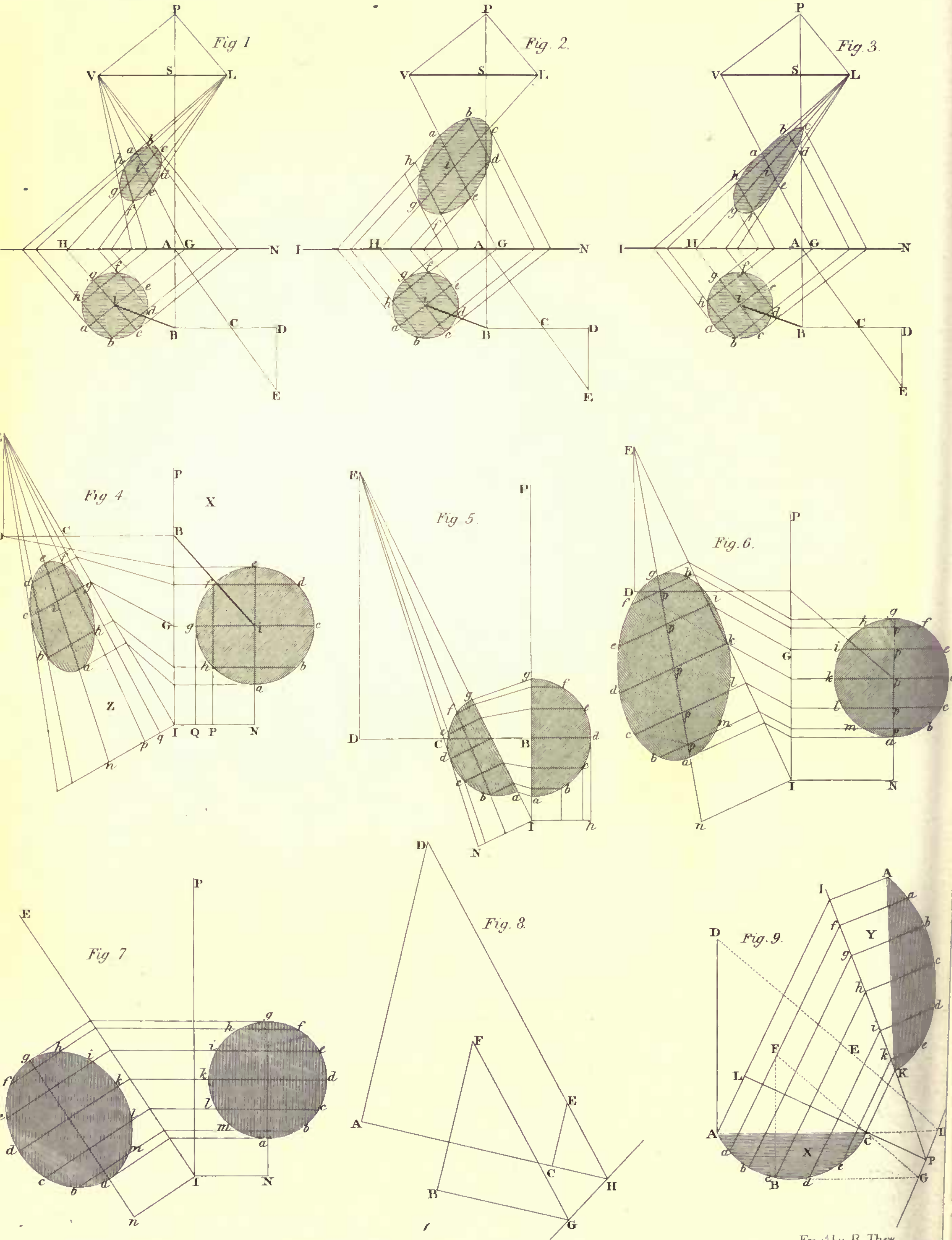


Fig. 4.

Invented & Drawn by P. Nicholson

Eng^d by R. Thew.



Drawn by P. Nicholson. Eng^d by R. Thew.

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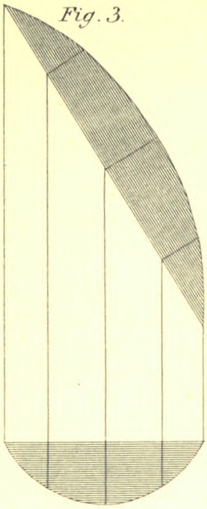

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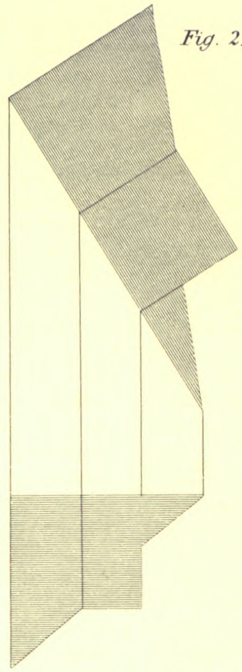


Fig. 1.

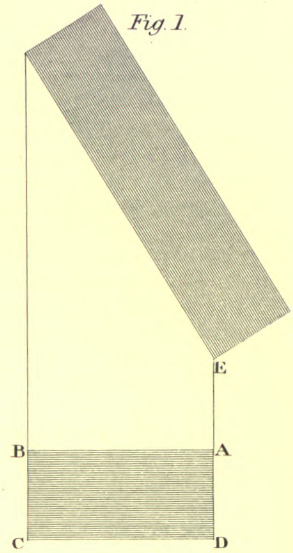
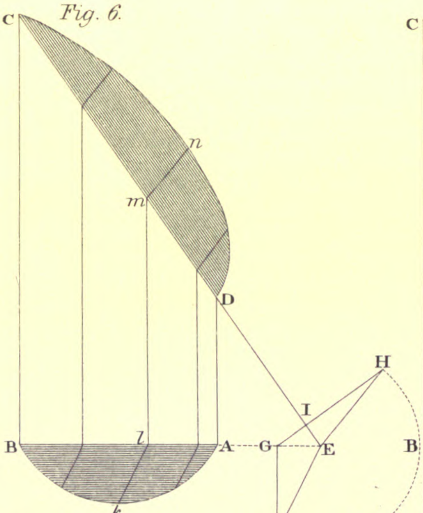


Fig. 6.



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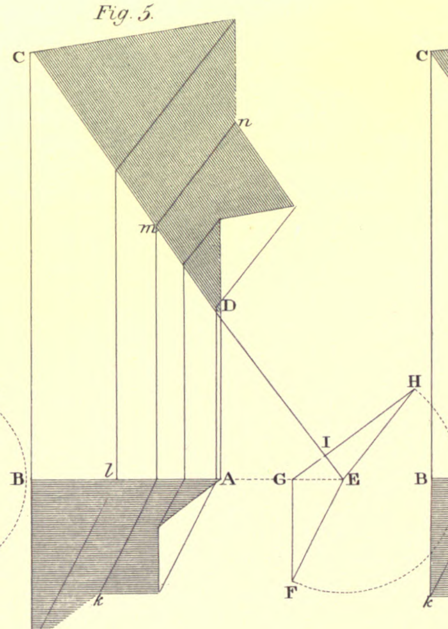

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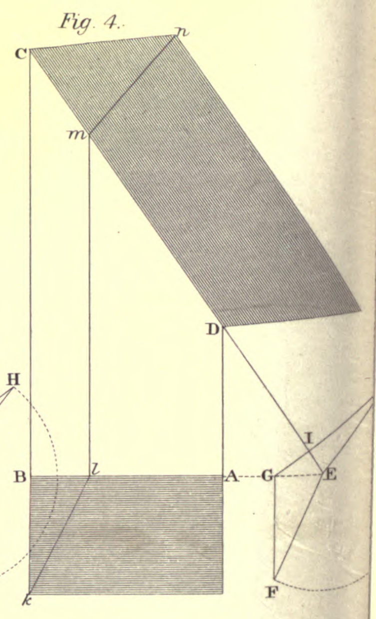


Invented & Drawn by P. Nicholson.

Engd by R. Thew.

line drawn from t to the point of section in o g produced; join $b\ m$ and $d\ n$; produce $m\ b$ to meet $f\ g$ at a, and let $d\ n$ meet $l\ k$ at c; then will $a\ b\ c\ d$ be the section required.

Figure 3.—*To find the section of a right cone.*

Let the circle A B C D E F G H be the base. Find the centre of the circle, and draw through it G V, parallel to I O, cutting O P at V, and the circumference at G and C; through the same point draw R L, perpendicular to I O, cutting I O at L, O P at R, and the circumference at A and E; divide the quadrants A C, C E, F G, G A, into any number of equal parts, as two, through the points of division draw lines parallel to G V and R L; one on each side of, and parallel to A E, cutting O P in Q and S; and the other parallel to G C on each side of it, cutting O P in U and W; draw R Y at Z, each equal to the height of the cone; draw P Y, Q Y, S Y, T Y, cutting O p in p, q, r, s, t respectively; also draw T Z, U Z, X Z, W Z, cutting O p in x, w, u, t; make O i, O k, O l, O m, O n, respectively equal to O I, O K, O L, O M, O N; join $p\ i$, $q\ k$, $r\ l$, $s\ m$, and $n\ t$; draw $x\ a$, $w\ h$, $v\ g$, $u\ f$, $t\ c$, parallel to O i, cutting $r\ l$ at a and e; $k\ q$ at f and h, and $m\ s$ at b and d; then $a\ b\ c\ d\ e\ f\ g\ h$ will be the section required.

Figure 4, shows how the section of an oblique cone is found; the method is the same as for a right cone: except that the intersection, B C, must be placed parallel to the inclination; by which means the axis, G I, has the same inclination to B C, which the axis has to the plane of the base.

Plate 4, is exceedingly useful in finding the bevels of the stones of oblique cylindric arches, where the joints of the stones run in planes perpendicular to the axis of the cylinder.

We shall here begin with the most simple case, which is *figure* 2. Let A B represent the axis of the cylinder, and let B C represent the plane of the arch; draw A D perpendicular to A B, and make the angle, D A E, equal to the inclination of the bed of a stone with the horizon; from the centre, A, with any radius, A E, describe the arc E D. Draw E C and D F parallel to A B, and C F parallel to A D; join E F; then if A B be the under-side of the joint or bed in the intrados of the arch, the angle, A B F, will be the angle which the under-side of the joint makes with the face of the arch.

Figure 4.—Exhibits the bevels for a complete arch, consisting of seven joints.

Figure 1.—Shows the method of finding the joints when the plane of the sides of the arch are not perpendicular to the horizon. Let A B represent the axis of the cylinder as before, B C the insisting-line of the side of the arch: produce I C to F; draw F G perpendicular to F C; make the angle, I F I, equal to the inclination of the end of the arch, and the plane of the horizon.

Figure 3.—Shows the joints for a complete arch.

Plate 5. *Figure* 1.—Exhibits the method of finding the section of a cone upon the general principles, as explained in *Plate* 2 of this article.

Figure 2.—The lines for the section of a cylinder.

Figure 3.—The lines for the section of a cuneoid.

Figure 4.—Another method for finding the section of a cone, which is plain to inspection, the principles being nearly the same as before.

Figure 5.—Section of a right cone.

Figure 6.—Section of an oblique cylinder.

Figure 7.—Section of a right cylinder.

Figure 8.—Method of the intersection of a plane from three given points, and the heights upon these points.

Figure 9.—Method of finding the section of the segment of a cylinder.

The principles and methods for these having been previously explained, it is presumed that, by barely inspecting the figures, the methods of tracing them will be sufficiently obvious without having recourse to the references of the letters.

Plate 6. *Figures* 1, 2, and 3.—Method of finding the section of a right prism when the plane of the section is perpendicular to one of the sides of the prism.

Figures 4, 5, and 6.—Method of finding the section of a right prism when the plane of the section is oblique to one of the sides of the prism, according to three given heights. *See* CYLINDER.

STERLINGS, *see* STILTS.

STILES, (from the Saxon, *stigele*,) in joinery, the vertical parts of a frame, into which the ends of the rails are fixed by mortises and tenons.

STILTED ARCH, an arch whose springing-line is above the impost, or which is raised, as it were, upon upright stilts or props.

STILTS, (from the Saxon *stælean*, supporters,) a set of piles driven into the ground-plot for the intended pier of a bridge; the tops of which being sawn to the low-water mark, the pier is raised upon them; a method formerly used, when the bottom of a river could not be laid dry. The stilts were surrounded, at a few feet distance, by a row of piles, with planks laid close to them, after the manner of a coffer-dam; this was called a *sterling*, or *jettee*; after which, loose stones, &c., were thrown into the space till it was filled up to the top; so as to form a kind of pier of rubble, or loose-work, which was kept together by the sides of the sterlings: the piling was then paved level at the top, and the arches were turned upon it. Most of the large old bridges in England were erected upon this method; but the inconveniences attending it are so great, that it is now quite exploded; for, on account of the loose composition of the piers, they must be made very large and broad, otherwise the arch would push them over, and fall down as soon as the centre was drawn. This great breadth of the piers and sterlings necessarily contracts the water-way so much, as not only to incommode the navigation through the arch, from the fall and quick motion of the water, but it also causes the bridge itself to be in danger, particularly in time of floods; besides this, there is great danger of the pier bursting out the sterlings, which are also subject to decay and damage, from the velocity of the water, and the passing of craft through the arches.

STOCK, (from the Saxon *stoc*,) a boring instrument, consisting of a double crank, so that one end may rest against the workman's breast, and the other upon the wood intended to be bored. It is provided with several steel cutters, called *bits*, of different dimensions, according to the holes to be made. It is, therefore, in London, called *stock and bits*, but in most country places, *brace and bits*.

STONE, (from the Saxon *ston*,) a hard mineral substance, not soluble in water, employed in the construction of edifices; of these there are various kinds, as described more largely under the article MATERIAL.

STONE ARCH, an arch constructed of stone: the general principles of the construction of which will be found under the article MASONRY.

STONE BRIDGE. In a former article, (BRIDGE) a general historical view has been taken, of the rise, progress, and present state, of bridge-building, exemplified in descriptions of the most celebrated edifices of the kind, in various parts of the world. Under the present head, the theory of the art will be principally considered; and we shall avail ourselves of the permission granted to us by the late Thomas Telford, Esq., to make considerable extracts from the able article on this subject, written by him for the Edinburgh Encyclopedia.

"The construction of a magnificent stone bridge, is justly looked upon as one of the greatest performances of the masonic art: for if we compare the enormous weight of a great arch, with the strength which the cohesion of the firmest cement can give, we readily admit, that it is only by the nicest adjustment and balancing of its parts, that they are hindered from instantly falling to pieces.

"Though there can be little doubt that the Romans, and latter Greeks, had paid some attention to this subject, from the beautiful specimens of their architecture which exist even in our times; yet, in none of their authors, either practical or scientific, is the smallest light afforded us respecting the principles upon which their practice was regulated.

"The architects of the middle ages, who constructed those great cathedrals, that are still the ornament of the chief cities in Europe, and the delight of the architectural antiquary, seem to have fondly indulged in the balancing of arches. They were, without doubt, directed by maxims which had been elicited from a varied and extensive practice; but whatever these were, they are to us unknown. None of these architects, though many of them were men of learning, seem ever to have committed to writing, either the history of any such erection, or the principles by which its construction was regulated. Nay, this knowledge seems rather to have been carefully kept secret, and regarded as a sort of mystery; a craft which was only to be communicated to the *brethren*, whose experience and skill had already qualified them to be initiated into the mysteries of the sublime degree.

"It does not appear that a knowledge of this subject could be acquired otherwise than by experience. The mathematical sciences were then little known, and we may see from the construction of the bridges of that age, that the priests, who were the only architects, have had in their eye, rather, the successive vaulting of a Gothic cathedral, than to have originally considered of the best way of forming a permanent and convenient road. It was only about a century ago, when Newton had opened the path of true mechanical science, that the construction of arches attracted the attention of mathematicians. Since that time, volumes have been written respecting the equilibrium of arches. It has been found one of the most delicate, as it is one of the most important, applications of mathematical science. Yet with all due deference to the eminent men who have prosecuted this subject, we are much inclined to doubt whether the greater part of their speculations have been of any value to the practical builder. He is still left to be guided by a set of maxims derived from long experience, and, as yet, little improved by theory. In truth, his works seldom fail, even where they differ furthest from the deductions of the theorist; and at all events, he finds that a much greater latitude is allowable than theory seems to warrant. He is therefore surely excusable in doubting of the justice of such theories, at least until they are more consonant to the approved practice.

"It is our intention, in the present article, to point out a new mode of considering this subject, to which, with great diffidence, we request the attention of the intelligent practitioner. It may indeed still be deficient, if not in some respects erroneous, but it will, we think, have this merit, that of being readily apprehended, and easily applied, without requiring much previous scientific information. Indeed, though we highly value the sublime geometry, we are inclined to think that the unnecessary parade of calculus in the application of science to the arts, has been one of the chief causes of the dislike which many able practical men of our country have shown to analytical investigation.

"Nevertheless, as many of our readers are well qualified to comprehend, and will naturally expect that we should point out, the modes of investigation usually pursued in this interesting subject, we shall previously, and in as succinct a manner as possible, endeavour to lay before them the commonly received theory of equilibration. From which, having cleared away the useless rubbish, if we can extract any proper materials, we may, like economical builders, make good use of them in our future structure.

"The first thing like a principle that we meet with is the assertion of the eminent Dr. Hook, that the figure into which a heavy chain, or rope, arranges itself, when suspended at the two extremities, being the curve commonly called the *catenaria*, is, when inverted, the proper form for an arch; the stones of which are all of equal size and weight.

"Now, as this idea, strictly just, has been very generally adopted, and affords some useful hints, it may be well worth while to examine it.

"*Figure* 1.—Let A B be a string or festoon of heavy bodies, hanging by the points A, B, and so connected, that they cannot separate although flexible. These bodies having arranged themselves in the *catenaria* A C B, conceive this to be turned exactly upside down. The bodies A and B being firmly fixed, then each body in the arch A D B, being acted on by gravity, and the push of its two neighbours, with forces exactly equal and opposite to the former, must still retain its relative position, and the whole will form an arch of equilibration.

"This arch, however, would support only itself; nay, a mere breath will derange it, and the whole will fall down. But if we suppose each spherule to be altered into a cubical form, occupying all the space between the dotted lines, the stability will be more considerable. And as the thrust from each spherule to its neighbour is in a direction parallel to the tangent of the arch at the point of junction, it is obvious, that the joints of our cubical pieces must be perpendicular to that, so as to prevent any possibility of sliding.

"Our arch is now composed of a series of truncated wedges, arranged in the curve of the *catenaria*, which passes through their centres; and we are disposed, with David Gregory, to infer, that when other arches are supported, it is only because in their thickness some *catenaria* is included.

"This curve is, indeed, the only one proper for an arch consisting of stones of equal weight, and touching in single points, but is not at all adapted to the arch of a bridge, which, independent of the varying loads that pass over it, must be filled up at the haunches, so as to form a convenient roadway. In this case, some further modification becomes necessary.

"*Figure* 2.—The haunch, E, of the arch A C B, bearing a much greater depth of stuff than the crown, it must be so contrived as to resist this additional pressure. Every variation of the line F G H, or extrados, will require a new modification of the curve A C B, or intrados, and the contrary. Accordingly, M. De la Hire has suggested a good popular mode of investigating this subject. Let it be required to determine the form of an arch of the span A B, and height C D, proper for carrying a road-way of the form F G H. Mark off upon a vertical wall, the points A, C′, B, inverting the required figure: suspend from A B an uniform chain or rope, so that its middle may hang a little below the point C′, and dividing the span, A B, into any number of equal parts, and drawing the perpendiculars *a b*, *c d*, &c., suspend from the intersections, *e*, *f*, bits of chain, *e b*, *f d*, &c., so trimmed, that their ends may fall on the line of the road-way; and it may be observed, that as those pieces, which hang near the haunch, will bring it down, the crown, C′, will thereby be raised into its proper position.

"But although this mechanical way of forming an equilibrated arch be founded upon principles sufficiently just, and be perhaps the simplest and best way in which the practical uilder could form the original design of such an arch; yet is it affords no general rules that may be applied to the construction of arches, we proceed to consider the same subject n a mathematical point of view.

"*Figure* 3.—And first, then, in the semicircular polygon, is it is called, where weights are hung on the thread A C′ C C″ B, which bring it into the position A C B, we have at each ingle three forces in equilibrio. Wherefore, by the principles of statics, they are to one another as the sines of the opposite angles; that is, the tension r C is to the tension l C, is sine l C W is to sine r C W, but the tension from C to l is the same as from C′ to r. Also, sine l C W is the same as sine r' C′ W′, since these angles are supplementary, C W, C′ W′ being parallel; therefore the tension r C is to the tension r' C′ is sine r' C′ W′ to sine r C W. *Or, the tension in each part of the chord is inversely as the sine of its inclination to the vertical.*

Again, we have as sin. d C l : sin. r C l : : tension r C : tension d C $= \frac{r \text{ C} \times \sin. r \text{ C } l}{\sin. d \text{ C } l}$; but as r C is inversely as sine r C d, therefore tension d C is as $\frac{\sin. r \text{ C } l}{\sin. r \text{C} d \times \sin. d \text{ C } l}$. Now, let an unlimited number of weights be hung from the chord, indefinitely near each other, and our polygonal thread becomes a curve; *Figure* 4 being in fact the curve of equilibration adapted to the weight which depends from it. The angles r C d and l C d become r' C d and l' C d, which are supplementary, and have equal sines, wherefore the product of these sines is the square of either. Also, as the sine of r C l or r C r' is as the curvature, or reciprocally as the radius of curvature, we have tension d C, or weight on C, inversely as rad. urv. $\times$ $\sin.^2$ inclination to vertical.

"This tension, in the present case, is usually produced by he gravity of the superincumbent materials, and may be neasured by the area contained between two indefinitely ear vertical lines E F, $e f$, *Figure* 4; but while the distance e is constant, the area F e will diminish with the sine of F e, as E e becomes more upright. To countervail this, we aust enlarge the depth E F in the same proportion as sine e F diminishes. And, therefore, we have E F inversely as ad. cur. $\times$ $\sin.^3$ F E e. *That is, the height of the superincumbent matter must be inversely as the radius of curvature, nto the cube of the sine of the inclination of the curve to the rtical.*

"Let us proceed to apply the theory to some practical ises.

"If the arch be the segment of a circle, then the radius of rvature is the same throughout, and the height will be inrsely as the cube of the sine of inclination to the vertical. nd from this we derive the following very simple construcon, for describing the equilibrating extrados of a circular ch, and which the reader, who has examined this subject, ll find much easier than those commonly given.

"*Figure* 5.—At any point, D, draw the vertical D d, and D from the centre C; then laying off D a equal to the thickss at the crown, draw the perpendiculars a b, b c, c d sucssively, D d is the vertical thickness at D, or d is a point in extrados.

"For it is evident, that D a : D b : : D b : D c : : D c : D d, cause of similar triangles; therefore, D a : D d : : rad. : ^{3} a D b, or inversely as radius to cube sine a b D. Now is the thickness at crown, and D d is therefore the thicks at D. *Figure* 6 is constructed in this way, and may ve as a specimen of the equilibrating extrados for a semiular arch. By reversing this operation, we may find the kness at the crown corresponding to a given thickness at other point. And here we may observe, that as D, *Figure* 5, approaches the extremity, D, of the semicircle, the line D d rapidly increases, until, at the point B, it is of an infinite length. But indeed this must evidently be the case with every arch which springs at right angles with the horizontal line; for the thrust of the arch should be resisted by a lateral pressure, and no vertical pressure can act laterally on a vertical line.

"We may also observe, that since the extrados or upper outline descends first on each side of the crown, and then ascends with an infinite arc, there is, for any thickness of the crown, a point on each side where the upper edge of the extrados is on a level with that on the crown. Thus, if B D $= 30^\circ$, its sine is half the radius. D a is therefore $= \frac{1}{8}$ of D d, so that if V v = D a be made $\frac{1}{14}$ of V C, the radius, we have the point d at the same level with V. Between this point, however, and the crown, there is a considerable depression, which is increased if the crown be made still thinner. On the other hand, if it be made thicker, the horizontal line drawn through the crown cuts the extrados much nearer the middle of the arch. It appears, therefore, that the circle is not well adapted for the purposes of a bridge, or a road, where the roadway must necessarily be nearly level; for no part of the extrados of the circular arch will coincide with the horizontal line. There is, indeed, a certain span, with a corresponding thickness at the crown, where the outline differs least from the horizontal; that is, an arch of about 54 degrees, with a thickness at the crown about $\frac{1}{4}$ of the span. But that is far too great for practical purposes.

"We may, however, extend the construction just given, even to those arches that are formed of portions of circles, differing in curvature. For the equilibrating extrados being first constructed for that portion of the arch in which the crown is, as far as the vertical line passing through the contact of the neighbouring curves, the thickness of the crown must be supposed to be enlarged, in proportion to the diminution of the radius of curvature, or the contrary, and, with this, proceed as before along the succeeding branch of the curve. This will, indeed, cause an unsightly break in the extrados, for which we shall not at present pretend to find any other remedy, than using materials of a different specific gravity.

"Those who wish to examine this subject farther, may consult Emerson's *Fluxions*, or Hutton's *Principles of Bridges*. We shall only observe here, that the extrados of the ellipsis, and of the cycloid, resemble that of the circle, having an infinite arc on each side at the springing; and indeed this, as has already been observed, is a general rule for all those curves which spring at right angles to the horizon. In the parabola the extrados is another parabola exactly the same, only removed a little above the other. In the hyperbola, the extrados is another curve, which approaches the interior arch towards the springing. None of these curves, therefore, can, with propriety, be employed for the arches of a bridge, though there may be cases where a single arch might, with propriety, be formed into a conic section.

"Mathematicians finding the circle, and other common curves, so little adapted to the arch of a bridge which has a horizontal roadway, have, in the next place, endeavoured to solve the converse of the problem, and give a rule for finding the intrados, or figure of the arch, which has the exterior curve a horizontal line.

"This problem can only be resolved by calling the fluxionary calculus to our aid. It is a case of the more general one to find the intrados when the extrados is given; and being the most useful case of that problem, fortunately admits of a solution comparatively easy.

"*Figure* 7.—We have already seen, that the load, D C, is inversely as rad. curv. × sine[3] inclination to vertical. Calling, therefore, as usual, the abscissa V E $= x$, C E $= y$, V C $= z$, we have C $f = \dot{x}$, f C $= \dot{y}$, C $c = \dot{z}$; and since C c : $c f$: : rad. : sin. inclin. at C; therefore the load D C is inversely as rad. curv. $\times \frac{\dot{y}^3}{\dot{z}^3}$. But as is well known, the rad. of curvature $= \frac{\dot{z}^3}{\dot{y}\ddot{x} - \dot{x}\ddot{y}}$; therefore, by multiplication, D C is inversely as $\frac{\dot{y}^3}{\dot{y}\ddot{x} - \dot{x}\ddot{y}}$, that is, directly as $\frac{\dot{y}\ddot{x} - \dot{x}\ddot{y}}{\dot{y}^3}$, or as $d\left(\frac{\dot{y}}{\dot{x}} \div \dot{y},\right)$ and is equal to $d\left(\frac{\dot{y}}{\dot{x}} \times \frac{\text{C}}{\dot{y}},\right)$ where C is a constant quantity, found by taking the real value of D C at the vertex, V, of the curve.

"Now, in the present case, calling A V $= a$, we have D C $= a + x$, (A V + V E,) therefore $a + x = \frac{\text{C}}{\dot{y}} \times$ flux. of $\frac{\dot{y}}{\dot{x}}$. Take $\frac{\dot{x}}{\dot{y}} = u$, and by integrating, we have $u = \sqrt{\frac{a\,2x + x^2}{\text{C}}}$, and therefore $\dot{y} = \left(\frac{\dot{x}}{u} =\right) \sqrt{\text{C}} \times \frac{\dot{x}}{\sqrt{2ax + x^2}}$; whence, by integration,

$y = \sqrt{\text{C}} \times \text{Lo.}\ (2ax + 2x^2 + 2\sqrt{2ax + x^2}) + \text{B}$. At the vertex $x = 0$, therefore $y = \sqrt{\text{C}} \times \text{Lo.}\ (2a)$. And consequently the ordinate $y = \sqrt{\text{C}} \times \text{Lo.}\ \frac{a + x + \sqrt{2ax + x^2}}{a}$.

"Lastly, to find the value of $\sqrt{\text{C}}$, we take some point of the extrados, where the ratio of x and y is known. For example, if the span, = 2 S, and height, = h, are given, we have $\text{S} = \sqrt{\text{C}} \times \text{Lo.}\ \frac{a + h + \sqrt{2ah + hh}}{a}$,

hence $\sqrt{\text{C}} = \text{S} \div \text{Lo.}\ \frac{a + h + \sqrt{2ah + hh}}{a}$,

and, finally, $y = \text{S} \times \frac{\text{Lo.}\ \frac{1}{a}\,(a + x + \sqrt{2ax + x^2})}{\text{Lo.}\ \frac{1}{a}\,(a + h + \sqrt{2ah + h^2})}$.

"We subjoin a table, calculated by Dr. Hutton from this formula, for an arch of 100 feet span and 40 feet rise, the thickness of the crown being taken at 6 feet. It is nearly of the same dimensions as the middle arch of Blackfriars Bridge, and which may answer for any arch where these dimensions are similarly related to each other.

EC.	DC or AE.	EC.	DC.	EC.	DC.
0	6.000	21	10.381	36	21.774
2	6.035	22	10.858	37	22.948
4	6.144	23	11.368	38	24.190
6	6.324	24	11.911	39	25.505
8	6.580	25	12.489	40	26.894
10	6.914	26	13.106	41	28.364
12	7.330	27	13.761	42	29.919
13	7.571	28	14.457	43	31.563
14	7.834	29	15.196	44	33.299
15	8.120	30	15.980	45	35.135
16	8.430	31	16.811	46	37.075
17	8.766	32	17.693	47	39.126
18	9.168	33	18.627	48	41.293
19	9.517	34	19.617	49	43.581
20	9.934	35	20.665	50	46.000

"The curve of *Figure* 7 is accurately drawn to these dimensions, and may give an idea of the form of an equilibrated arch. It is not destitute of grace, and is abundantly roomy for craft.

"Such, then, is the analytical theory of equilibration: for a practical subject it does, we confess, appear abstruse.

"Let us turn, therefore, to another mode of considering this subject, which has been adopted by De la Hire, Parent, Belidor, and many others on the continent, and in our own country by the ingenious Mr. Atwood.

"The latter has, from the known properties of the wedge, and the elementary laws of mechanics, exhibited a geometrical construction for adjusting the equilibration of arches of every form.

"*Figure* 8.—The wedge A, if unimpeded, would descend in the direction V O, but is prevented by the reaction of B and B′, acting in the direction P Q and K I, perpendicular to the sides A G, Q D; and it is known, from the properties of the wedge, that if P Q, or K′ I, be to the weight of the wedge A, as D O is to D G, the wedge A will remain at rest. If also the wedge A be only at liberty to slide down G A, considered as a fixed abutment, then the force P Q alone will keep it in equilibrio. The force P Q being perpendicular to D O, has no tendency to make A slide either up or down on that line, but produce it towards N, making N M equal to P Q, then this force acting obliquely at N, may be reduced to two others, viz., M R perpendicular to A G, expressing the perpendicular pressure on the abutment of A, and R N expressing the force or tendency it has to make A slide upwards along A G. Again, take the vertical line A a, expressing the weight of A, and draw a H at right angles to A G; it is very evident, that A H expresses the tendency of A by its weight to slide down G A. A H is opposite, and is equal to N R.

"For, draw the perpendiculars D d and A p, then the triangles A a H, A G p, D G d, are evidently similar; and also the triangles O D d, O Q N, M N R, as they have always a common angle besides the right angle. Now, the force P Q, that is, M N, is to the weight of A, that is A a, as O D to D G, by supposition;

"And, A a : A H : : A G : A p : : D G : D d;

"Therefore, M N : A H : : O D : D d : : M N : N R.

"Or M N has the same ratio to A H, that it has to N R; that is, A H and N R are equal; or the tendency of A to slide downwards by its weight, is balanced by the tendency of M N to make it slide upwards; wherefore the section A remains at rest in equilibrio.

"Considering the whole arch as completed, with its parts mutually balancing each other, the force P Q, which is necessary for sustaining the wedge A, will be supplied by the reaction of the adjacent wedge B. Now, let it be required to ascertain the weight of B in proportion to A, so that they being adjusted to equipoise, may continue to be in equilibrio when left free to slide along K B. Since M R is the pressure produced by P Q, in a direction perpendicular to A G, we must add to this, H a, which is derived from the wedge A; therefore, make M n equal to H a, produce M R to Y, take Y Z equal to R n, draw Z W at right angles to K B; Y W is the force tending to make B slide up B K: take therefore B H′ equal to Y W, draw the perpendicular H′ b meeting the vertical B b in b; B b will represent the necessary weight of the wedge B, and the whole is so evident from the composition of pressures as to require no farther demonstration." Such is Atwood's construction; he has rendered the demonstration much more prolix, by the unnecessary introduction of trigonometry; and after showing how the weight of the sections C, D, &c., may be found in the same way, he goes on to reduce these weights and pressures to analytical and numerical values. He finds these in terms of the sines and tangents of the successive angles of inclination; but in reducing these to numbers, he has been led, by the accumulation of small errors, in that very operose way of proceeding, to give erroneous results; and into the singular mistake of conceiving, that the real expression of these values was only an approximation.

"The weight of the section C may be determined in the same way as the foregoing. But surely more simply thus: From C draw C S parallel to W Z, that is, at right angles to K O, and make it equal to W Z + H′ *b;* draw S *c* at right angles to L O, meeting the vertical C *c* in *c*, then C *c* represents the weight of C. From D draw D T parallel and equal to S *c*, draw T *d* perpendicular to D O, meeting the vertical D *d* in *d*, D *d* is the weight of D, and so on successively.

"Nay, instead of drawing D T parallel to S *c*, and T *d* perpendicular to D O, we may at once draw from S, S *d′* perpendicular to D O, which will cut off for us *c d′* = D *d*, the weight of the section D. It is of no consequence, although the lines of abutment do not all run to the same centre O.

"And thus we obtain a general construction for all the sections, which turns out abundantly simple; for upon any vertical line, *b′ e*, *Figure* 9, if *c b* be taken to represent the given weight of any section, C, and *c* T be drawn at right angles to C O, and *b* T at right angles to B O, meeting the other in T; then T *b* represents the pressure against the abutment O B, and T C the pressure against O *c;* and by drawing T *d* at right angles to D O, T *e* to E O, &c., we have the weights of the successive sections represented by *c d*, *d e*, &c., and the pressure on their lower abutments represented by T *d*, T *e*, &c.

"We may carry the same mode of determination to the other side of C, and pass the vertex of the arch. The divisions representing the weights of the sections will run upwards along the indefinite line *c b′*. The pressures on the abutments will be determined as before. Should the two sides of a section be parallel, the perpendiculars through T upon them will coincide; such a section, therefore, should have no weight. But should the two lines of abutment diverge towards the lower side, the line expressing the weight of that section will return upon the vertical, showing that such a section requires the reverse of weight, viz., a support from below. The line T V drawn horizontally through T, exhibits the horizontal pressure, which is uniform through the same equilibrated arch. But it is evidently greater, the less *b* T and *c* T are inclined to each other, the weight *b c* being constant, that is, the smaller the angle of the wedges, or sections. It also increases directly as the weight of the section C, &c. The line V *e* expresses the weight of the semi-arch, or perpendicular pressure on each pier; being the sum of the weights of all the sections in the semi-arch.

"Again, it is obvious that the angles *b* T *c*, or *c* T *d*, &c., are equal to the angles of the sections B O C, C O D, &c. If, therefore, the weight of any section, E, be given = *d e*, and the requisite angle of that section be required, everything else being known, we have only to join T *e*, and the line E *o*, being drawn perpendicular to T *e*, will exhibit the inclination of the lower abutment of the section; *d* T *e* is the angle of that section. And here it matters not where the point E be, that is, how great the base of the section be, provided the weight is equal to *d e*. We also see, that while the angles remain the same, and the weights proportional, it is of no consequence what the curve passing through the lower edges of the sections, or through their upper edges, may be, they may even be straight lines. According to this principle, the architect is not confined to given forms of intrados or extrados; he may take whatever curve appears most beautiful or useful: and, what is more, by the proper adjustment of the joints, *he may cast the ultimate pressure in any direction which he thinks most conducive to the strength of the edifice.*

"We now proceed to show the application of this investigation to some practical cases; and the first we shall consider, is that known by the common, though awkward name of the *flat arch;* one with which every mason is perfectly familiar, though it be seldom noticed by writers one quilibration.

"*Figure* 10.—A B *b a* is a structure of this kind, adjusted to this equilibrium, and resting on the abutments A *a*, B *b*. Its construction is exceedingly simple; nothing more is necessary than to draw all the joints, *m* M, *l* L, &c., to one centre, C: and the reason is obvious; for D K, K L, &c., are the differences of the natural tangents of the inclinations of the abutments, the perpendicular, C D, being radius; and the same thing is true in the line *d a*, and in every other parallel section. The surface, therefore, A *m*, M *l*, that is, the bulks or weights of the stones, are in the same ratio, and it is that which is required by the above principles. Also, if we assume the line of its base to represent the weight of any stone in the arch, for example, K D for half the keystone; then the perpendicular C D is the horizontal *thrust*, *drift*, or *shoot* of the arch. By increasing D C, or diminishing it, that is, by drawing the joints to a lower, or a higher centre, we may alter this thrust at pleasure. What if we should take C up to D? Some curious ideas occur here, but being chiefly speculative, we shall not now pursue them. They serve to connect this case very neatly with the lintel and the Egyptian arch, (or that formed by flat courses of stones gradually overlapping each other, until the opening be covered,) in each of which the horizontal thrust vanishes. We ought also to observe, that whatever weight of stuff lies on an arch of this kind, there is no change of design requisite, so long as the upper surface, or roadway, is horizontal. For being everywhere of the same height, the mass incumbent on any stone will be proportional to its base, viz., the back of that stone; since we must conceive the stuff to press vertically. It is therefore the same as if the whole arch had undergone a change of specific gravity; every pressure will be increased in the same proportion.

"The design of an equilibrated horizontal arch, or platband, being thus easily formed, it will not be difficult to extend it to a curve of any form; *a δ b b′ d′ a*,′ *Figure* 10, is an arch of this kind. It is a circular segment from the centre, C, to which the joints of the horizontal arch were directed; the two key-stones have the same weight and obliquity of abutment; consequently, the horizontal thrusts are the same. The other arch-stones being previously intended to have the same weight with those of the flat-arch, it is only necessary to draw the lines 1 1, 2 2, 3 3, parallel to M *m*, L *l*, K *k*, so as to produce this equality.

"This being merely a simple problem in mensuration, we shall not occupy the reader's attention with the solution of it. In the *Figure* referred to, we have divided the soffit, A B, of the flat arch into equal parts; all the stones, therefore, of that, as well as the curvilinear form, are of equal magnitude and weight, the angles of the arch-stones only, varying.

"The reader must have already observed, that when C D expresses the horizontal thrust, or pressure of the vertex, C M, C K, C L, &c. express the perpendicular pressures on the successive joints M *m*, K *k*, L *l*, &c. Now it is obvious, that K *k*, L *l*, &c. are proportional to C K, C L, &c.; for A D, *a d*, are parallel. Therefore, the vertical sides of the arch being parallel, the pressure on each joint of the flat-arch is always proportional to the surface of that joint, and the pressure on each square inch of joint throughout the arch is always the same. It may readily be found too, by dividing the horizontal thrust by the area of vertical section, D *d*. This is a most valuable property, for it secures uniformity of action in every part of the structure. But it is not to be found in the arch *a b d;* for there, the joints being nearly equal, the pressure on each increases as we descend from the vertex, and may, at the lower sections, be eventually so great as to overcome the cohesion of the materials.

"It may be objected to the straight arch, that acute angles, as A *a m*, B M *m*, are very apt to chip away, and weaken the arch. Now this is certainly true, but it has no connection with the doctrine of equilibration. There is, however, a very ingenious mode of remedying it; for if the upper and lower extremities of each joint be drawn to a centre, considerably below the former, or even if they be formed into vertical lines, as at N, *n*, it will materially strengthen the acute corners without injuring the equilibration. We may conclude, therefore, that a structure of this kind possesses every requisite that can be looked for in an equilibrated arch. But, before we take any further notice of it, we shall proceed somewhat farther with the applications of our theory.

"The segment *a δ b* was adjusted to equilibrium, with reference to the flat arch, upon the principle that the weight of the arch-stones was only to be provided for. In general, an arch of this kind is filled up at the flanks, so as to form a roadway as nearly as possible horizontal. We must, in that case, when considering the weight of each arch-stone, not lose sight of the difference of pressure upon it, arising from the varying height of the incumbent mass. Having, therefore, divided the back of the arch into sections, *d* 1, 1 2, 2 3, *Figure* 11, each containing one, two, or more arch-stones, and having drawn the vertical lines from these divisions to the line of roadway, we calculate the weight of the trapezoid of the stuff over each section; add this to the weight of the section; and divide the tangent line, or flat-arch, accordingly.

"We may even give a construction for this. The stuff over any section, 2 3, is proportional to the trapezoid, *t* 2 3 *v*, or nearly $t\,v \times s\,w$; for we need take no notice of the small segment of the circle between 2 and 3, but consider the arch as polygonal, in which case the mean height is *s w*.

"But 1 2, 2 3 being equal, we have *t v* or 2 *y* as sine of 2 3 *y* (*i. e.*) as sine of the inclination of the arch; wherefore, drawing the mean height, *w s*, and producing C *w* to meet the perpendicular *s x*, take the weights over the sections to be represented on the horizontal line, by lines equal to *w x* respectively; for *s w* is to *w x* nearly as 2 3 is to 2 *y*, and *t v*, at the vertex of the arch, is equal to 2 3; and since the weight of the arch-stone will be nearly constant, and that on the supposition that the weight over each section is represented by the trapezoidal space included between it and the roadway, let us assume the weight of the keystone, as represented by the part *d* P, and the others by similar additions. If we have an arch differing in gravity from the stuff which loads it, we can measure to a circle within or without the circle of intrados, P T *u* W. Draw, therefore, the horizontal line P *o*, and lay off P *a* equal to $\frac{1}{2}$ P *q* for the half keystone and its load, lay off, also, $a\,b = l\,n$, $b\,c = u\,x$, &c., and these divisions will represent the weight of the several sections, the superincumbent matter being included.

"This method is evidently only an approximation; we consider the principal load as arising from the mass incumbent on each section, or at least that the weights of the sections are proportional to these masses. It becomes pretty accurate, by taking *w* in the mean circle drawn between the soffit and back of the arch; and we might render it still more accurate, by giving the determination a fluxionary form, but we write at present for the practical builder, to whom the calculus is seldom known; besides, as the reader will see hereafter, we do not think the rigid determination of this matter as yet of much consequence.

"Having thus discovered the weights of the sections, and laid them off on the horizontal line, as if for a flat arch, and having, either from the given form of the keystone, or the horizontal thrust, drawn the angles of abutment which a flat arch would require, the joints of the arch in question are to be drawn parallel to these, and through the extremities of the proper sections, previously marked out, as above mentioned. If there be intermediate joints, they may either be drawn properly related to the others, or be separately discovered by a repetition of the construction.

"*Figure* 11.—For example, let C be the given centre for the keystone; draw C *a*, C *b*, C *c*, &c.; and through 1 draw the joint 1 R parallel to C *a*, also 2 T parallel to C *b*, and 3 W to C *c*, &c.: the arch would then be in equilibration.

"Thus we find, that, *by the proper adjustment of the joints to the weight of the section, we may form equilibrated arches, having soffits of any figure that may be thought proper*, and with any proportion of dead weight over them that circumstances may require. Let us now look at the converse of this Problem; where the inclinations of the joints being given, it is required to discover the mass or weight which must be allotted to each section, so as to preserve the whole in equilibrium.

"Pursuing the mode already employed, it is evident, that if we lay off from one centre the angles to be formed by the successive joints, or abutments, with the vertical line, a horizontal line drawn to cut them will represent, by its successive segments, the weights of the several sections; while, at the same time, the perpendicular let fall from the centre on this line will exhibit the horizontal thrust. If the arch, therefore, must be throughout of equal thickness, we have only to mark off upon the soffit, or rather upon the mean curve, segments proportional to those of the horizontal line. If the upper and lower outline of the arch be determined, we must divide it into trapezoids, having the same proportions; then draw the joints parallel to the lines expressing the given angles of inclination. Such joints will run to several different centres, thereby showing us, that their union in one is not at all necessary to the security of the arch, even should that be a portion of a circle.

"The position of the joints is usually given in a different way from that which we have just considered. In circular arches, they are generally formed by producing the radii from the centre; and in others they are commonly drawn perpendicular to the curve. Now, though we have just shown, that this is by no means necessary to the equilibrium, yet, as it is in reality the most convenient in practice, it may be of importance to attend to the effects likely to be produced by this modification.

"*Figure* 9.—We see that the tangents on the horizontal line rapidly increase as we pass outward, and we should therefore increase, in the same proportion, the weight of our sections. We cannot increase the base, as proposed above, for that is necessarily given by the position of the joints, but as we are still able either to increase the height, or the breadth of the sections, we may consider the effect of both these modes.

"Let it be required, then, to equilibrate a circular arch where the stones being all of equal thickness, with joints equally distant, are drawn all to one centre, we are only at liberty to increase the width of the roadway, or length of the horizontal courses.

"Considering each course of arch-stones as a prism of given base, a supposition sufficiently accurate, it is eviden that its magnitude or weight increases with the length only. But this weight must, from the principles already laid down, be as the difference of the tangents of its abutments; the length, therefore, must be in that ratio. Accordingly, we find the breadth at different distances from the vertex, in the same way with the weights of the sections: the breadth at 45° must be double, and at 55° must be about triple of that at the crown, and will increase still more rapidly afterwards. Proportions such as these may answer well in the short flight of steps for a flying staircase, but are quite unfit for our present purpose. When we recollect, however, that in a bridge, the extraordinary expansion towards the haunches is materially corrected by the increased pressure of the incumbent mass in that part, we are encouraged to proceed a little farther, and consider the effect of the second mode of effecting the equilibrium.

"*Figure* 11.—The pressure of matter upon each section has already been stated as proportional to $t\,v \times s\,w$; but $t\,v$ is the difference of the sines of the angular distances of the successive abutments from the vertex, and $s\,w$ is the mean versed sine added to the given thickness at the crown, when the roadway is horizontal. We have therefore the pressure as the difference of the sines $\times$ (mean versed sine $+$ thickness at vertex.) But these pressures are also, from the theory, as the difference of the tangents of these angular distances.

"In the common mode of building we must give the arch a sufficient thickness at the keystone, to resist the horizontal thrust, ensure stability, and bear the loads likely to come upon it. We must also cover this part with a certain thickness of gravel, or other matter, so as to form a roadway. The varying pressure of the wheels of a loaded carriage, when it is propagated through this stratum of gravel, will be so far diffused as not to disturb the stone immediately below it, nor injure the bridge by splintering away its corners. This thickness is made as small as possible, that the bridge may not be unnecessarily elevated, and the roadway is preserved nearly horizontal. The other courses of arch-stones, too, do not often differ much in thickness from that at the crown. But although these things are pretty constant, there is a considerable degree of latitude in filling up the space between the back of the arch and the roadway. It may be done with substances varying in density, from the lightest charcoal or pumice, open shiver, or chalk, to closely rammed clay, or even solid masonry; and it is not uncommon to make, in various ways, open spaces in the masonry of the spandrel, covering them above, so as still to support the roadway.

"It will, therefore, be proper for us to inquire, what is the density requisite over every section of an arch, where the thickness of the crown is given, the roadway horizontal, the arch of uniform thickness, and the angles of abutment of the several sections constant, that is, all drawn from the same centre; or, what is the same thing, let us suppose the structure built up to the horizontal roadway with parallel sides, and then inquire, what is the proportion between the pressure borne by each section in this way, and the pressure of equilibrium; we shall thereby discover the ratio in which the density of the backing must, if needful, be diminished; and the quantity of expansion necessary towards the springing of the arch, that the advantages of equilibration may be preserved, even in this state of things.

"Before we give a more rigid determination, we should wish to show the practical builder, that the solution of this problem may be easily approximated, by the help of the trigonometrical tables. For we may suppose the matter of the arch-stones to be the same in specific gravity with that which lies above it; and as there can be no impropriety in considering the arch as polygonal, from joint to joint, our mean versed sine is only half the sum of those at the two joints. The supposition is not strictly accurate, but it is sufficiently near: greater strictness would only serve to render the calculation more complicated without making it more useful.

"It was customary in the construction of bridges, to fill up the haunch with solid matter, such as gravel earth, or the like, until a roadway of a proper slope was procured. Where the arches were small, this might not be attended with any perceptibly bad effect, provided the arch-stones were of a good depth. But the necessity of lightening the haunches, has been forced upon the attention of builders, whenever large arches have been attempted.

"In all probability, the first inventors of this mode of building, besides employing it with the view of equilibrating the arch by lightening the part over the haunches, had also an idea of steadying it by the lateral abutment. They appear to have considered the spandrel walls as a sort of hoops, that would keep the parts of the arch together, and hinder any stone from moving, by their great friction, inertia, and mutual abutment. Hence various ingenious modes have been employed for locking them into the back of the arch-stones, propagating the pressure through, and securing them from sliding away at the bases.

"They indeed act in this way; nevertheless the equilibration of the arch should be attended to in their construction, that every unnecessary strain may be avoided. The thickness of these walls may be varied indefinitely, and the vacant spaces made in any proportion to the solid parts. The walls ought to be near each other, that their effect may be felt over the whole arch, and perhaps they should spread out towards the bottom; but this is not so very necessary, for the courses of arch-stones break joint with each other, and the inequality of pressure in one course is immediately corrected by being propagated to the succeeding.

"We have now determined a method of constructing an equilibrated arch for sixty degrees on each side of the vertex; and this method, so far from having anything unusual, is even strictly analogous to that which is adopted by the practical builder. Why then cannot we keep pace with him throughout, and give a construction for the entire semicircle? No difficulty is felt by the mason in that case. He constructs such arches every day. Nay, they are not only the most common, but the most ancient of all arches. But the reader must have ere now observed, that our theory is in this particular defective. The enormous expansion of the roadway, or the infinite height of superincumbent matter, which it seems to require when the joints are nearly horizontal, are altogether preposterous and impracticable. We are sure they are unnecessary; for many semicircular arches have existed from the time of the Romans, and are still in good order. What is more, the failure of such arches near the springing, where they differ farthest from the theory, is a most unusual, and, indeed, unheard of phenomenon. Is our theory erroneous, then, or is it only defective? There is no reason for distrusting any of the consequences we have hitherto deduced. They are mathematically derived from an unquestionable principle, the action of gravity. But we have not yet considered all the causes of stability. The lateral resistance of the masonry, or other matter behind the arch, acts powerfully in preventing any motion among its parts; and independently of that, the friction of the arch-stones, assisted by the cohesion of the cement, affords a great security to the structure. We have even seen a semicircular ring of stones, abandoned to itself without any backing, and stand very well; long enough, at least, to admit of the other work being leisurely applied to it. Here was no lateral pressure; no equilibration: why did not the lower courses yield to the pressure propagated from above, and slide off? It was only their friction that could retain them. It is greatly increased by this very pressure. And it is unquestionable, that a ring of polished blocks in that situation would not have hung together for a moment. The force of friction, therefore, makes so important a part of our subject, that it deserves a separate inquiry. Let us see how it may be estimated.

"When a mass of matter is moved along other matter of the same kind, the resistance produced by friction has been usually stated at $\frac{1}{3}$ of the weight. That of freestone, indeed, is supposed to be greater than $\frac{1}{3}$, perhaps it is $\frac{1}{2}$. And in the case to which we are going now to apply it, there can be little doubt, that, aided by the inertia of the stones, and the cohesion of the cement, the friction is even much more. But this force is inert; and we are at present inquiring, how far we are benefitted by it in promoting the stability of our structure. It will, therefore, be proper to underrate it, at least until we discover how far we are warranted to say it must be beneficial.

"*Figure* 12.—Let L, M, N, exhibit the three sections (10° each) of an arch, which we may conceive equilibrated above the section L, or 60° from the crown. Draw L T, expressing the direction and magnitude of the ultimate pressure, perpendicular to the upper surface of L. In like manner, T V is the horizontal thrust, and V L the weight of matter over L to the vertex. Draw the perpendicular T *y b*; T L is the direction of the ultimate pressure when propagated to the lower surface of L; *y* L is its tendency to make L slide upwards along the joint. Now it is evident, that, if *y* L has to *y* T a less ratio than the friction has to the pressure, L will not move. Nay, what is more, L will itself have some weight. Take L *a* to represent it, which, in the case of equal sections, = the tangent *x z*. Draw T *a* for the ultimate pressure in the lower surface of L, and *a b* for the force to be resisted by friction, in this case equal to .1343, or about $\frac{2}{15}$ of the pressure, and of course less than the friction, which will at least be one-third of the same.

"Since L does not move upon the section M, they are to be considered as one solid mass, and we pursue the pressure through the section M. For this purpose, lay off *a c* for the weight of M, draw the perpendicular T *d*, and the parallel *c d* to the joint M O, *c d* is the force opposed to friction in that joint, and still is less than one-third of T *d*, the pressure being, in the case of equal sections, = .2796, or about $\frac{11}{40}$. Lastly, lay off *c e* for the weight of the lowest section, N, and draw as before. It is evident, that *e f*, the force opposed by friction here, is just equal to T V, the horizontal thrust, as might have been concluded without any investigation. In the case of equal sections, its proportion to T *f* or V *e*, the weight of the semi-arch or perpendicular pressure, is as .4425, or about $\frac{7}{16}$, which is probably more than the friction will oppose without other assistance.

"If, therefore, the friction on the horizontal bed at the springing be not equal to the thrust of the arch, we must increase it, as by dowelling it, for example, into the lower stones, or by backing it with other masonry, or by increasing the pressure on that joint, without altering the thrust of the arch, which may be done by thickening, or loading the arch just over the springing. And here the theorems for the extrados of equilibration come to our aid; for we see, that any quantity of matter may be laid over the springing-courses, and, far from disturbing the arch, it will tend to increase its stability.

"It may not be improper to inquire, what are the conditions for equilibrating an arch by means of the friction of its segments alone? that is to say, what are the alterations practicable in the position of the joints, or in the weights over the several sections, until the tendency of each section to slide is just balanced by the friction at its lower surface?

"Whether we inquire into the position of the joints, or the weight that may be applied, there are two cases; for the friction being an inert force, will resist the stone in sliding either upwards or downwards.

"I. Let it be required to determine the position of the joints in an arch, when each section is just prevented from sliding outwards by the friction at its lower surface.

"*Figure* 13.—Let the arch spring from a horizontal joint, as N *n*, where, of course, the friction acting in V N, is just equal to the horizontal thrust, and must therefore have to T *n′* or V N the weight of the semi-arch, the ratio which friction has to the incumbent pressure, say $\frac{1}{3}$. T N is the direction of the absolute pressure at the abutment N *n*. Take M M the weight of the section N, T M is the pressure on the joint of M, and making M T *m* similar to N T *n′*, M *m* will also represent the extreme friction in that joint, and T *m* its load, and so on successively. Wherefore, if T *m*, T *l*, &c. be found, the joints of the arch may be drawn at right angles to these lines respectively, and every stone will be exactly in the predicament of N, that is, just kept by its friction from sliding away.

"The positions of T *m*, T *l* may be readily discovered; for the angle *n′* T *m* must be equal to N T M. If, therefore, we make T *a* equal to T N, draw the tangent *a w*, and making *a b*=N M, and joining T *b*, we have *a* T *b*=N T M. And, in this manner, taking *a b*, *b c*, &c. for the weights of the successive sections from the scale, and drawing lines from T, the joints may be formed perpendicular to the lines thus drawn.

"*Figure* 14.—But a more convenient construction perhaps would be, to take the horizontal thrust, or quantity of friction in the vertical line C *d*, lay off the weight of the semi-arch *d a*, draw C *a*, make C *x* equal to it, also *x z*, mark off the weight of the sections along *x z*, and through the divisions draw lines from the centre; the joints required are parallel to these lines.

"II. Let it be required, in the next place, to determine the other limit to the position of the joints, or that in which each section is just prevented from sliding in, by the friction on its lower bed.

"Here it is evident, that as the friction acts precisely opposite to its direction in the former case, the joints may have on the opposite side, exactly the same degree of obliquity to the position of equilibrium. Draw, therefore, the tangent *v y* parallel to *a* C, cut it with C *v* equal to *a* C, lay off the weights of the sections along *v y*, and draw lines from C; these lines will exhibit the positions of the joints, which of course may be drawn parallel to them. We have marked these two limits of position in three joints of the half-arch above the same figure, assuming the friction at one-third, and taking the first section of 30° as equal to the thrust; and any other arch might have been introduced as well as the circular. Any of the lines in the triangle C *d a*, makes with the corresponding line in C *y v*, or in C *z x*, an angle equal to *a* C *x*, that is, when the friction is one-third of the pressure, equal to 18° 26′; and when the friction is one-half, this angle is 26° 34′. The position of any joint, therefore, may vary, in the former 18° 26′, and in the latter case 26° 34′, on either side of the position of equilibrium, before any sliding can take place among the sections. Nay, the friction of polished freestone is even more than one-half, perhaps it is two-thirds, of the pressure, which would give 33° 4′. And it is proper to observe, that this is not confined to the annulus of arch-stones, but holds equally with whatever weight the sections may be loaded. We may observe, then, that, in any arch, the position of the joints may be varied about 20°, perhaps 30°, from that of equilibrium, before any derangement can arise from the sliding of the arch-stones.

"This is a most important conclusion, and leads to extensive practical consequences. It affords a true explanation of the facility with which arches are everywhere constructed, even by the common country mason.

"For this reason, therefore, we approve highly of the practice, which we believe is very general among artificers, we mean that of backing up the arch with solid masonry, for several courses above the springing. If great security is thought necessary, cement, being a compressible substance, ought to be sparingly employed in the vertical joints at the back of the arch-stones.

"The friction of the sections of the arch, as it permits a considerable variation to take place in the position of the joints, will also admit of a considerable deviation from the load which is necessary for equilibrium over any point of the curve.

"It would not be difficult to investigate the extent to which this variation of weight might be carried. But we shall at present only remind the reader, that, as we find a variation of 20° practicable in the position of the joints, he may conclude that each section will admit of its load being altered to that which would suit a point in the curve 20° on either side of it.

"One thing only remains to be considered in this department of our subject, which is, the lateral pressure likely to arise on the back of the arch, from the materials employed to raise the structure to the horizontal line.

"If the materials employed here be only a solid mass of masonry, it is not easy to see, everything being steady, how it can act in any other way than in the vertical direction. If, however, a motion takes place in the arch, the mass of materials lying nearly over the springing, when the arch is not very different from a semicircle, will have such an enormous friction, if well built and bonded together, as would appear equal to the resistance of any pressure that is likely to be opposed to it. And when the arch is a segment much smaller than a semicircle, the rules we have already given for its equilibration must be considered. But, instead of solid courses of masonry, the haunches of arches are often filled up with coarse gravel, or shiver, and sometimes with mere earth or sand. Materials of this description do by no means act by mere dead weight. They have a tendency to slide down towards a horizontal position; and, of course, possess, in some slight degree, the *quaquaver sum* pressure of a fluid. This may act on our arch in a manner altogether new, and produce strains for which hitherto we have made no provision. We shall first consider the back of the arch as filled up with a fluid substance, as water. The pressure in every part will be in a direction perpendicular to the curve, and will be proportional to the depth. A pressure perpendicular to the curve will be equivalent, in effect, to a vertical pressure, which exceeds it in the ratio of the secant of the inclination to the vertical. Of course, the pressure at the springing, when all is equilibrated, must be equal to the horizontal thrust in a semicircular arch.

"Though the action of sand, gravel, or mould, in situations such as this, be not exactly the same with that of water, in following the laws of hydrostatical pressure; yet these materials resemble water, and may be conceived to hold the middle place between the fluid and the solid backing. In some respects they are more advantageous than the fluid. They are stiffer, so to speak, affording a lateral abutment to the arch, if it is likely to yield; and as the parts have a great friction among themselves, it will require a much greater pressure, acting horizontally, to make the matter rise, than in the case of a fluid. We must not, however, be too confident. Materials of this kind are compressible; and we have already seen that very slight shifts are attended with dangerous consequences. At the same time, we need not be much afraid of a trivial departure from exact equilibration; for it is not likely that materials of this kind will act with the powerful effort of hydrostatical pressure.

"But there is another case, where matter of this kind is likely to be attended with more pernicious effects than even a fluid of equal density would be. We mean, when the back of the arch is gorged up with water from land-floods: if the backing be open gravel, or shiver, we have superadded to its weight that of the whole quantity of water admitted into the structure. This, even if it acts equally on both sides, must be a dangerous experiment on any arch; but where it is confined to one side, as is generally the case, and between lofty side-walls, the effects are likely to be serious indeed. Accordingly, the builder forms gutters in the side-wall to let off the water ere it collect;—a practice which is in general highly useful, but which, in the case of sand, clay, or mould, is of small service. The water enters into such matter by its capillary attraction; and fills it to the upper surface, in spite of our gutters. It of course expands it, and this with a force which we cannot measure, but which we are sure is very great. Here the friction of the parts, which was so useful in the former instance, proves extremely hurtful. For as the matter cannot easily rise, and probably the adhesion of its particles is increased by the water, the expanding force becomes an enormous hydrostatical pressure acting perpendicularly on the side-walls and extrados of our arch, and which in all probability they may not sustain.

"The dangerous consequences of this mode of backing are, in some degree, prevented by ramming the layers of matter, especially if it consists of mould or the like: or, by puddling them, so as to form a mass impervious to water. And here we should observe, that as this ramming will produce an extraordinary lateral pressure, we must attend to equilibration, as we rise along the arch, and secure the side-walls by thickening them below or curving them horizontally or vertically.

"The thickness of the arch-stones is an important department of the theory of arches. It is natural that we should endeavour to make them as small as possible. That will diminish the expense of the structure, lessen the pressures in the arch, and increase the security at the springing. But there is an evident limit to this diminution; for though we take every pains to render the joints close, the stones may come at length to be so small as to crush by the thrust of the arch. This is, indeed, a curious branch of inquiry. It depends intimately upon the corpuscular actions of the particles of stone; a subject on which, we regret to say, our information has been hitherto very scanty.

"The question evidently depends on the amount of the tangential pressure. At the crown this is the horizontal thrust. We shall suppose all the joints to be duly drawn to equilibration, the sections fairly abutting on each other, and no weakness arising from acute angles.

"Stone, it is said, will carry from 250,000 to 850,000lb. avoirdupois per foot square, and brick 300,000lb. They have been made practically to carry one-sixth of this, and even more. The pillar in the centre of the Chapter-house at Elgin carries upwards of 40,000lb. on the square foot, and there was formerly a heavy lead roof on it. It is a red sandstone, and has borne this pressure for centuries.

"We shall therefore take 50,000lb. per foot as a load which may be safely laid on every square foot in the arch.

A cubic foot of stone weighs about 160lb. per foot; and brick weighs less. Suppose, therefore, the arch to be one foot thick at the crown, and the keystone one cubic foot, it will bear a horizontal thrust of 50,000lb. that is, $312\frac{1}{2}$ times its weight.

"But, 50,000 : 160 : : R : Tang. 11′ 0″ 3‴, which will be the angle of the keystone in that case. So that an arch of $312\frac{1}{2}$ feet radius, or a semicircular arch of 625 feet span, might bear to have a keystone of a foot deep, without risking its being crushed more than in structures which have already stood for many years. And this may be called the limit of stone-arch building; for if we double the depth of the stone, we will thereby double the weight also, and its ratio to the horizontal thrust will still be the same. Indeed this limit does not much exceed what has been actually executed. A considerable portion of the bridge of Neuilly is an arch of 250 feet radius; and Gautier mentions a platband in the church of the Jesuits at Nismes, the camber of which, after settling, would make it a portion of an arch of 280 feet radius. The length or span is $26\frac{1}{2}$ French feet, the rise only 4 inches, and therefore the diameter of its circle would be 560 English feet.

"'This singularly bold platband was made under the conduct of Père Mourgues, after the design of Cubisol, an able architect. The stones are 1 foot thick, their depth is 2 feet towards the key, and 2 feet 4 inches at each end. It had a camber given it of about 6 or 7 inches, and descended near 3 inches on striking the centres.'"—*Gautier.*

"We see, that the horizontal pressure does not determine the vertical thickness of the arch-stone. But as we pass down the arch, it is plain that the butting surfaces must increase in proportion to the increasing tangential pressure.

"At sixty degrees from the vertex, granting that the arch is equilibrated, the depth of the arch-stones must be doubled; and though the equilibration be carried no farther, yet, at the springing or horizontal joint, a small increase will still be necessary. The ratio will soon be found. To the square of the weight of the semi-arch, add the square of the horizontal thrust, the square root of the sum is the pressure at the springing. If we divide this by the horizontal thrust, it will give the thickness at the springing, compared with that which is necessary at the crown. Or if we divide it by $312\frac{1}{2}$, it will give the smallest depth of joint which should be used at the springing. The thrust and weight are supposed to be given in solid feet. If given in pounds, divide the above quotient by 160, or divide at once by 50,000.

"If we calculate upon the same principles, the depth of arch-stone at the spring-course of a semicircle of 100 feet span, 10 feet thick at the crown, we shall find it to be 5 feet, and at the crown the depth may be 19 inches. In the great arches of the bridge of Neuilly, the thickness at the crown is about 4 feet 8 inches, the span 128.2 feet, and height 32. The horizontal thrust is great, the crown being drawn with a radius of 150 feet; consequently, this arch would require a depth at springing of about 4 feet. But when the centre was struck, the crown of this arch descended 23 inches, which has rendered it a portion of a much larger circle, and has greatly increased the horizontal thrust.

"The piers and abutments of a bridge must be so constructed, that each arch may stand independent of its neighbours. For though, by the mutual abutment of arch against arch, the whole may rest upon very slender piers, if once the structure is erected; yet, as they must be formed singly, and are exposed to many accidents, it will be best to contrive them, so that the destruction of one arch may not involve in it that of the whole.

"Some of the writers on the principles of bridges, in treating this department of their subject have found it necessary, by the help of the higher calculus, to find the centre of gravity of the semi-arch. The solution of the problem, we are convinced, so far as it is useful in practice, lies much nearer the surface.

"The reader has already frequently seen, that the ultimate pressure may, in every case, be reduced to two others, viz., the weight of the semi-arch above, and the horizontal thrust. In the equilibrated arch, this pressure is directed perpendicularly to the joints of the sections; and these being usually drawn at right angles to the curve, the pressure is in the direction of the tangent to the arch. Hence, we have often called it the tangential pressure. Upon this principle, however, when the curve springs at right angles to the horizon, an infinite pressure is required in the vertical direction,—a supposition which cannot have place in practice. We must accordingly call in the assistance of friction in that case; a force which may be set in opposition to the horizontal thrust, and which, increasing with the superincumbent weight, very fortunately keeps pace also with what it is intended to oppose.

"Granting, then, that the friction is so contrived, upon the principles already explained, that there is no danger of any slide at the horizontal or springing-joint; it will be readily admitted, that no slide is likely to take place in any horizontal course below that, till we arrive at the foundation; for the disturbing force is constant, but the friction increases as we descend.

"*Figure* 15.—Our principal care then must be, that the pier does not overset, by turning on the farther joint, E, O its base, as a fulcrum. Take a in the horizontal joint, A a as the centre of pressure; draw a V to represent the weight of the semi-arch, and V T the horizontal thrust; then T a is the ultimate pressure; and if, when produced, it falls within the base of the pier, it is perfectly obvious that it can never overturn it. And this is altogether independent of the weight of the pier: for if that were a mass of ice, immersed to the springing in water, the case would be exactly the same.

"But the pier itself has a considerable stability, arising from its own weight; and even though the direction of the ultimate pressure of the arch alone pass out of the base, the tendency to overturn the pier may be balanced by its weight. This weight may be supposed concentrated in the centre of gravity of the pier, and of course to act in the vertical line which bisects it.

"Its effect will be nearly found by laying off in that line from the point q, where the direction of the ultimate pressure of the arch intersects it, $q\ r =$ the weight of the pier, and taking $q\ s =$ the ultimate pressure $= a$ T, and completing the parallelogram, the diagonal drawn from q will represent the direction and magnitude of the united pressure of the arch and pier. This is not strictly accurate; it would be so if a and q coincided, which is the case with a single arch standing on a pillar: but in general, the ultimate pressure is still more favourable than this. Its direction at any point is in the tangent of a curve, which approaches the vertical as we descend, since the proportion arising from the weight of the pier increases with its height.

"In order to find analytical expressions for these forces, let the horizontal thrust of the arch $= t$. The weight of the half-arch $= a$, and that of the pier $= p$, the height of the pier to the springing of the arch $= h$, the breadth at the base $= b$.

"1. Then the horizontal thrust acting in A G, tends to overturn the pier, and its force round the fulcrum, E, will be represented by multiplying it by the perpendicular distance A D, viz., $h \times t$.

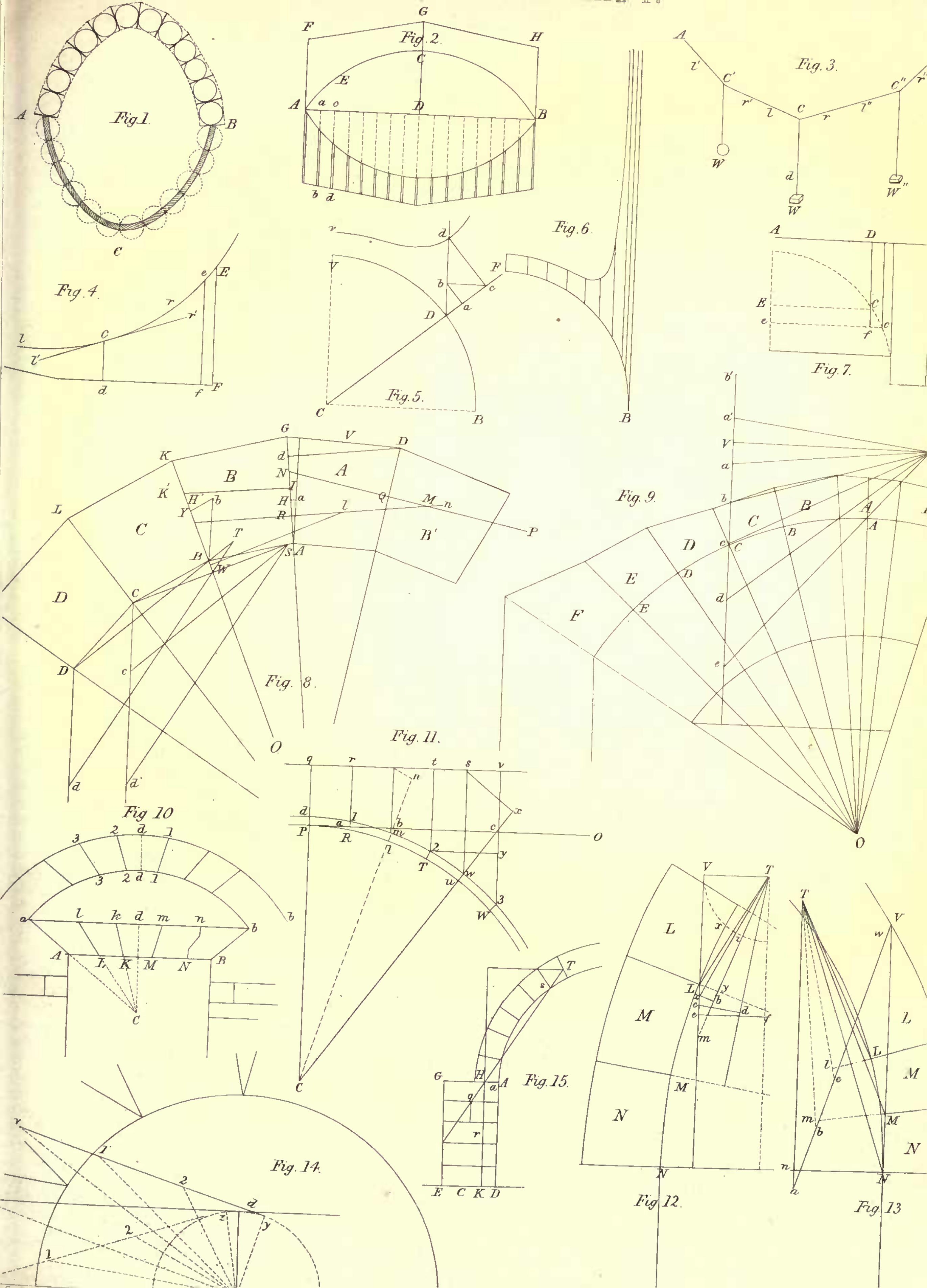


Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Fig 10
Fig. 11.
Fig. 12.
Fig. 13
Fig. 14.
Fig. 15.

"2. The weight of the pier acts in the direction B C, and its effect will be represented by multiplying it by the leverage C E, viz., $p \times \frac{1}{2} b$.

"3. The arch acts with the leverage E K, which is not equal to the breadth of the pier, by the part K D = A H, say one-half of the depth of the joint at the springing. This will never exceed one-fourth of the breadth, when two different rings of arch-stones rise from the same pier, unless the pier widen below. Call E K, therefore, $= \frac{3}{4} b$.

"We have now $h\,t = \frac{1}{2}\,b\,p + \frac{3}{4}\,b\,a$; whence,

"1st, $b = \dfrac{h\,t}{\frac{1}{2}\,p + \frac{3}{4}\,a} = \dfrac{4\,h\,t}{2\,p + 3\,a}$, and consequently,

to find the least breadth of the pier at its base, divide the horizontal thrust by half the pier added to three-fourths of the half-arch. Multiply the height of the pier by the quotient.

"2d, $h = \dfrac{b\,(\frac{1}{2}\,p + \frac{3}{4}\,a)}{t}$, that is,

the height of a pier to the springing, having a given base and weight, is found by adding the half-pier to three-fourths of the arch, multiplying by the breadth of the base, and dividing by the horizontal thrust.

"3d, $p = \dfrac{h\,t - \frac{3}{4}\,b\,a}{\frac{1}{2}\,b} = \dfrac{2\,h\,t}{b} - 1\tfrac{1}{2}\,a$;

or the weight of the pier cannot be less than the excess of the horizontal thrust multiplied by twice the height of the pier, and divided by the base, above one and a half times the semi-arch.

"In the above determination it may be observed, that we consider the weight of the pier as independent of its base. Now, though it may be said with propriety, that the weight of the pier cannot be known until we know its thickness, which is the very thing sought, yet a little consideration will show, that we may give different magnitudes to piers which have equal bases, and that, either by altering the outline of their sides, the density of their structure, the gravity of their materials, or the weight of solid matter over them, we may therefore, when the base is given, apply the weight necessary to keep the pier in equilibrio, provided this does not require the pier to be any more than a solid mass up to the roadway. Should the base assumed admit of the pier being much less than the solid parallelopiped, we may diminish it in various ways: as, 1st, By opening arches over the pier, where, in case of floods, we will procure an addition to the water-way; a practice very usual in the ancient structures: or 2d, By tapering the pier towards the springing of the arches, or by making each pier only a row of pillars in the line of the stream, arching them together at top; a mode which may perhaps be objectionable in a water-way, but which would have a very striking and light effect in land-arches. Something of this kind has been done by Perronet, at the Pont St. Maxence.

"When piers indeed are to be exceedingly high, as in the columns which are sometimes employed in supporting a lofty aqueduct, the best way is to make them hollow, and give them stability, by enlarging the base. They will, in that case, press less on the foundations, be less expensive, and they may be greatly stiffened by hooping.

"Indeed, it is not usual to make piers solid all the way up to the road; the spandrel-walls are carried back so far as to unite with those of the neighbouring arch, are locked together by a cross wall just over the middle of the pier, having also walls longitudinally, and the whole arched or flagged over from spandrel to spandrel just under the roadway.

"Nevertheless, as the case of solidity will enable us to assign a limit to the breadth of piers, which it may be proper to be acquainted with, we shall proceed in that investigation.

"The weight of the pier in that case will be as the rectangle under its height and thickness, expressing the weight of arch and pier by the cubic feet of stone. The pier indeed will be somewhat more; for the sterlings, or breakwaters, at each end, will add something to its stability; and this will be still farther increased in proportion to the horizontal push, if the whole bridge be wider at the foundation than at top, as is very common. Excluding these collateral advantages, we shall consider the whole as rectangular, and then the stability may be found in the longitudinal section. We have already $b = \dfrac{h\,t}{\frac{1}{2}\,p + \frac{3}{4}\,a}$, and in the case of a parallelogram $\frac{1}{2}\,p = \frac{1}{2}\,b\,(h + c)$, c being the height from springing to the roadway. By substitution, there arises $\frac{1}{2}\,b^2\,(h + c) + \frac{3}{4}\,a\,b = h\,t$; and by resolving this quadratic equation,

we have $b = \sqrt{\dfrac{2\,h\,t}{h + c} + \left(\dfrac{3\,a}{4\,(h + c)}\right)} - \dfrac{3\,a}{4\,(h + c)}$

or thus, $b = \dfrac{\sqrt{2\,(h + c)\,h\,t + \frac{3}{4}\,a\,|^2} - \frac{3}{4}\,a}{h + c}$, as a formula

for the thickness of solid piers to support equilibrated arches; and it must be observed, that if the arch be understood to act otherwise than at three-fourths the thickness of the pier, this co-efficient may be altered accordingly.

"When the arch is a segment less than a semicircle, a greater thickness of pier becomes necessary. For, the span continuing the same, we must either make the arch a part of a circle of greater radius, which would increase the horizontal thrust, or we must, in order to obviate that, diminish the thickness at the crown. In either case the weight of the arch is diminished, and with it the assistance which it gives to the stability of the pier.

"There is an interesting subject of inquiry, which might not be unappropriately noticed here; we mean the lowest versed sine that can be used for arches in proportion to the span. We conceive this, however, as in a great measure a practical question. We have already given some idea of the greatest possible arch of stone, or brick; a segment of that circle may, of course, be employed in any situation, but the piers (if the arch be of considerable span and height to the springing) must be made very great. Indeed, the investigation depends intimately on the thickness of piers. We ought to know the dimensions of the largest pier that can be trusted, and this, we conceive, depends chiefly on the care of the mason; for stone, and especially cement, is a compressible substance; and when an arch is very flat, a very small yielding at the springing produces an enormous depression at the crown, insomuch that there may be reason to dread, lest the arch pass down below the horizontal line, and fall to pieces before the stability of the abutments can be acted upon. A compression in the joints is equivalent to a yielding at the abutments, and appears equally difficult of remedy.

"In great horizontal thrusts, where the segment is flat, the immersion of the pier in water comes to have an important effect. On the weight of the pier, in those cases, the stability chiefly depends, and a deduction from that of two-fifths must be compensated by enlarging the thickness.

"But, indeed, the immersion of the pier, if it be very tall, that is, if the depth of water be great in proportion to the span, will demand attention, although the arch should not be very flat. In such a case, the stability arising from the pier is often as great as that which is derived from the weight of the arch. It can seldom be greater, and consequently can seldom require, an addition of more than one-fifth of that breadth, which would be sufficient were there no immersion.

"But although the total immersion, even of a lofty pier, will seldom require any great alteration in the thickness, there is yet another circumstance which well deserves attention. Bridges are often built, especially in a tideway, with the arches springing below the high waters; we have in that case a diminution from the weight of the arch itself; but unless the keystone be under water, the horizontal thrust is unchanged; we must, accordingly, in our calculation, make the same diminution for that part of the arch which is thus immersed, as we did in the above example for the piers. The result will oblige us still more to increase the thickness of pier.

"On the whole, we may conclude from this investigation respecting the piers, that the increase of breadth which may be, and usually is, given to the pier, is of much less importance, on account of the weight that is thereby gained, than by its increasing the length of that arm of the lever, whereby the weight of the whole resists the effect of the horizontal thrust oversetting it.

"Instead, therefore, of building up the pier with perpendicular sides, we should think it more advisable to begin the foundation of the pier on a base much wider than usual, and from thence, by regular recesses, or otherwise, gradually to diminish it, until, at the springing of the arch, it does not exceed the depth of the two arch-stones, while the outline of the pier may be a curve of any shape that is most pleasing. Many advantages would, in our opinion, be obtained by this construction: the water-way will be enlarged; the pier equally strong; the stability equally great, nay, much greater than usual; and the chance of the foundations being hurt in floods will be greatly diminished; and all this with a smaller quantity of materials."

It is manifest, that before an arch of equilibration can be destroyed, the pressure applied must be so great as to overcome the resistance offered by the friction of the adjoining voussoirs, or the adhesive power of the cements; and be it remembered, the greater the pressure, the greater also is the friction. We give the following as a method of discovering the extent of license allowed in practice, on account of this quality in the materials employed.

To find the quantity of friction in individual instances,— Place the stone to be used upon a platform of the same material, and raise up one end of the platform, until the least additional elevation would cause the stone to slide down, and measure the angle of elevation so found.

Now the effect of friction is this, that instead of being compelled to place the joints of the voussoirs in the position assigned them by theory, we may place them in any position on one side of it, provided the joints fall within an angle from their theoretical position, not greater than the angle of elevation, determined as above; or if the joints of the voussoirs are maintained in their original position, we may allow a proportionate variation in their weight. On this account very great latitude is allowed in construction, for we may depart very far from the rules laid down from theory, before we can endanger the stability of the edifice.

Dr. Robison is of opinion, that the voussoirs may be considered as a solid mass, and that the principal object to be attended to, is that the arch should be made so flat, as to admit the same straight line being drawn in such a manner as to pass through some point in every voussoir on either side of the keystone, and where this is impracticable, he recommends that the straight line should be carried through as many arch-stones as possible, and that the arch should be carefully loaded at the intersection of such lines, considering each number of voussoirs passed through by one line as a separate block of stone. Generally, he supposes, that the pressure at the crown, is communicated in a straight line through as many stones as one straight line will pass through. All suggestions, however, on this subject, must be attended with considerable doubt and difficulty, as we are almost entirely ignorant of the method by which the communication and distribution of pressure is regulated, and even, in many cases, of the nature of the materials employed.

In accordance with the intention expressed by us in our article on Bridges, we now proceed to give a description of the principal stone bridges erected over the Thames, commencing with Westminster, as being the oldest. The first stone for that bridge having been laid on January the 29th, 1739, by the Earl of Pembroke, and the bridge itself being entirely completed on the 10th of November, 1750.

Westminster Bridge was built according to the designs, and under the superintendence of, a Swiss architect, named Labeyle, who, in its construction, adopted the practice of forming the foundations by means of caissons, instead of driving piles into the ground, or making use of coffer-dams, according to the general custom. This he effected in the following manner:—Large timber cases, consisting of a strong platform, or raft, surrounded by sides, were made water-tight, and floated on the surface of the Thames to such places as the piers of the intended bridge were eventually to occupy. In these, when firmly moored in proper position, the masonry of the piers was commenced: the caissons gradually sinking in the water as the masonry advanced, until at length they finally settled on the bed of the river; the sides of the caissons were then removed, to be used elsewhere, and the piers, which were built of Portland stone in blocks, each of which was at least a ton in weight, and many of them weighing as much as five tons, were carried up to the springing of the arches. These blocks of stone were cemented together with Dutch tarras, besides being connected with each other by iron cramps fastened with lead.

The building of this bridge occupied nearly twelve years, owing to the plan that had been adopted in laying the foundation; in consequence of which, one of the piers sunk so much, as seriously to endanger the stability of the structure, and it was found necessary to put another in its place; this circumstance greatly enhanced the cost of construction, and the various sums expended amounted to £389,500. It appears that materials of this bridge, to the value of £40,000, are constantly under water. The caisson on which the first pier was erected, contained 150 loads of timber, on which were laid 3,000 cubic feet, or nearly three tons of solid stone.

Westminster Bridge is 1,220 feet long, and is 44 feet wide, including the foot-path for passengers on either side of the carriage-way; it consists of 13 large, and two small arches, 14 piers, and two abutments. The arches spring at about 2 feet above low-water mark, they are all semi-circular. The centre arch is 76 feet span, and the others decrease on either side by 4 feet, so that the arches near the banks of the river are only 52 feet span. There are, besides, the two small arches each of 25 feet span.

The piers are 70 feet in length, and terminate in cut-waters, pointing up and down the stream. Those which support the centre arch are each 17 feet wide, and every successive pier is diminished a foot in breadth, so as to leave a water-way in the clear of 870 feet.

There was formerly a handsome stone balustrade, which formed the parapet of the bridge on either side, and over every pier there was a bay or recess, covered in with a kind of half cupola; while over the central arch, a rectangular space increased the width of the bridge by means of a projection towards the water.

The soffits of the different arches in this bridge, were carefully turned in Portland-stone. Over this, another arch was formed of Purbick-stone, well bonded with the preceding, and so arranged as to make the thickness of the double arch about the haunches four times that at the crown. The spandrels were constructed with barrel and intermediate arches, so as to maintain the edifice in equilibrio.

When Old London Bridge was taken down, and a more uninterrupted outfall was thus afforded to the stream, the bed of the Thames became considerably deepened, and the foundations of the different bridges which had been previously constructed, were thereby more or less affected. Westminster Bridge suffered particularly from that cause; for, owing to the very insecure substructure on which it was founded, its piers have been gradually giving way for years; and, in consequence of the inequality of yielding which has taken place, the entire bridge is now in a deplorably dilapidated condition. It has been deemed absolutely necessary to prop up several of the arches by centerings, to remove the weight over others, and in order to prevent a too manifest appearance of the unsightly breaks which have taken place in the roadway, the stone balustrade has been replaced by a temporary wooden fence or parapet.——To our thinking, the repairs which it has lately undergone, were effected in a most injudicious manner. In the first place, the system of propping up some of the arches, and allowing others to sink freely, was highly prejudicial to the stability of the bridge; and indeed one of the arches was only partially supported, so that the remaining portion separated from it, and sunk several inches, to the imminent peril both of its real and apparent efficiency. Again, the uselessness of facing the piers with new stone, at a time when the entire demolition of the structure became inevitable, must be evident to every one who will give the subject but a passing consideration.

As, however, this bridge is to be taken down very shortly, and a handsome modern structure will ere long supply its place, we do not think it necessary to say more on this subject at the present time.

Next in point of date among the stone bridges of the Thames, is that of Blackfriars, which was commenced in the year 1760, and finished in 1770, by Robert Mylne, a Scotch engineer, who had just before returned from Rome, where he had been pursuing his studies, and where he had earned a well-deserved reputation; having received a silver medal from the Roman Academy, which he deposited, together with several coins of George the Second, in the foundations of the bridge.

Blackfriars Bridge is about 1,000 feet in length, and about 43 feet wide, including a carriage-way of 28 feet, and two raised footpaths for pedestrians, each 7 feet in width; it is built of nine nearly semi-elliptical arches, of which the centre one is 100 feet, and the others decrease in span, as they are placed nearer the banks of the river, being respectively 98, 93, 83, and 70 feet, by which it will be seen that there is a water-way of 788 feet in the clear. The roadway is a uniform curve, being the segment of a very large circle.

The architecture of this bridge is exceedingly beautiful, and great taste is displayed in the design; the bays over each of the piers being supported by Ionic columns, which give a light and graceful character to this really handsome edifice; and it is to be regretted, that the materials of which it is composed are of so perishable a nature. In consequence of the curved roadway, the entablature of the columns is not made horizontal; and the consequent inequality in the height of the columns, is a marked defect in an æsthetic point of view. The parapets of this bridge are formed by a very handsome stone balustrade, 4 feet 10 inches in height; so that, while the security of persons passing over the bridge is amply assured, the view both up and down the river is uninterrupted. The expense of constructing Blackfriars Bridge amounted to £152,840.

The plan of forming the foundations by means of caissons, was unfortunately again resorted to in this case, and although short piles were driven into the bed of the river on which the bottoms of the caissons were made to rest, still the scouring process to which the channel of the Thames has been subjected of late years, has seriously affected the stability of the piers, and the change which has consequently taken place in the form of some of the arches, plainly point out the necessity of constructing a new bridge for this reach of the river at no very distant period.

Waterloo Bridge is one of the finest stone bridges constructed over the Thames; its bold, solid style of architecture being admirably suited to the character of a bridge over a large and important river, where massiveness and strength, combined with taste in design, have been judiciously and pleasingly combined; and when to these considerations are added the circumstance of its having a roadway perfectly level throughout, we may safely come to the conclusion, that it is one of the most successful specimens of bridge-building which has ever been produced. The celebrated Canova was loud in its praises, and extolled it as the *beau-ideal* of such constructions.

It was built by the late eminent engineer Rennie, who submitted two plans, one with seven arches, and the other nine; the latter was adopted, and the first stone of the new structure was laid in the October of 1811. The foundations he formed by means of coffer-dams, composed of three rows of piles one within the other, at a distance of about 3½ feet between the rows; the intermediate spaces having been carefully filled in with well-rammed clay. The water was then pumped out of the coffer-dam, and piles a foot square, and about 20 feet long, were driven into the bed of the river. A framework of timber was then constructed on the top of those piles, and the spaces between the pile-heads, to a depth of about a foot and a half, were filled in with stones tightly packed, and well grouted with liquid mortar. A floor of beech-planking, six inches in thickness, was bolted to the timber frame-work, on which the masonry of the piers and abutments was then commenced.

The entire surface-work of this bridge was built of Cornish granite, and the interior consists principally of Craigleith sandstone, well bonded, and cemented by a grouting of mortar. The spandrels of the arches were left hollow, to avoid an undue loading of the haunches, with the exception of six transverse brick-walls, for the purpose of supporting the roadway.

All the arches of the bridge are the same—semi-elliptical in form, 120 feet in span, and having a rise or versine of 35 feet. This allows a clear waterway of 1,080 feet. The piers are 87 feet long, from the extremity of one cut-water to another; they are 30 feet in width at the foundations, and diminish to 20 feet at the springing of the arches. Over each pier there is a rectangular recess, which is supported by Doric pillars, these, together with an open stone balustrade, give a certain degree of lightness to the edifice, without interfering with its characteristic solidity.

The entire length of Waterloo Bridge, including its approaches, which are built on land-arches, at either side of the river, is 2,456 feet.

This bridge took only six years to construct; and it was so carefully put together, every stone having been accurately put into its place, and so well driven home, that on removing the centres, the arches did not sink more than an inch and a half at the crown; which is truly wonderful, when their immense span is taken into consideration.

Waterloo Bridge was built by a Joint-Stock Company, empowered by act of Parliament to raise a million of money; to pay off which, and reimburse its proprietors, a small toll is levied from passengers; and now that the South Western Railway is completed as far as the Waterloo-station, the traffic over the bridge, and consequently the returns derived from the tolls, have been considerably augmented.

London Bridge was built somewhat to the west of the site formerly occupied by Old London Bridge, an antiquated stone structure, that was erected about the beginning of the 13th century, by Peter of Colechurch, who combined the professions of architect and priest: he died in the year 1205, and was buried in a crypt within the centre pier of the old bridge, over which there was a chapel dedicated to St. Thomas à Becket.

The contractors for the building of the new bridge, Messrs. Jolliffe and Bankes, under the superintendence of Mr. (now Sir John) Rennie, the engineer, drove the first pile of a coffer-dam for the south pier, on the 15th of March, 1824.

The general form of the dam was elliptical. Three rows of piles shod with iron, and many of them measuring between 80 and 90 feet, were driven into the ground, and after being bolted together by means of walings, the spaces between them were puddled with clay, &c.; wooden stays or props were also placed between the different rows of piles and the interior space of the dam, strongly truss-framed between longitudinal beams. This coffer-dam having been completed, the first stone of the new bridge was laid by the then Lord Mayor of London, in the presence of H. R. H. the Duke of York, on the 15th of June, 1825.

Piles of beech-wood were driven into the natural bed of the river, consisting of stiff blue clay, to the depth of about 20 feet; two rows of horizontal sleepers, about a foot square, were laid on the tops of those piles, and these again were covered by a planking of beech, 6 inches in thickness; and on this flooring the foundations of masonry were laid. The same system was adopted for all the piers and abutments.

The construction of centering for the arches was the next step in this great undertaking. Each centre was composed of ten frames, joined together on the principle of the diagonal truss—each frame rested at either end on a pile driven into the river. The ten frames were then boarded over with planks placed within 2 or 3 inches of each other. In consequence of a difference in size in the arches, it was necessary to have four sets of centres.

On these centres the arches were turned in the ordinary manner, and in the spandrels hance-walls were built, longitudinally, so as to oppose the thrust of the arches without overloading the haunches. On the top of those walls heavy blocks of stone were bedded, and on these were laid stone landings, upon which was placed a layer of tarras, and over that again, the puddling, on which the roadway was formed. The first arch was keyed in on the 4th of August, 1827, and the last on the 19th of November, 1828.

The approaches on either side of the bridge were carried on arches over some of the streets running along the banks of the river. The arch over Thames-street, in particular, is worthy of attention, being very flat, having been constructed over the roadway and both the footpaths of Thames-street, and the centering for it had to be so made as to leave an uninterrupted passage for vehicles and pedestrians; it was entirely supported by struts ranged along the junction, between the carriage-way and footpaths, and the abutments of the arch; on these the wedges were placed upon which the centering was made to rest.

The only alteration in the original plan of Mr. John Rennie, the engineer who designed the work, was the addition of 6 feet to the roadway, and an increased height of 2 feet in the abutment arches. The alteration in the width of the roadway was loudly insisted on by the public; and the government ordered that the additional cost it would necessitate, should be met by a public grant to the amount of £42,000. The additional height in the side arches was proposed by the present Sir John Rennie, on whom the execution of the work had devolved on the demise of his father. This great undertaking was entirely completed on the last day of July, 1831, after having been about seven years and a-half in the course of construction.

London Bridge is composed of five semi-elliptical arches, four piers, and two abutments. The centre arch is 152 feet span, having a rise of 29 feet 6 inches above high-water mark. The two arches next to this are each 140 feet in span, and rise 27 feet 6 inches. The two abutment arches are 130 feet in span, and rise 24 feet 6 inches. The two piers which support the centre arch are each 24 feet wide, and the others 22 feet in width.

The line of roadway, which is the segment of a great circle, the rise being only 1 in 132, is marked externally by a modillion cornice, over which there is a close parapet wall in place of the open balustrade which we have mentioned connected with the other three stone bridges.

The abutments are each 73 feet at the base. On either side of these are two straight flights of steps, 22 feet in width.

The entire length of the bridge, from the extremities of the abutments, is 928 feet; and the clear water-way is 690 feet. The carriage-way is 35 feet wide, and each of the footpaths 9 feet.

This admirable bridge was built of the best Aberdeen, Penryn, and Heytor granite; and the quantity of stone used in its construction amounted to 120,000 tons. In addition to this, many of the arches forming the approaches were built of brick. The cost of construction for the bridge itself was but little over half a million of money; but the expense of making new approaches, purchase of land for the same, and cutting through valuable and important premises, increased the expense considerably; and the various sums expended on the new bridge, and the different improvements it rendered necessary, came to nearly two millions sterling; to which amount the government, however, contributed to a considerable extent.

London Bridge was opened to the public on the 1st of August, 1831, by King William the Fourth, who proceeded in state by water, to be present at the inauguration ceremony, attended by the most distinguished personages connected with his court; and the king took the opportunity of complimenting the citizens of London on the "skill and talent" which they had displayed in "many magnificent improvements," and especially in the successful accomplishment of that splendid undertaking. The day's festivity was concluded by a princely banquet, which was served up on London Bridge; and that beautiful erection, admirable in design—simple in appearance—but substantially useful in its character, became thenceforward public property, and was freely thrown open, without toll or restriction, for the use and benefit of the entire nation.

Skew Bridges may fairly come under the head of Stone

Bridge; for though they are frequently built of brick and other materials, the vast majority of such constructions are either formed of stone, or stone and brick combined.

Oblique, or Skew bridges, have been introduced contemporaneously with railways; for few bridges of the kind were constructed anterior to that time. We hear, indeed, of one having been thrown over the river Mugone, at Florence, so early as the year 1550; but the true principles on which oblique bridges depended were not previously known or studied, as their application to general purposes was rarely, if ever, absolutely called for, until the plan of rapid locomotion, which the system of railways gave rise to, made their use constant, and in many cases indispensable.

In the construction of oblique bridges, the main object to be kept in view is to bring the thrust of the arch into such a position as will enable the abutments, or piers, properly to counteract it; and the most effective way of so doing, and at the same time the most simple, is found to be by making the direction of the courses at right angles to the face of the bridge.

There have been various methods suggested for building these bridges; but the one most commonly adopted, is to form the arch by regular spiral courses, all parallel to one another, and so arranged, that any section taken at right angles to the axis of the cylindrical segment which constitutes the arch, shall exhibit the coursing-joints tending in a radial direction to the centre of the cylinder at the point of section. All the voussoirs are rectangular in plan, both on the extrados and intrados, with the exception of those on the faces of the bridge, because a spiral line, touching the outer edge of both abutments, would form a curve of contrary flexure, falling partly within and partly without the line bounding the arch. In this case, the face-line will evidently not be parallel to the heading-joints of the voussoirs, which, therefore, will be of a constantly varying shape and size on the faces of the bridge. Again; it is important to remark, that in this particular system of construction, the joints of the voussoirs are not, properly speaking, straight lines on the elevation of the arch, but segments, whose chords should all tend to a common centre, which, in every case, must be more or less below the axis of the cylinder, according to the angle of the skew bridge.

One of the best works on the subject of skew bridges, was written by Buck, wherein formulæ are given, from which all the dimensions of skew arches of every kind may be arrived at with mathematical accuracy, and the principles of their construction are clearly and correctly explained. Nicholson published two admirable works on this important department of bridge-building—one in 1828, entitled, "A Practical Treatise on Masonry and Stone-cutting;" and the other in 1839, called, "A Treatise on the Oblique Arch." To him we are indebted for the first sound exposition of the principles on which such constructions are founded; and from the practical bearing of this, as of all his works, it was of the greatest use in presenting the subject to men's minds in a correct and intelligible point of view, and setting it forth in its proper light.

The method of forming oblique arches, as above explained and treated of by Buck and Nicholson, supposes the arch to be a segment of a circle on the square section. It is not, however, necessary that such should be the case; the form of the arch may be elliptical on the square section, in which case the elevation is a much flatter ellipse, according to the amount of skew; as it is clear that the minor semi-axis is constant, while the major semi-axis will increase with the skew; and this arch may be again modified by making the joints of the voussoirs perpendicular to the radius of curvature on the square section, instead of making them tend to the axis of the cylindrical segment.

Many changes of this kind have been recommended and tried, with varying success, by Messrs. Hart, Adie, Roebuck, and several others.

Stone Columns, such columns as are constructed of stone; in which, the fewer the joints, the better the appearance. If columns are necessarily composed of more than one piece, from the difficulty of procuring stones of sufficient magnitude, they ought to consist of three, five, or some odd number; more especially if the joints be few in number, than when they are many.

In columns constructed of several pieces, a mould must be made for every joint; and in setting the pieces, a sheet of thin milled lead, well bedded in white-lead, ought to be inserted between the joints, so as to come within about three-quarters of an inch of the convex surface of the column.

In the act of building, the diminishing rule ought to be applied to every course as it is set; and when the whole column is completed to its height, it ought to be tried again, and all the inequalities in the height reduced to the regular curve; for it is hardly possible, even though constructed by the best workmen, that some irregularities should not occur: and, at the same time, the circularity, or roundness, of the column ought to be attended to.

The most accurate method of fluting columns is, to cut the flutes after the columns are built, and brought to the curve; but in performing this, great care ought to be taken to prevent the chipping of the stone at the joints; which is best avoided by working each adjoining stone, or piece, from the joint, at least so far as to be out of danger of splitting the part of the stone next to it.

Stone Stairs, those constructed of stone. When stone stairs are supported by a wall at both ends, nothing difficult can occur in the construction; in these the inner ends of the steps may either terminate in a solid newel, or be tailed into a wall surrounding an open newel. Where elegance is not required, and where the newel does not exceed two feet six inches, the ends of the steps may be conveniently supported by a solid pillar; but when the newel is thicker, a thin wall surrounding it would be cheaper.

In the stairs of a basement story, where there are geometrical stairs above, the steps next to the newel are generally supported upon a dwarf wall.

Stone geometrical stairs have the outer end fixed in the wall, and one of the edges of every step supported by the edge of the step below, and constructed with joggled joints, so that they cannot descend in the inclined direction of the plane, nor yet in a vertical direction; the sally of every joint forms an exterior obtuse angle on the lower part of the upper step, called *a back rebate*, and that on the upper part of the lower step, of course an interior one, and the joint formed of these sallies, is called *a joggle*, which may be level from the face of the risers, to about one inch within the joint. Thus is the plane of the tread of each step continued one inch within the surface of each riser, and the lower part of the joint is a narrow surface, perpendicular to the inclined direction, or soffit, of the stair at the end next to the newel.

In stairs constructed of most kinds of stone, the thickness of every step at the thinnest place of the end next to the newel, need not exceed two inches for steps of four feet in length, measuring from the interior angle of every step perpendicular to the rake. The thickness of steps at the interior angle should be proportioned to the length of the step: but allowing the thickness of the steps at each interior angle to be sufficient at two inches, the thickness of steps at the interior angles will be in inches half the length of the steps in feet: thus, a step of five feet long would be two inches and a half at that place.

The stone platforms of geometrical stairs, viz., the landings, half-paces, and quarter-paces, are constructed of one, two, or several stones, as they can be procured. When the platform consists of two or more stones, the first platform stone is laid upon the last step that is set, and one end is tailed in and wedged into the wall; the next platform stone is joggled, or rebated, into one set, and the end also fixed into the wall, as that and the preceding steps are; and thus with every stone in succession, till the platform is completed. If there is occasion for another flight of steps, the last stone of the platform becomes a spring stone for the next step, and the joint is to be joggled, as well as those of the succeeding steps, in the same manner as in the first flight. Geometrical stairs, executed in stone, depend upon the following principle: that everybody must, at least, be supported by three points placed out of a straight line, and consequently, if two edges of one body in different directions be secured to another, the two bodies will be immovable in respect to each other. This last is the case in a geometrical stair: one end of a stair stone is always tailed into the wall, and one edge either rests on the ground itself, or on the edge of the preceding stair stone, whether it be a plat or step. The stones of a platform are generally of the same thickness as those forming the steps.

Stone Walls, such walls as are constructed of stone.

The modern methods of constructing stone walls, with a description of the materials employed, have already been given under the head Masonry; we shall, therefore, confine this article to the construction of walls used by the ancient Greeks and Romans.

Vitruvius has left us an account of the construction of the walls of the ancients as follows: "The sorts of walls are the *reticulated*, (*Figure* 1,) and the ancient, which is called *the uncertain*, (*Figure* 2.) Of these, the reticulated is the handsomest, but the joints are so ordered, that all the parts of the courses have an infirm position; whereas, in the uncertain, the materials rest firmly one upon the other, and are interwoven together; so that they are much stronger than the reticulated, though not so handsome. Both sorts are formed of very small pieces, that the walls, being saturated with mortar, may endure the longer; for the stones, being of a porous and spongy nature, absorb the moisture from the mortar; and when there is an abundance of mortar, the wall, having more humidity, will not so soon decay, but will, on that account, be rendered more durable; for as soon as the humidity is extracted from the mortar by the suction of the stones, then the lime and sand separating, the cement is dissolved, and, the mortar, no longer uniting the materials, the walls soon become ruinous. This may be observed in some tombs near the city, which are built with marble, or hewn stone, and the internal parts rammed with rubble stones; the mortar being by length of time drained of its humidity by the suction of the stones, and the union of the joints being dissolved, they separate and fall to ruin.

"To avoid this error, the middle space (*Figure* 2) must be strengthened with abutments of the red hewn-stone, or bricks, or common flints, built in walls two feet thick, and bound to the front with cramps of iron fixed with lead; for the work being thus built in a regular manner, and not laid in promiscuous heaps, will remain without defect; and being, by the orderly arrangement of the courses and joints, firmly united and bound together, it will not be liable to fractures, nor will the abutments suffer it to fall to decay. For this reason, the walls of the Greeks are not to be despised; for though they do not use smooth or polished materials, yet where they discontinue the square stones, they lay the flints, or common hard stones, that they use, in the same manner as bricks are generally laid, bonding the courses together with alternate joints, and thus making their works strong and durable.

"These walls they build in two manners; one is called *isodomum*, (*Figure* 3,) and the other *pseudisodomum*, (*Figure* 4.) Isodomum is when all the courses are of an equal thickness; and pseudisodomum when they are unequal. Both these sorts are firm; first, because the stones themselves are of a compact and solid nature, and do not absorb the moisture from the mortar, but preserve its humidity to a great age; and, secondly, being situated in regular and level courses, the mortar is prevented from falling, and, the whole thickness of the wall being united, it endures perpetually.

"Another sort is that which they call *emplecton*, (*Figure* 5 and 6,) which is also used by our villagers. The faces of the stones, in this kind, are smooth; the rest is left as it grows in the quarry, being secured with alternate joints and mortar; but our artificers, quickly raising a shell, which serves for the faces of the wall, fill the middle with rubble and mortar; the walls, therefore, consist of three coats, two being the faces, and one the rubble core in the middle, (*Figure* 5 and 6.) But the Greeks do not build in that manner; they not only build the facing courses regularly, but also use alternate joints throughout the whole thickness, not ramming the middle with rubble, but building it the same as the face, and of one united coat they construct the wall; besides this, they dispose single pieces, A, which they call *diatonos*, in the thickness of the wall, extending from one face to the other, which bind and exceedingly strengthen the walls. Those, therefore, who would build works of long duration, must attend to these rules, and make use of such methods of building; for the smooth polish, and beautiful appearance of the stones, will not prevent the wall from being ruined by age."

STOOTHINGS, a term used in the north of England, and perhaps in some parts of the south of Scotland, for battening to walls.

STORY-POSTS, upright timbers, disposed in a story of a building, for supporting the superincumbent part of the exterior wall, by means of a beam over them. They are chiefly used in sheds and workshops. Story-posts should have a solid wall below, or they should stand upon a strong wooden sill, or upon inverted arches, or upon large stones, with their ends let into sockets. When the distance between story-posts is considerable, they should have two braces on either side; and these should be resisted at the top by a straining-beam, and at the bottom by joggles cut in the posts themselves; the upper surface of the straining-beam should also coincide with the lower surface of the upper beam, or bressummer. In cases where the distance between the story-posts is still greater than above supposed, not only braces and straining-beams are to be employed, but every interval should be arched upon the top of the bressummer.

Story-Posts, or Prick-Posts, as they are called in old books on architecture, are used in wooden buildings, between the stories, to support the floors.

Story-Rod, a measure used in staircasing, in length equal to the height of the story; or from the upper surface of the boards of one floor to the under surface of those of the next; it is divided into as many equal parts as there are to be risers in the stair, for the more accurately carrying up the steps.

STOUP, a stone bason, frequently found in the porches and at the entrances of our old churches, and employed to contain holy water, with which the worshippers sprinkled themselves upon entering the church. This was a relic of a very ancient practice observed in the early church, and the holy-water stoup seems to have been a substitute for the foun-

Fig. 1.
Reticulated

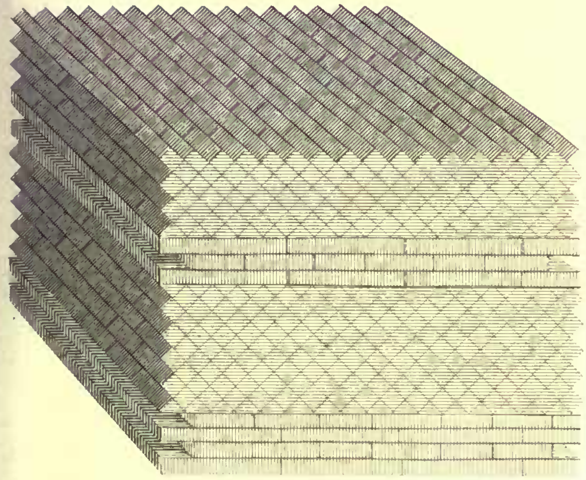


Fig. 2.
Incertain.

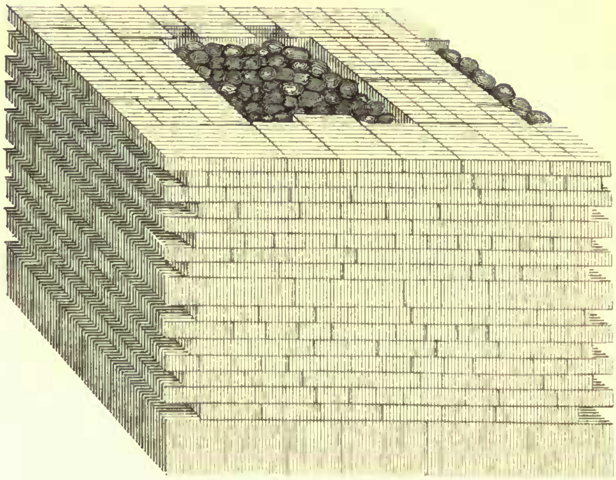


Fig. 3.
Isodomum

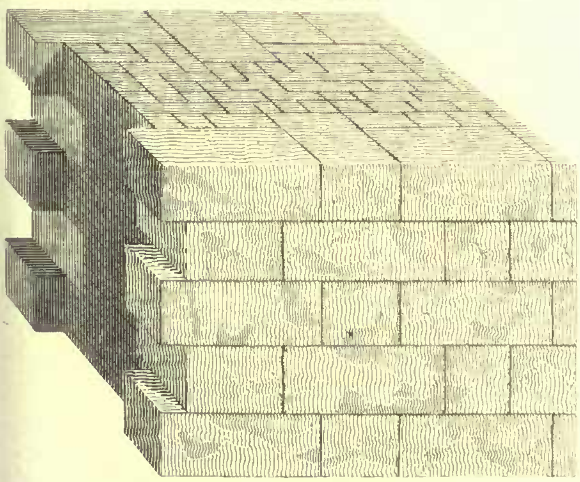


Fig. 4.
Pseudisodomum.

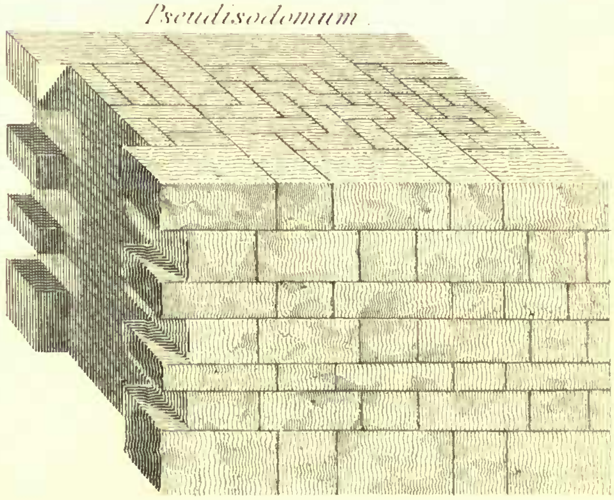


Fig. 5.
Roman Emplection.

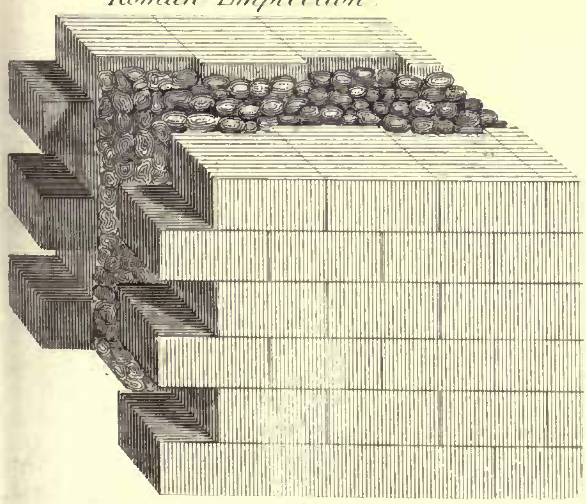
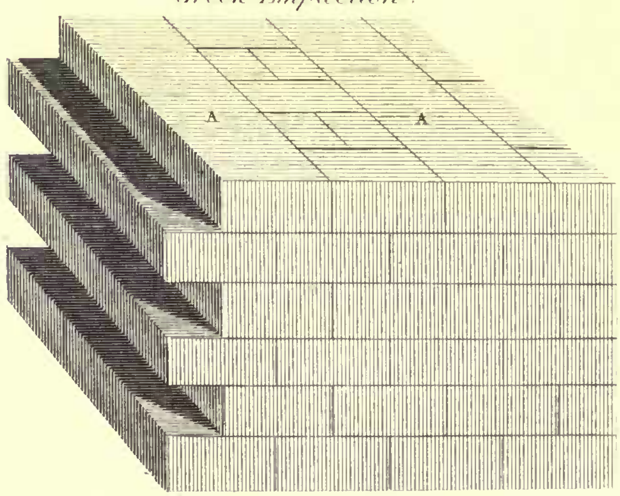


Fig. 6.
Greek Emplection.



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tain which existed in the atria of the early churches. The stoup, or *benatura*, in our old churches, is of small size, usually situated in an arched recess, and of similar form to the piscina, which, however, has its place by the side of an altar, and was used for a different purpose. Many examples still exist of various forms, and of different degrees of ornamentation.

STRAIGHT-JOINTED FLOOR, a floor in which the joints are continued from one end of the apartments to the other; and where the heading-joints are not in the same straight line, as in folded floors.

STRAINING-PIECE, or STRUTTING-PIECE, a piece of timber acting in opposition to two equal and opposite forces at its extremities, for the purpose of preventing their nearer approach towards each other. Principal rafters, camber-beams, hip-and-valley rafters, collar-beams, or straining-beams, auxiliary rafters, or principal braces, struts, studs, and story-posts, are all of this description. Straining-pieces are distinguished as beams or sills by the term *beam* or *sill* immediately following the word *straining;* as *straining-beams*, *straining-braces*, or *straining-sills*.

STRAINING-SILL, or STRUTTING-SILL, a beam that is both a straining-piece and a sill.

STRAP, (from the Dutch, *stroppe*,) in carpentry, an iron plate placed across the junction of two or more timbers, either branched out or straight, as may be found requisite, and each branch bolted, or keyed, with one or more bolts, or keys, through each of the timbers, for the purpose of securing them together. When one piece of timber stands upon another, so as to form two right angles on the same side of the standing-piece, the strap is most frequently made to go round the cross-piece, and to embrace the two opposite sides of the standing-piece, which may be bolted, or keyed, with one or two bolts passing through the tails of the strap. When it is inconvenient to make a strap embrace both opposite sides of the timbers, it is necessary that a branched strap should be placed upon each side, and every timber must be bolted to the opposite branches.

When two pieces of timber press upon each other, and one of them extends on both sides of the joint, a strap is unnecessary: but where neither extends beyond the joint, it is necessary to have one. All ties having shoulders abutting against transverse pieces at the ends, whether the angle formed by the transverse pieces be right or oblique, should be strapped to those pieces.

STRATA, the layers of earth, sand, gravel, clay, chalk, stone, and other substances, which form the crust of the earth. A knowledge of geological strata is very necessary in all extensive building-operations.

STRENGTH OF MATERIALS, the force which any material is capable of resisting before it breaks, whether from pulling, compressing, squeezing, or from being twisted, or from bending by a force applied laterally.

As the laws of resistance are the same, whatever be the material employed, under the specific name of *Strength of Timber*, the reader will find ample satisfaction, at least as far as regards useful knowledge in its application to practical architecture.

STRENGTH OF TIMBER, the resistance that a bar, or beam, is capable of exerting against a superior power, before it breaks, whether the force be applied in its longitudinal or transverse direction, or by twisting. The theory of this subject, illustrated by various examples, will be found in the following Propositions :—

PROPOSITION I.—*The force which elastic strings, or fibrous bodies, &c. exert, when drawn or compressed in a direction of their length, is proportional to the increased or contracted space to which they are lengthened or shortened.*

As the extension or contraction of bodies, when drawn out or compressed by superior forces, depends entirely on the law of corpuscular attraction; and as this law has not yet been developed, it does not, therefore, come within the limits of demonstration: but from numerous experiments on different elastic bodies, it has been sufficiently proved, that when these bodies have been stretched by forces at each end, the additional lengthening was always as the force applied, except when near the point of breaking, where the force was something less than in that proportion; and when compressed by forces, this law has been found to hold equally, except where the compressing forces were enormous; in which case, the contracted spaces were less than the proportion of the force; the truth may, therefore, be looked upon as sufficiently established.

Remark.—Dr. Robert Hook was the first who attended to this subject, and assumed this law as a property of bodies.

PROPOSITION II.—*If a beam be supported at the two ends, and a force, or weight, applied to the middle of it, the deflection of the beam, or space through which it bends, will be as the force applied, nearly.*

This proposition may be determined from the law of elasticity and attraction, supposing them once established; but, perhaps it will be more easily determined by experiment; and the analogy is the same with regard to the deflection in this, as it is in the preceding Proposition, with respect to the increase or decrease of length; and it is found also in this, as in the extended state of the other, that when the beam is nearly upon the point of breaking, a less proportion of weight is required, than the space through which the beam descends. Therefore this Proposition may also be looked upon as sufficiently established.

PROPOSITION III.—*If a solid be supported by four forces, of which two and two are parallel: then, in each pair of parallel forces, one force is equal to the other, and its direction contrary.*

Plate I. *Figure* 3.—Let A B C D represent the section of a solid, supported in the plane of its section, in the parallel directions A G, C P, and A F, C S, by four forces, H, P, I, L, three of which may be weights going over the pulleys G, F, S. Join A C; then let the weight P be represented by the part C M, and complete the parallelogram C M N O; make A R equal to O C; produce G A to K; and complete the parallelogram A K R Q. The point C is now sustained by the three forces, C O, C N, C M, and the point A by the three forces A Q, A R, A K; and the forces A R and O C being equal, and opposite in the same straight line, they mutually balance each other. Now the triangles A K R and O N C are similar, and A R is equal to O C; therefore A K and O N are equal; that is, A K is equal to C M, as A Q is to C N; but A K and C M are the forces at H, as P and A Q and C N are the forces at I and L; therefore the forces at H and P are equal to each other, as are also the forces at I and L. Now, as the string C P is in a state of tension, and as any two of the three angles P C S, S C A, A C P, are greater than two right angles, the lines C S and C A are in a state of tension; and because A C is in a state of tension, A G and A F are so likewise; because any two of the three angles G A F, F A C, C A G, are greater than two right angles; therefore the forces in each pair of parallel lines, A G, C P, A F, and C S, act equal and contrary to each other.

Corollary.—If the body be a prism, and A B C D a section parallel to one of its faces; and if the directions of the forces be in the lines A B, B C, C D, D A, then the force at P, or the contrary force at H, is to the force L, or its contrary force I, as the breadth of the prism to the length; for as the triangles O N C and A D C are similar, O N : N C : : A D : D C.

Definition.—*Power* is the weight, or force, employed to break a beam.—*Momentum of Power*, *mechanical energy*, or *stress*, *upon a given section of a solid*, the force which a power has to produce fracture at that section, which forms the fulcrum of a lever acted upon by such power.

Corollary.—Hence the strain is as the momentum of power.

PROPOSITION IV.—*If, instead of the weights* I, L, H, *as in the last Proposition, the points* A *and* D, *Figure* 4, *be supported by two springs*, A G *and* D H, *in the direction* A B *and* D C, *parallel to the horizon, and by a prop* D F, *perpendicular to it; and if* A D *be divided into any two parts*, A E *and* E D, *then will* $P \cdot CD = ED \cdot f + EA \cdot f$; *that is, the momentum of power is equal to the sum of the momentum of tension and compression, where f is the tension of the upper spring, or the compression of the lower.*

For, by the *Corollary* of the last Proposition, $f : P :: CD : DA$; therefore $P \cdot CD = f \cdot DA$; but $ED \cdot f + EA \cdot f = AD \cdot f$; therefore $ED \cdot f + EA \cdot f = P \cdot CD$.

Corollary 1.—Hence, if a prismatic rectangular beam, A B C D, projecting from a wall, be loaded with a weight, P, sufficient to balance the resistance of the fibres at the place of fracture; there will be a certain line in that place, on which the beam will turn as on an axis, and all the fibres from that line to the upper surface will be extended in the ratio of their distances, whilst all those below will be compressed in the same ratio towards the lower surface.

Corollary 2.—Hence, if E be the quiescent axis, the forces of all the fibres in a state of tension will be equal to $EA \cdot f$; and those in a state of compression will be equal to $ED \cdot f$; their whole resistance, therefore, is equal to $EA \cdot f + ED \cdot f$, that is, equal to the weight, or power, P, multiplied by its distance, D C, from the wall, the momentum of power.

PROPOSITION V. *Figure* 5.—*If a beam be supported by the two ends*, A, B, *and a weight*, W, *be applied over the middle section*, C D; *then will the momentum of power occasioned by the weight*, W, *to overcome the resistance of the beam, be equal to half the weight*, W, *multiplied into half the length of the beam.*

For the beam is under the same circumstance as if it had been supported by three forces in parallel directions; and because the weight, W, is in the middle of the beam, each of the props must support half of it. Now the part D B may be considered as if acted upon by a power at B, equal to half the weight, W, drawing it upwards, while the other part, A C, is fixed in the same manner as if built in a wall; therefore, by the last Proposition, the force to balance the resistance made by the fibres at the section, C, will be equal to $\frac{W}{2} \times DB$.

Corollary 1.—Hence, if the weight, W, be given, the strain at C will be as the length, A B.

Corollary 2.—Hence it is also evident, that in beams of the same dimensions of breadth and depth, the strain by their own weight is as the square of the length; because the weight is as the length.

Corollary 3.—The greatest strain is where the weight is applied.

Corollary 4.—If there are two beams, having equal weights placed upon them, so as to divide them into segments of equal ratios, the strain in each will be as its length.

Corollary 5.—Hence the strain in a beam fixed in a wall, from any weight hung to its end, is equal to the strain in a beam of twice the length, with double the weight, supported at the ends.

PROPOSITION VI. *Figure* 6.—*If a beam*, A B, *be supported in four points*, A, B, C, D, *and a weight*, W, *appended to the middle of the part* C D *at* F, *it will carry twice as much as if it were only supported by the two middle points* C D.

For, suppose the beam cut through at the section E, then, by *Corollary* 5 of the last Proposition, the strain at C, from a weight at E, will be equal to the strain in a beam of double the length; therefore it will require the same weight to break the parts E C and E D, at C and D together, when cut at E, as it would when C D is whole, and supported at C and D only: therefore, to break all the three sections C, E, D, at once, it will require twice that weight.

PROPOSITION VII. *Figure* 7.—*If a weight*, W, *or any force, act perpendicular to the length of a beam, supported at the two extremities*, A *and* B, *the strain at the section*, C, *on which the force acts, will be equal to the rectangle of the two segments into the weights, divided by the length; that is, as* $\frac{AC \cdot CB \cdot W}{AB}$.

For, by the property of the lever, $AB : AC :: W :$ the force at $B. = \frac{AC \cdot W}{AB}$; but the strain at C, from a force acting at B, is as the distance and force applied; that is, $BC \cdot \frac{AC \cdot W}{AB} = \frac{AC \cdot CB \cdot W}{AB}$.

Corollary 1.—In beams of equal lengths, the strain at the section, C, is as the rectangle of the two segments and the weight.

Corollary 2.—In beams of equal lengths, having equal weights applied, the strain in each is as the rectangle of the two segments only.

Corollary 3.—If the force applied be in the middle, the strain will be as the square of the length.

Corollary 4.—The greatest strain of a beam is in the middle, because the greatest rectangle is there.

PROPOSITION VIII. *Figure* 8.—*The strain on any section*, D, *of a beam resting on two props*, A *and* B, *occasioned by a second force applied perpendicularly upon another section*, C, *is equal to the rectangle of the two extreme segments into the weight, divided by the length; that is*, $\frac{AC \cdot DB \cdot W}{AB}$, *equal to the strain at* D.

For, by Proposition VII., the strain at C is $\frac{AC \cdot CB \cdot W}{AB}$; but the strain at C is to that at D as B C to B D; therefore, $BC : BD :: \frac{AC \cdot CB \cdot W}{AB} : \frac{AC \cdot BD \cdot W}{AB}$ equal to the strain at D.

Corollary 1.—Hence, the strain at D, from a weight, W, placed at C, is equal to the strain at C, from the same weight, W, placed at D.

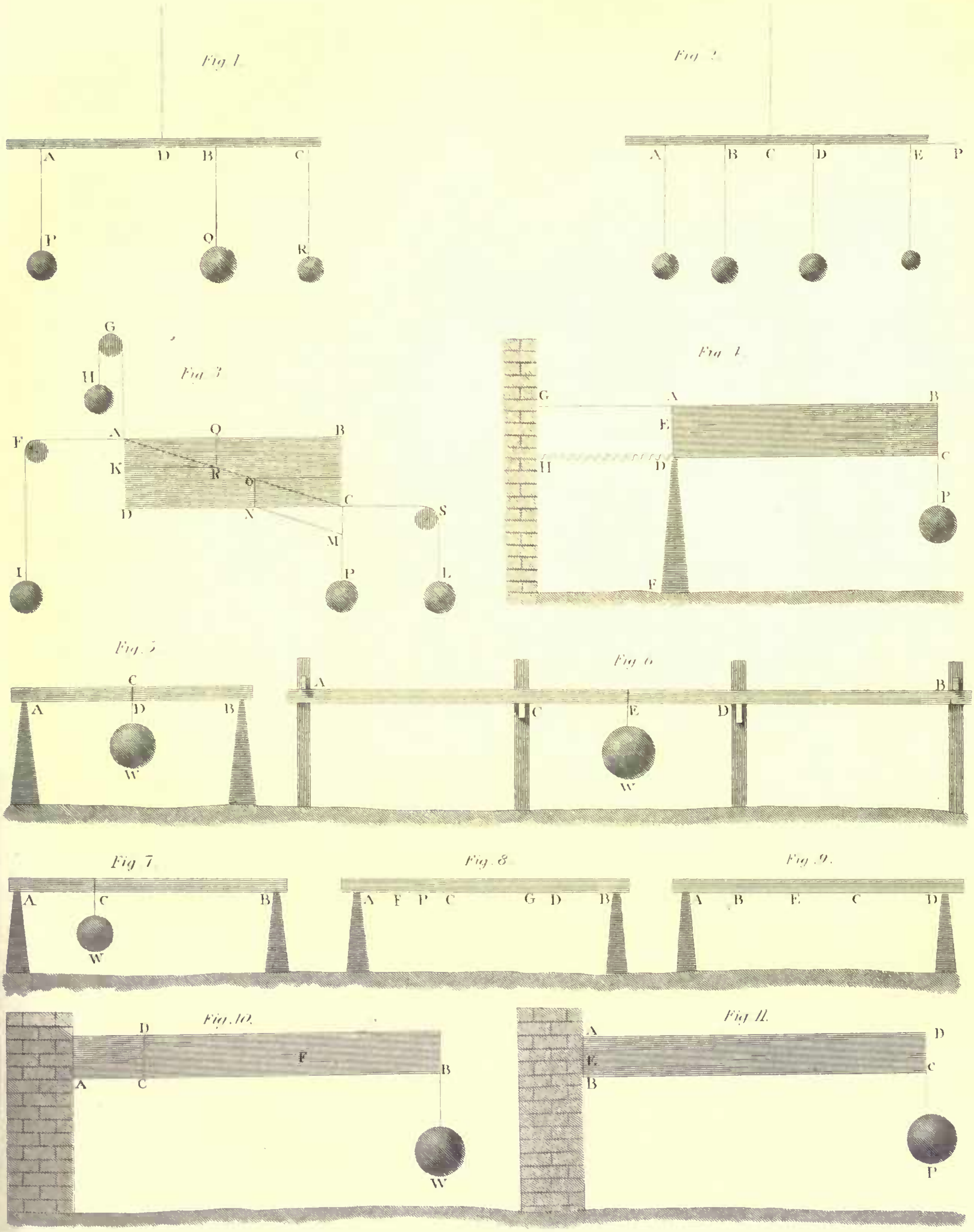
Corollary 2.—Hence, the strain of a beam at any section, from an equal weight placed upon any other section, is as the rectangle of the two exterior segments directly, and length reciprocally.

Corollary 3.—Hence, in the same beam, from the same weight, the strain at any section, D, by the weight at C, is as the rectangle of the two exterior segments.

PROPOSITION IX. *Figure* 9.—*If a weight be equally diffused throughout any part*, B C, *of a beam*, A D, *the strain at either end*, C, *of the diffused part, is to the strain at the same place, from the same weight being suspended there, as* A B + A C *to twice* A C.

Let the weight of the part B C be represented by W, and conceive W to be accumulated in its centre of gravity, E;

STRENGTH of TIMBER.



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then, by the last Proposition, the strain at C from the weight W is $\frac{AB+\frac{1}{2}BC.CD.W}{AD}=\frac{2AB+BC.CD.W}{2AD}=\frac{(AB+AC.)CD.W}{2AB}$; and, by Proposition VII., the strain at C, supposing W to be suspended there, is $\frac{AC.CD.W}{AD}$.

Now, $\frac{(AB+AC.)CD.W}{2AD}:\frac{AC.CD.W}{AD}::AB+AC:2AC$.

Proposition X. *Figure* 8.—*The strain of a prismatic beam supported at the two ends,* A *and* B, *by its own weight at any section,* C, *is equal to the rectangle of the two segments into the weight of the beam, divided by twice its length; that is,* $\frac{AC.BC}{2AB}$.

Conceive the parts A C and C B of the beam to be accumulated in their centres of gravity, F and G. Let W equal the weight of the whole beam; the weight of the part A C will be $\frac{AC.W}{AB}$, and the weight of the part B C will be $\frac{BC.W}{AB}$. By Proposition VIII., the strain at C, from the weight of the part, A C, is $\frac{AF.CB}{AB}\times\frac{AC.W}{AB}=\frac{AF.CB.AC.W}{AB^2}$, and the strain at C, from the weight of the part B C, is $\frac{GB.AC}{AB}\times\frac{CB.W}{AB}=\frac{GB.AC.CB.W}{AB^2}$.

Therefore the whole strain at C will be

$$\frac{AF.CB.AC+GB.AC.CB}{AB^2}\times W=\frac{(AF+GB.)AC.CB.W}{AB^2}.$$

Now, $AF+GB=\frac{AB}{2}$; therefore, the whole strain by the whole weight, is $\frac{AC.BC.W}{2AB}$.

Corollary 1.—Hence, the strain of a beam at any point, C, from a weight suspended there, is double what it would be at the same point, C, from the same weight being uniformly distributed over it; because, by Proposition VII. the stress is $\frac{AB.BC.W}{AB}$, and by Proposition X. it is $\frac{AB.BC.W}{2AB}$.

Corollary 2.—Because, in the same beam, W and A B being given, the strain at any point, C, is as rectangle of the two segments A C and C B.

THE SAME BY FLUXIONS.

Let w = W, equal to the whole weight of a = A C, b = B C, l = A B, and x any indeterminate part, A P. Then the weight of $AP=\frac{wx}{l}$, and the fluxion of $\frac{wx}{l}=\frac{w\dot{x}}{l}$ equal to the weight acting at P. Then, by Proposition VIII., the strain at C, from a weight acting at P, is $\frac{bx}{l}\times\frac{w\dot{x}}{l}=\frac{bwx\dot{x}}{l^2}$; therefore, by taking the fluent, the strain at C, from the whole weight of A P is $\frac{bwx^2}{2l^2}$. So the strain at C, from the weight of B C, will be found to be $\frac{ab^2w}{l^2}$; therefore, the whole strain tending to break the beam at C is $\frac{ba^2w+ab^2w}{2l^2}$ $=\frac{\overline{a+b}\times abw}{2l^2}$; but $a+b=l$; therefore, $\frac{a+b\times abw}{2l^2}=\frac{abw}{2l}=\frac{AC\times CB\times W}{2AB}$

Proposition XI. *Figure* 10.—*If a prismatic beam,* A B, *be fixed in a wall at* A; *the strain at any section,* C D, *from its own weight will be as the square of the distance,* B C, *of that section from the extremity.*

The strain which the weight of the part B C occasions at the section C D, is the same as if the whole weight of B C were collected in its centre of gravity, F, and the length of the lever, C F.

Let W represent the whole weight of A B; then, because the beam is prismatic, the weight of the part B C will be $\frac{BC.W}{AB}$; therefore, by Proposition IV., *Corollary* 2, the strain at C is $CF\times\frac{BC.W}{AB}=\frac{BC}{2}\times\frac{BC.W}{AB}=\frac{BC^2.W}{2AB}$; but in the same beam, W and 2 A B are given quantities, consequently, the strain at the section C D is as BC^2.

Proposition XII. *Figure* 11.—*To determine the relative strength of a rectangular prismatic beam,* A B C D, *projecting horizontally from a wall, supposing the beam to be incompressible at the fulcrum.*

Let A B C D be considered as a longitudinal section, and let A B be the section of fracture; let A B C be considered as a bent lever, whose fulcrum is at B; A B, B C, the two arms; and P the power employed to overcome all the resistances in the section A B. Now, in the act of breaking, all the fibres in A B will be stretched, and this the more in the same ratio as they are more remote from the axis of fracture passing through B; and those at A will break first. Let f be a force just sufficient to destroy the cohesion of a fibre: also, let l equal the length, d equal the depth, b equal the breadth or horizontal dimension, and x equal any indeterminate distance from B; then, because the tension of any fibre is as its extension (by Proposition I.) and the extension as the distance of the fibre from the axis of fracture, $d:x::f:\frac{fx}{d}$ the force or tension of a fibre; therefore, the force of all the fibres in the breadth is, $\frac{fbx}{d}$; but the momentum of any force applied to a lever, is that force multiplied by its distance from the fulcrum, consequently, $\frac{fbx}{d}\times x=\frac{fbx^2}{d}$, the momentum of the fibres in the breadth; and the sum of all these momenta upon the lever x is the fluent of $\frac{fbx^2\dot{x}}{d}=\frac{fbx^3}{3d}$; and when $x=d$, $\frac{fbx^3}{3d}=\frac{fbd^2}{3}$; now, the momentum of the power is P l, therefore, $Pl=\frac{fbd^2}{3}=bd^2\times\frac{f}{3}$, or $P=\frac{bd^2}{l}\times\frac{f}{3}$.

THE SAME WITHOUT FLUXIONS.

The momentum of the fibres in the breadth is $\frac{fbx^2}{d}$ as above; but $\frac{bx^2}{a}$ is the section of a pyramid, having b and d for the dimensions of its base, and for its altitude a, at the distance x from the vertex; now, the sum of all the $\frac{b\,x^2}{a}$, in the altitude d of the pyramid, is equal to the whole pyramid; but every pyramid is one-third of a prism, having the same base and altitude, or it is equal to one-third of the base multiplied by its altitude, namely, $\frac{b\,d}{3} \times a$; that is, d times $\frac{b\,d}{3}$ are equal to the sum of as many times $\frac{b\,x^2}{d}$; consequently, the sum of all the $\frac{f\,b\,x^2}{d}$, or the whole momentum of resistance, is $\frac{f\,b\,d^2}{3}$, as above; therefore, $P\,l = \frac{f\,b\,d^2}{3} = b\,d^2$, or $P = \frac{f\,b\,d^2}{3\,l} = \frac{b\,d^2}{l} \times \frac{f}{3}$.

Corollary 1.—Because $P = \frac{b\,d^2}{l} \times \frac{f}{3}$, and $\frac{f}{3}$ is a given quantity, P is as $\frac{b\,d^2}{l}$; that is, the power is as the breadth and duplicate ratio of the depth directly, and length reciprocally.

Corollary 2.—Because $P\,l = b\,d^2 \times \frac{f}{3}$, and $\frac{f}{3}$ is a given quantity, $P\,l$ will be as $b\,d^2$; that is, the power, or weight, multiplied by the length, is as the breadth multiplied by the square of the depth.

Corollary 3.—In square timber, the power multiplied by the length is as the cube of the breadth or depth.

Corollary 4.—Because $P = \frac{b\,d^2}{l} \times \frac{f}{3}$, and $\frac{f}{3}$ are given, the force, or power, required to break similar prisms is as the square of their corresponding dimensions.

PROPOSITION XIII. *Figure* 11.—*To determine the relative strength of a prismatic rectangular beam, projecting horizontally from a wall, supposing it to turn round some intermediate axis, in the section of fracture.*

Let A B C D be a longitudinal section of the beam, parallel to two vertical sides; now it has been shown, by Proposition IV. *Corollary* 1, that here is a certain line passing through some point, E, on which the beam turns in the act of bending, or breaking: that all the fibres above this line are in a state of tension, while those below are in a state of compression; and that the compression or extension of any fibre is as its distance from that line; it also appears, that $P \cdot CB = AE \cdot f + EB \cdot f$; where f is the whole force of extension or compression. Let m equal the extension of a fibre in the upper part, at the instant of breaking; n equal the compression of a fibre in the lower surface at the same instant; and let b equal the breadth of the beam; $a = AE$, $e = EB$, $l = BC$, $x =$ any indeterminate part of A E, or a, from E towards A: then, since, by Proposition I. the force of a fibre is as the distance to which it is extended or compressed, $a : m :: x : \frac{m\,x}{a}$, the force of a fibre at the distance x; but the energy, or resistance, of this force, is as the length of the lever, x, upon which it acts; consequently, as $\frac{m\,x^2}{a}$, and the sum of all the resistances in the breadth, is $\frac{m\,b\,x^2}{a}$, the whole resistance of the extended fibres in x is the fluent of $\frac{m\,b\,x^2\,\dot{x}}{a} = \frac{m\,b\,x^3}{3\,a}$; and when $x = a$, then $\frac{m\,b\,x^3}{3\,a} = \frac{m\,b\,a^2}{3}$. In the same manner, it may be shown, that the sum of all the resistances of the compressed fibres is $\frac{n\,b\,e^2}{3}$, and, therefore, the whole sum of all the extended and compressed fibres is $\frac{m\,b\,a^2 + n\,b\,e^2}{3} = AE \cdot f + EB \cdot f = l\,P$.

Now, if the ratio of m to n be known, that of a to e will also be known; for $f\,a = \frac{m\,b\,a^2}{3}$, $f = \frac{m\,b\,a}{3}$, and $f\,e = \frac{n\,b\,e^2}{3}$. $f = \frac{n\,b\,e}{3}$, therefore $\frac{n\,b\,e}{3} = \frac{m\,b\,a}{3}$, or $n\,e = m\,a$, consequently, $n : m :: a : e$. Hence, it will be seen, that the distance of the axis of fracture depends on the nature of timber. Now, let $d = a + e$, the depth of the beam, and let a and e be equal to each other, then will m and n be also equal to each other; and $\frac{m\,b\,a^2 + n\,b\,e}{3} = \frac{m\,b\,d^2}{6} = \frac{m}{6} \times b\,d^2 = P\,l$, or $P = \frac{b\,d^2}{l} \times \frac{m}{6}$.

It will readily appear, that all the Corollaries in the preceding Propositions will equally flow from this; it may, nevertheless, be observed, that the relative strength of such beams as are equal rectangular prisms of homogeneous texture, upon supposition, is only one-half of what is expressed in the former.

The celebrated Galileo, who first undertook the discovery of the law of resistance, supposes that at the place of fracture the body breaks at once, so that the whole of the fibres resist with their ultimate force: a supposition that would be correct, were the matter of bodies of a homogeneous and unelastic texture.

Mariotte, an eminent French philosopher and mathematician, who first corrected the Galilean notion of equal resistances made by the fibres of a beam at the section of fracture, having observed that all bodies bend before they break, considered the fibres as so many bent springs, which never exert their utmost force till stretched to a certain distance. But the axis of fracture was still considered as in the convex side of the beam. Now, as it has been shown, that timber in a state of bending, or breaking, is both compressed and extended, it follows that this axis cannot be in the convex surface, but must have some indeterminate situation between the upper and lower superficies. To compare the three suppositions with each other: in the act of breaking, the resistance of a fibre, according to Galileo, is a constant force in the section of fracture; therefore, let f denote the force of a fibre, then its momentum will be $f\,x$, and the sum of all the $f\,x$ will be the fluent of $f\,x\,\dot{x} = \frac{f\,x^2}{2}$, and the sum of all the $\frac{f\,x^2}{2}$ in the breadth will be $\frac{f\,b\,x^2}{2}$; and when $x = d$, the depth, $\frac{f\,b\,x^2}{2} = \frac{f\,b\,d^2}{2}$, for the relative strength. Now, it has been shown in Proposition XII., which is that of Mariotte, that the relative strength is $\frac{f\,b\,d^2}{3}$, and by Proposition XIII., it is $\frac{f\,b\,d^2}{6}$, by substituting f for m; but $\frac{f\,b\,d^2}{2}$, $\frac{f\,b\,d^2}{3}$, and $\frac{f\,b\,d^2}{6}$, are to each other as 3, 2, 1; hence, the relative strength of beams, according to the system of Mariotte, is two-thirds of Galileo's; while, according to the supposition of the axis fracture being in the middle of the beam, the relative strength is only one-third of Galileo's, or half of Mariotte's.

It is worthy of notice, that, although the relative strength is very different on the three suppositions, yet in each it is as the breadth, duplicate ratio of the depth, and reciprocal ratio of the length. This relation is the most important; and, if exactly true, would answer every purpose: for, by having the weight that a piece of timber of any given dimensions will carry, that which a piece of timber of any other given dimensions would bear, might be ascertained, without paying any attention to the absolute strength.

A very commodious formula may be had from this analogy, as follows:—

Suppose a piece of timber, a foot in length and an inch square, would carry w pounds; let l be the length of any other piece of timber in feet, b the breadth, and d the depth in inches; and let w be the weight in pounds that these dimensions will carry; then $\mathrm{w} = \frac{b\, d^2\, w}{l}$, for, by this analogy, $\frac{1 \times 1^2}{1}$, or $1 : \frac{b\, d^2}{l} :: w : \mathrm{w}$; therefore, $\mathrm{w} = \frac{b\, d^2\, w}{l}$.

That is, the strength of any piece of timber is equal to the relative strength of a piece of timber a foot in length and an inch square, multiplied into the breadth and square of the depth, divided by the length.

Example.—Suppose a piece of timber a foot in length and an inch square, would carry 500 pounds, how much will a piece eight feet in length and five inches square carry? Here $w = 500$, $b = 5$, and $d = 5$; therefore,

$$\frac{b\, d^2\, w}{l} = \frac{5 \times 5^2 \times 500}{8} = 7812.5.$$

In pieces of timber of the same length, the relative strength, being as the breadth and square of the depth, differs but in a very small degree from that which actual experiment gives; but in order to show how far the practical carpenter may confide in the rule just found from the theory, we have two sets of experiments, made on oak timber, one by the celebrated French engineer Belidor, on a small scale, the other by M. De Buffon, much more extensive, with which the result found by rule may be compared. The pieces tried by Belidor were sound, evenly-grained oak, and tolerably well seasoned; and the relative strength resulting from the various dimensions tried, are exhibited in the following Table; where, it must be observed, the lengths are in the second vertical column, under L, on the left, and the other dimensions in the columns under the initials B and D. The weight required to break the beams is given in lbs. in the fifth column. Three pieces of each dimensions were tried, and the mean taken. The experiments were of two kinds; one set with the ends loose, the other with the ends firmly fixed.

In the following table—

No. 1 and 2 show the strength to be as the breadth.

No. 1 and 3, as the square of the depth.

No. 1 and 4, nearly as the reciprocal of the length.

No. 4 and 5, nearly as the breadth multiplied into the square of the depth.

No. 1 and 5, nearly as the breadth multiplied into the square of the depth, divided by the length.

The two lower numbers, 7 and 8, show the increase of strength derived from fastening the two ends. By comparing No. 1 with No. 7, and No. 4 with No. 8, the strength of the loose bar to that of the fixed one, appears to be in the ratio of 2 to 3; but the theory shows it to be in the ratio of 1 to 2, that is, as 2 to 4; though a difference in the manner of fixing may produce this deviation.

Table I.

N.	L.	B.	D.	lb.	Medium.	
1	18	1	1	400 415 405	406	Ends loose.
2	18	2	1	810 795 812	805	
3	18	1	2	1570 1580 1590	1580	
4	36	1	1	185 195 180	187	
5	36	2	2	1550 1620 1585	1585	
6	36	1⅜	2½	1665 1675 1640	1660	
7	18	1	1	600 600 624	608	Ends fixed.
8	36	1	1	285 280 285	283	

The following Table is an abstract of experiments on beams of four inches, by Buffon. The first column contains the length of the bar in the clear, between the props. The second, the weight of the bar, the next day after it was felled, in pounds. The third column exhibits the number of pounds necessary for breaking it in the time shown by the fifth column. Column the fourth shows the inches bent in the act of breaking; and the fifth, the time required to break each beam. Two bars of each length were tried, and each of the first three pairs were cuts of the same tree.

Table II.—*Experiments on Beams Four Inches Square.*

Length of Bar in Feet.	Weight of Bar in lbs.	lb. to break Bar.	Inches bent in breaking	Time in breaking
7	69 56	5350 5275	3.5 4.5	29 22
8	68 63	4600 4500	3.75 4.7	15 13
9	77 71	4100 3950	4.85 5.5	14 12
10	84 82	3625 3600	5.83 6.5	15 15
12	100 98	3050 2925	7. 8.	

The cut next to the root was always found to be the heaviest, stiffest, and strongest; and from this invariable coincidence of weight and strength, M. De Buffon recommends, as an unerring rule, to make choice of timber by its weight. He finds, that this was always the case when timber had grown vigorously, forming thick annual layers; but observes, that this is only during the advances of the tree to maturity; for the strength of the different circles approaches gradually to an equality, during the healthy growth of the tree.

M. De Buffon also made experiments on other sizes of timber of a square section. Thr medium of two pieces of the same length and section were taken; and the following Table exhibits the results of those mediums. The lengths are contained in the vertical column on the left hand, and the dimensions of the section, or scantling, are expressed at the top, in inches.

The experiments on the five-inch bars were considered, by M. De Buffon, as a standard, he having both extended their number, and tried other pieces of the same length. He found, after repeated trials, that oak timber lost much of its strength in seasoning, to secure uniformity; and therefore, he caused it all to be felled at the same time of the year, squared the day after, and tried on the third day; which gave him an opportunity of observing a very curious phenomenon. For when the weights were laid quickly, and were nearly upon the point of breaking, a sensible smoke was observed to issue from the ends with a sharp hissing noice, which continued while the beam was bending. This evidently shows, that it must have been compressed throughout its whole length.

TABLE III.

L.	4 In.sq.	5 In.sq.	6 In.sq.	7 In.sq.	8 In.sq.
7	5312	11525	18950	32200	47649
8	4550	9787½	15525	26050	39750
9	4025	8308½	13150	22350	32800
10	3612	7125	11250	19475	27750
12	2987½	6075	9100	16175	23450
14		5300	7475	13225	19775
16		4350	6362½	11000	16375
18		3700	5562½	9245	13200
20		3225	4950	8375	11487½
22		2975			
24		2162½			
28		1775			

In the above Table, the weight of the beams is not taken into the account; therefore, to make a just comparison with the theory, it will be necessary to add half the weight of each beam to itself. The half-weights will be found in the following Table, in the same manner as in the preceding; the lengths being contained in the first vertical column, and the dimensions of the section at the top.

TABLE IV.

L.	4 In. sq.	5 In. sq.	6 In. sq.	7 In. sq.	8 In. sq.
7	28.777	44.965	64.750	88.131	115.111
8	32.888	51.388	74.000	100.722	131.555
9	37.000	57.812	83.250	113.312	148.000
10	41.111	64.236	92.500	125.902	164.444
12	49.333	77.083	111.000	151.083	197.333
14		89.930	129.500	176.263	230.222
16		102.777	148.000	201.444	263.111
18		115.625	166.500	226.625	296.000
20		128.472	185.000	251.805	328.888
22		141.269			
24		154.166			
28		179.861			

The numbers in the above Table, added to the preceding, give the following, omitting the decimals.

TABLE V.

L.	4 In. sq.	5 In. sq.	6 In. sq.	7 In. sq.	8 In. sq.
7	5340	11570	19014	32288	47764
8	4582	9838	15599	26150	39881
9	4062	8365	13233	22463	32948
10	3653	7189	11342	19600	27914
12	3036	6152	9211	16326	23647
14		5389	7604	13401	2005
16		4452	6510	11201	16638
18		3815	5728	9471	13496
20		3353	5135	8626	11815
22		3116			
24		2316			
28		1954			

By taking the weights in the above Table, corresponding to the seven-feet lengths as a standard, the following Table may be calculated, by making the succeeding weights follow in the reciprocal ratio of their lengths.

Table VI.

L.	4 In. sq.	5 In. sq.	6 In. sq.	7 In. sq.	8 In. sq.
7	5340	11570	19014	32288	47764
8	4672	10123	16637	28252	41793
9	4153	8998	14788	25112	37149
10	3738	8099	13309	22601	33434
12	3115	6749	11091	18834	27826
14	......	5785	9507	16144	23882
16	......	5061	8318	14126	20897
18	......	4499	7394	12556	18574
20	......	4049	6654	11300	16717
24	......	3681	......	......	......
28	......	3374	......	......	......

By comparing this table with the fifth, it will be found, that the strength of beams decreases in a ratio much more than that of the reciprocal ratio of the length; and it would also appear, that the greater the dimensions, the more rapid will the decrease be; for, taking any two numbers as a ratio of any given dimension of section, belonging to any two different lengths, and comparing them with that of a greater dimension of section immediately following, of the same length, the fourth number resulting will be greater than that which is found by experiment, thus:
11570 : 3352 : : 19014 : 5510, which should only be 5135;
19014 : 5135 : : 32288 : 8719, which should only be 8626; and
32288 : 8626 : : 47764 : 12760, which should only be 11815.

The preceding theory will not account for this great deviation from rule. It is probably owing to our ignorance of the law of attraction, by which the particles of fibres are held together, and of the law by which the fibres slide longitudinally on each other; but in order to show this more particularly, all the five-inch bars in Table V., as far as the twenty-feet lengths, are taken as standards, and a set of numbers are found in proportion to the cubes of the sides of their sections; the result of these calculations are exhibited in the following Table: where the sign + subjoined to any number, shows that an addition is to be made to the number, in order to make it equal to that found by experiment; and in like manner, the sign — subjoined to any number, indicates a deduction to be made from that number.

Table VII.

L.	4 In. sq.	5 In. sq.	6 In. sq.	7 In. sq.	8 In. sq.
7	5923—	11570	19992+	31748+	47320+
8	5037—	9838	17000—	26995—	40296—
9	4282—	8365	14454—	22953—	34263—
10	3680—	7189	12422—	19726—	29446—
12	3149—	6152	10630—	16881—	25198—
14	....	5389	9312—	14787—	22073—
16	....	4452	7692—	12216—	18235—
18	....	3815	6592—	10468—	15626—
20	....	3353	5793	92000—	13734—

The columns in the succeeding Table contain the differences between the above and Table V. of experiments, corrected by the half-weights; the + shows that the number to which it is prefixed, is to be added to that found by rule, and the sign — denotes, that the number to which it is prefixed, is to be abstracted from what is found by rule.

Table VIII.

L.	4 In. sq.	5 In. sq.	6 In. sq.	7 In. sq.	8 In. sq.
7	—573	000	— 978	+ 540	+ 374
8	—455	000	—1401	— 845	— 415
9	—220	000	—1221	— 490	—1315
10	— 27	000	—1080	— 126	—1532
12	—113	000	—1419	— 555	—1551
14	......	000	—1708	—1386	—2068
16	......	000	—1182	—1015	—1597
18	......	000	— 864	— 997	—2130
20	......	000	— 574	— 574	—1919

By comparing the different lengths of the five-inch beams with those of the other scantlings, they will be found to be much too strong; for the numbers in the other columns are all in excess, except two: but by reducing the five-inch bars about the twentieth part of their strength, a set of numbers may be calculated, not greatly differing from those found by experiment. In each of the succeeding horizontal columns, the excess of those found by rule, at an average, is continually greater than what is given by experiment; which shows that the different lengths have an effect upon the strength, and, therefore, in two pieces of the same length, the relative strength is not in the same proportion as in two other pieces of different lengths, but of the same dimensions of section. Hence, as the length is greater, the strength, in advancing from a less dimension to a greater, is continually less than that of the cube of their sides. Experiments on timber are too few, and too anomalous, to afford any certain means of correction.

It has been found, that by adding 1245 to each of the weights in the column of five-inch bars, a set of numbers may be generated nearly in the proportion of the inverse ratio of the lengths; and, therefore, if s denote the relative strength, w the weight found by experiment necessary to break a beam of five inches square, L its length, and l the length of any other beam; the strength of this latter will be expressed by $\frac{\overline{w + 1245} \times L}{l} - 1245$. From this formula, by making $L = 7$, and $w = 11570$, the weight found, by experiment, necessary to break the seven-inch beam, the numbers in the following Table have been calculated. The first column contains the lengths; the second, the result of calculation; the third, the weight found to break each beam, taken from Table V.; and the fourth, the difference between those found by rule, and those given by experiment.

TABLE IX.

1st.	2nd.	3rd.	4th.
7	11570	11570	0
8	9968	9838	130
9	8722	8365	357
10	7725	7189	536
12	6230	6152	78
14	5162	5389	227
16	4361	4452	91
18	3738	3815	77
20	3240	3353	113
22	2832	3116	284
24	2492	2316	176
28	1958	1954	4

From the above rule, which is only applicable to the five-inch bars, another more general one has been derived; which is, $s = \frac{651\ b\ d^2}{l} - 10\ b\ d^2$.

This formula is founded on the following observations: a constant number may be added to each column, which will increase the numbers therein contained in the reciprocal ratio of their lengths: the constant additive number of one column is to that of another as the cube of the side of the beams of the former to the cube of the side of the beams of the latter; therefore, $5^3 : 1^3 :: 1245 : 9.96$, or 10 nearly, for the additive number to a bar of an inch square. Again, $5^3 : 4^3 :: 1245 : 6.37$, or 6.40 nearly, for the additive number to a beam of four inches square; consequently, the relative strength of a piece of a foot in length, and an inch square, taking 5312 for a radical number, is $\frac{5312 + 640 \times 7}{64} - 10 = 641$.

The relative strength of a piece in general will, therefore, be $\frac{651\ b\ d^2}{l} - 10\ b\ d^2$, or, in square beams, $\frac{651\ b^3}{l} - 10\ d^3$.

Example.—What weight will be required to break an oak beam twenty feet long and eight inches square?

$$\frac{651 \times 8^3}{20} - 10 \times 8^3 - 11545.$$

That the reader may judge properly of the application of this rule, the following Tables have been calculated. The first contains the numbers according to calculation; the second, the differences between the first Table and the Table of experiments; where it may be observed, that six, seven, and eight-inch beams differ less and less from the experiment, as the beams are longer: the greatest difference is in the seven-inch beam of seven feet long, which is something greater than one-ninth, and less than experiment.

This rule is sufficiently exact for practical purposes, as in most cases it gives a solution within the fifteenth part of what would result from experiment: though the principle upon which it is founded cannot be admitted to be just, for when the length is 65.1 the quantity $\frac{651\ b\ d^2}{l} = 10\ b\ d^2$, and, consequently, the strength would be nothing.

TABLE X.

L.	4 In. sq.	5 In. sq.	6 In. sq.	7 In. sq.	8 In. sq.
7	5312—	10375+	17928+	28469+	42496+
8	4568—	8925+	15417—	24481+	36544+
9	3989—	7791+	13464—	21380+	31914+
10	3526+	6887+	11901—	18899+	28211—
12	2832+	5531+	9558—	15177+	22665+
14	....	4462+	7884—	12519+	18688+
16	....	3835+	6628—	10525+	15712+
18	....	3270+	5652—	8975+	13397—
20	....	2818+	4870+	7734+	11545—
22	....	2448+	....	....	....
24	....	2140+	....	....	....
28	....	1656+	....	....	....

TABLE XI.

L.	4 In. sq.	5 In. sq.	6 In. sq.	7 In. sq.	8 In. sq.
7	0	+1150	+1022	+3731	+5153
8	+ 18	+ 866	+ 108	+1569	+3206
9	+ 36	+ 517	— 314	+ 970	+ 886
10	+ 86	+ 238	— 651	+ 576	+ 461
12	+ 155	+ 544	— 458	+ 998	+ 794
14	....	+ 738	— 409	+ 706	+1087
16	....	+ 515	— 266	+ 475	+ 663
18	....	+ 430	— 90	+ 270	— 197
20	....	+ 407	+ 80	+ 641	— 58
22	....	+ 527	....	....	....
24	....	+ 22	....	....	....
28	....	+ 119	....	....	....

The succeeding Table is calculated upon other principles, viz. that the strength is as the breadth and square of the depth, and reciprocally as the fourth root of the fifth power of its length; and that the mean relative strength of a bar of oak, one foot in length, and an inch square, is found to be 1,000 lb. nearly; therefore, let s be the relative strength of a piece of timber, b the breadth, and d the depth; then $s = \frac{1000\ b\ d^2}{l^{\frac{5}{4}}}$. This formula is exceedingly easy; and the arithmetical operation will be much simplified by the use of logarithms. The radical number, 1000, is founded on Buffon's experiments, and is reduced to a piece of one foot long and an inch square, by the last given note. Mr. Emerson says, a piece of good oak, an inch square and a yard long, supported at both ends, will bear in the middle, for a very little time, 330 lb. avoirdupoise, but will break with more than that weight: now, upon the supposition that the strength is reciprocally as the length, the section being the same, 1 : 3 : : 330 : 990, for the strength of a piece of oak one foot long and an inch square, which is nearly 1000 lb., but as $3\frac{5}{4}$ is greater that 3, and almost equal to 4, we have $330 \times 4 = 1320$, instead of 1000; so that Emerson's timber is stronger than Buffon's.

Table XII.

L.	4 In. sq.	5 In. sq.	6 In. sq.	7 In. sq.	8 In. sq.
$7\frac{5}{4}$	5621—	10978+	18970+	30125+	44968+
$8\frac{5}{4}$	4756—	9290+	16054+	25494+	38055+
$9\frac{5}{4}$	4105—	8018+	13856—	22003+	32845—
$10\frac{5}{4}$	3599+	7029+	12146—	19288+	28792—
$12\frac{5}{4}$	2865+	5596+	9671—	15357+	22925—
$14\frac{5}{4}$	....	4615+	7976—	12665+	18908—
$16\frac{5}{4}$	....	3906+	6750—	10715+	16000—
$18\frac{5}{4}$	....	3371+	5826—	9251+	13810—
$20\frac{5}{4}$	....	2955+	5107+	8109+	12105—
$22\frac{5}{4}$	....	2623+	....	....	....
$24\frac{5}{4}$	....	2353+	....	....	....
$28\frac{5}{4}$	....	1939+	....	....	....

The succeeding Table contains the differences between the above and the Table of experiments: most of them are within the fifteenth part of the truth, excepting those of the five-inch bars, marked with a star: that column, as has been observed, appears to have much stronger timber than the others.

Table XIII.

L.	4 In. sq.	5 In. sq.	6 In. sq.	7 In. sq.	8 In. sq.
7	— 281	+ 592	+ 44	+ 2163	+ 2796
8	— 174	+ 548	— 455	+ 656	+ 1826
9	— 43	+ 347	— 623	+ 460	+ 103
10	+ 54	+ 160	— 804	+ 312	+ 878
12	+ 171	+ *556	— 460	+ 969	+ 722
14	....	+ *774	— 372	+ 736	+ 1097
16	....	+ *546	— 240	+ 486	+ 638
18	....	+ *444	— 98	+ 220	— 314
20	....	+ *398	+ 28	+ 517	— 290
22	....	+ *493	....	....	....
24	....	+ 37	....	....	....
28	....	+ 15	....	....	....

M. De Buffon uniformly found, that two-thirds of the weight necessary to break a piece of timber, in a few minutes impaired its strength, and frequently broke it at the end of two or three months: the half of that weight brought it to a certain degree of curvature, which did not increase after the first minute or two; and this, he found, might be borne for any length of time; but when the weight was removed, the timber had acquired a curvilinear figure. One-third of the weight appeared to have no effect; and, when properly seasoned, the timber recovered its rectilinear figure, after being loaded several months. Therefore, when the strength of a piece of timber is known, according to any of the preceding methods, and if it is applied to any mechanical purpose, in bearing or supporting a heavy body, it ought to have sufficient strength to bear thrice, or rather four times, the weight to be applied.

Several reasons may be assigned for the irregularity of experiments; some pieces, even from the same tree, might be much stronger than others. M. De Buffon says, that healthy trees are always strongest at the root. The ligneous coats might not be disposed in the same way, and their resistance is always greater when perpendicular to the force applied, than when in an horizontal direction. The trunk of a tree is composed of many hollow cylinders, each formed in the annual growth; these are only united by a soft medullary substance; and when the tree is brought to a square, or cut into beams, the portions of the ligneous cylindric coats at the angles, present but a very small resistance.

A bar of small size, such as an inch square, cut out of a large tree, may have its annual plates nearly in planes, disposed perpendicularly to one of its sides, and, consequently, it will be as much stronger, or weaker, than the largest square beam cut out of a tree of the same size and texture, as the force is applied to the side, or edges, of the plates. M. De Buffon found, from repeated trials, that the strength of a bar, with its plates in the direction of the breaking force, was to that of a bar with its plates perpendicular to it, as 8 to 7, nearly.

From what has been said, and exhibited in the foregoing Tables, it appears that the resistance of timber increases in a ratio somewhat less than the square of the depth, and somewhat greater than in the reciprocal ratio of the length.

The cohesion of timber is probably of a nature different from that of metal, and is subject to greater inequalities: which inequalities are occasioned either by the soil in which the tree was reared, the growth of the tree, or the part from which it is cut.

To what has already been said, the following practical remarks may be added.

Mr. Petit, on the authority of his own experiments, and those of M. Parent, declares that the utmost strength of a square inch of oak, by pulling in the direction of its length, does not exceed 8640 lb., whereas Muschenbroeck makes it 17,300 lb., but by experiments tried at the Royal Military Academy, Woolwich, the strength of oak has been found but little exceeding 9,000 lb., its specific gravity being 774. The writer of the article, Strength of Materials, in Rees's *Cyclopædia*, observes, that "We have not this datum in either of the above cases; yet we conceive it to be a very important one, as we have always found the strength of wood of the same kind, to depend a great deal upon the weight, or specific gravity. The same experiments give for the strength of ash 17,000 lb. and fir from 10,000 lb. to 13,000 lb., both considerably different from Muschenbroeck's tabular results." The same writer, or experimenter, adds, that "an oak rod of an inch surface requires a weight of about 9,000 lb. to produce fracture; while the same, or a similar rod, fixed in a wall, and acted upon at the distance of a foot, is broken with a weight of 132 pounds."

He farther remarks, that "a beam of fir, 6 feet long and 2 inches square, supported at each end, broke with 744 lb.; and the mean of several experiments of similar pieces of the same dimension, fixed at each end, required 1,105 lb.; while the fragments of the same, 3 feet long, broke with one end in a wall, required at a medium 400 lb."

Upon the experiments of Buffon and Belidor, this writer observes, that "Another discrepancy between theory and experiment is, where the strength ought to be inversely as the length; it shows itself in the above experiments, but is very remarkable in those of M. De Buffon; and though our preceding remarks will explain very satisfactorily this deviation, we are almost afraid to offer it as an illustration, after seeing it treated as an inexplicable paradox by some writers of the first eminence. We have seen that if W be the computed weight, independent of the deflection, the absolute weight will be W cos. D, D being the angle of deflection; and as this deflection, both from theory and practice, is found to increase as the square of the length; it follows, that when the length is quadrupled, the depth of the deflection will be sixteen times greater; that is, the sine of the angle of deflection will be sixteen times more in one case than in the other, while the radius will be only four times longer; and therefore the angle in the one case about four times what it is in the other, (supposing, in a rough way, the angle to vary as the sine). Consequently, if $W \times \cos. D$ is the weight which breaks the shorter beam, $\frac{1}{4} W \times \cos. 4 D$ ought to be that which breaks the longer one, and this, we presume, will nearly, if not entirely, account for the decrease of the strength in Buffon's experiments. We cannot perceive but that this reasoning is perfectly legitimate, yet we are astonished that it should not have occurred to so keen a mathematician as the one to whom we have alluded, or to some one of the writers on this subject; and on this account we offer it with some hesitation."

This excellent writer concludes thus: "Our limits will not admit of reporting here the nature of the experiments, nor the calculations founded upon them, which led to this determination; but we hope soon to see them laid before the public in another form. We can only give here the result, which, as far as it is at present ascertained, is as follows:

"The centre of tension and centre of compression are nearly, or exactly, coincident with the centre of gravity; and the neutral line, whatever may be the figure of the section, is so posited, that the rectangle of the area of tension into the distance of its centre of gravity from the said line, is to the rectangle of the area of compression into the distance of its centre of gravity, as 1 to 3.

"From which theorem, the neutral line for any formed beam may be determined, and the absolute strength may then be found as follows, *viz.* Let d denote the distance of the centre of tension, and l the length of the beam, all in inches; D the angle of deflection, and f the strength of direct cohesion on a square inch; then, without considering the increased length of lever,

"1. When a beam is fixed at one end,

$$W = \frac{2 f a d}{l \cos. D}.$$

"2. When the beam is supported at both ends,

$$W = \frac{8 f a d}{l} \times \cos. D.$$

"3. When the beam is fixed at both ends,

$$W = \frac{12 f a d}{l} \times \cos. D.$$

"And when the beam is fixed at one end at any angle, formula I will still apply; only increasing or decreasing the angle of deflection by the quantity of the first angle of inclination, according as that inclination is downwards or upwards.

"And when the beam is supported, or fixed, at both ends, and either resting obliquely, or acted upon by an oblique force, the two latter formulæ become,

"4. For the beam supported at each end,

$$W = \frac{8 f a d}{l} \times \frac{\cos. D}{\cos. I}.$$

"5. For the beam fixed at each end,

$$W = \frac{12 f a d}{l} \times \frac{\cos. D}{\cos. I};$$

where I denotes the angle, which the direction of the force makes with the direction of the beam.

"*Note* 1.—It should have been observed, that the preceding theorem for determining the neutral line, is principally drawn from experiments on fir beams. A different ratio than 1 : 3 may be necessary in other kinds of wood, but at present that ratio has not been found.

"*Note* 2.—The deflection, D, as we have before observed, is not a necessary datum in estimating the strength of timber, for any practical purposes of building, &c., it is merely introduced in order to reconcile the theory with the result of experiments made upon the absolute and ultimate strength, in which cases, particularly in long beams, it becomes an important quality, and must not be omitted; and in all cases where it is required, it must be drawn from some prior experiment on the same kind of wood, by means of the following theorem, viz.

"Let l, d, D represent the length, depth, and deflection, of any beam; l', d', the length and depth of any other beam, whose deflection, D′, is required; then $D' = \frac{l' d D}{l^2 d'}$.

"*Example* 1.—*The strength of direct cohesion on a square inch of fir being* 13,000 *lb., required the weight necessary to break a rectangular bar,* 30 *inches long,* 2 *inches deep, and* 1 *inch in breadth, when fixed at one end in a wall, and the weight acting at the other: the deflection, computed from other experiments, having been found to be* 5 *inches.*

"First find the neutral line: here, since the section is a rectangle, the centre of tension and compression are each on the centres of their respective areas; therefore call the depth of tension x, the depth of compression will be $2 - x$, which also denote these areas; and we must have, therefore,

$$\frac{x^2}{2} : \frac{(2-x)^2}{2} :: 1 : 3;$$

or $3 x^2 = 4 - 4 x + x^2$ or $x^2 + 2 x = 2$.
Whence $x = -1 + \sqrt{3} = .732 = a$;

also $\frac{.732}{2} = 366 = d$;

tan. of deflection $= \frac{5}{30} = \frac{1}{6} = .16666666$.

When the angle $D = 9° 34'$, and its cosine $= .9860$; therefore, by formula 1,

$$W = \frac{2 f a d}{l. \cos. D} = \frac{2 \times 13,000 \times .732 \times .366}{30 \times .986} = 235 \text{ lb.}$$

"*Example* 2.—*Required the weight that would break the same beam, when supported at each end, rejecting the deflection, which is very inconsiderable.*

"By Formula 2,

$$w = \frac{8 f a d}{l} = \frac{8 \times 13{,}000 \times .732 \times .366}{30} = 928 \text{ lb.}$$

"*Example* 3.—*Required the weight that would break the same beam, fixed at each end.*

"Rejecting the deflection, we have, by Formula 3,

$$w = \frac{12 f a d}{l} = \frac{12 \times 13{,}000 \times .732 \times 366}{30} = 1492 \text{ lb.}$$

"*Note.*—We have assumed 13,000 for the force of direct cohesion; this, however, rather exceeds the greatest strength of fir, which varies from 10,000 to about 13,000 lb.

"*Example* 4.—*Assuming the direct cohesion at* 13,000, *and the specific gravity of fir at* 720; *how long must a beam be, that is two inches deep and one inch broad, which, when fixed, with one end in a wall, will just break with its own weight?*

"Let x be the required length of the beam in inches; its weight will be $\frac{2\,x \times 720}{1728}$ ounces, or $\frac{90\,x}{1728} = \frac{5x}{96}$ pounds; and this weight will have the same effect as if it acted all at one point on the centre of the beam, or at the distance $\frac{1}{2}\,x$.

"Hence, by substituting $\frac{5x}{96}$ for w, in Formula 1, we have $\frac{5x}{96} = \frac{2 \times 13{,}000 \times .732 \times .366}{\frac{1}{2}x}$; or $5\,x^2 = 192 \times 2 \times 13{,}000 \times .732 \times .366 = 133{,}728$; whence $x = \sqrt{\frac{133728}{5}}$ inches, or 47 feet.

"In this case, the angle of deflection is not introduced.

"When the deflection is considered, as it should be in this case, we find it to be, from the data of Example I., and the theorem for the deflection, as $30^2 : 5 :: \frac{1}{4}x^2 : \frac{5\,x^2}{3600}$; whence the cosine $= \sqrt{\left(1 - \frac{25\,x^2}{(1800)}\right)}$; and the above equation becomes $\frac{5x}{96} = \frac{2 \times 13{,}000 \times .732 \times .366}{\frac{1}{2}x\sqrt{\left(1 - \frac{25\,x^2}{(1800)^2}\right)}}$; which produces a cubic equation, whence the value of x may be determined.

"Mr. Banks, after many experiments made, at various times, on the real and comparative strength of oak, fir, and iron, has deduced the following inferences: the worst, or weakest, piece of dry heart of oak, one inch square and one foot long, bore 660 lb., though it was much bent, and 2 lb. more broke it. The strongest piece he tried, of the same dimensions, broke with 974 lb. The worst piece of deal bore 460 lb.; but broke with little more. A bar of the weakest kind of cast-iron, of an inch square and a foot long, would break with 2190 lb.

"The following are some of the experiments he mentions; (see Banks *On the Power of Machines.*)

"*Experiment* 1.—Two bars of cast-iron, once inch square and three feet long, were placed upon a horizontal bar, so as to meet in a cap at the top, from which was suspended a scale; these bars made each an angle of 45° with the base-plate, and of course formed an angle of 90° at the top; from this cap was suspended a weight of 7 tons, which was left for sixteen hours, when the bars were a little bent, but very little.

"*Experiment* 2.—Two bars of the same length and thickness, were placed, in a similar manner, making an angle of 22½° with the base-plate; these bore 4 tons upon the scale; a little more weight broke one of them, which was observed to be a little crooked when first put up. In this case the pressures would be as the sines of the angles of elevation, viz., as 3826 to 7071, and as 3826 : 7071 : : 4 tons : 7.6 tons; that is, if the second bars broke with 4 tons, the first ought to have taken 7.6 tons to break them; and it is likely that such would, if tried, have been the case.

"*Experiment* 3.—Another bar was placed horizontally upon two supporters, exactly three feet distant, which bore 6 cwt. 3 qrs. or 675 lb. but broke when a little more was added.

"*Experiment* 4.—The same experiment repeated with the same result.

"*Experiment* 5.—The bearings were 2 feet 6 inches apart, the bar broke with 9 cwt.

"Three more experiments were tried at three feet, the average result was 6 cwt. 2 qrs. and 6½ lb.

"Mr. Banks made some experiments on the strength of cast-iron, at Messrs. Aydon and Elwell's foundery, Wakefield. The iron came from their furnace at Shelf, near Bradford, and was cast from the air-furnace; the bars, one inch square, and the props exactly three feet distant; one yard in length weighed exactly 9 lb. or one about half an ounce less, the other a very little more; they all bent an inch before they broke.

	lb.
1. The first bar broke with	963
2. The second bar with	958
3. The third bar with	994
4. A bar made from the cupola	864
5. A bar equally thick in the middle, but the ends formed into a parabolic form, weighing 6 lb. 3 oz.	874

"The same gentleman, after many other experiments, concludes from the whole, that cast-iron is from 3½ to 4½ times stronger than oak of the same dimensions, and from 5 to 6½ times stronger than deal.

"We shall only observe here, (says the writer of the Strength of materials, in Rees's *Cyclopædia*,) that Mr. Banks's pieces of oak exceed very considerably the specimens we had an opportunity of trying, while his fir falls something short of ours."

The following Tables of Experiments on the strength of various materials under different circumstances will be found useful. They are extracted principally from Tredgold, to whose works, and those of Barlow, we would refer for further information :

Cohesion of a Square Inch, pulled asunder in a direction perpendicular to the Length of the Fibres.

Kind of Wood	Cohesion of a square inch perpendicular to fibres, in pounds.	Experimentalist.
Oak	2316	Tredgold.
Poplar	1782	Idem.
Larch	from 970 to 1700	Idem.
Memel fir. . . .	from 540 to 840	Bevan.
Scotch fir. . . .	562	Idem.

Cohesive Force of a Square Inch of different Woods pulled asunder in the direction of their Length.

Kind of Wood, and specific gravity.		Cohesion of a Square Inch in pounds.	Experimentalist.
Oak, English	.7	19,800	Bevan.
Oak		17,300	Muschenbroek.
Ditto, dry English from		12,000	Barlow.
to		8,889	
Beech	.72	22,000	Bevan.
Do.		17,709	Muschenbroek.
Do.		11,500	Barlow.
Alder		14,186	Muschenbroek.
Sycamore	.69	13,000	Bevan.
Chesnut, Spanish		13,300	Rondelet.
Do.	.61	10,500	Bevan.
Ash from		17,850	Barlow.
to		15,784	
Do.		12,000	Muschenbroek.
Elm	.69	14,400	Bevan.
Do.		13,489	Muschenbroek.
Mahogany	.87	21,800	Bevan.
Do.		8,000	Barlow.
Walnut		8,130	Muschenbroek.
Do.	.59	7,800	Bevan.
Teak		15,000	Barlow.
Do. old	.53	8,200	Bevan
Poplar	.36	7,200	Bevan.
Do. from		6,641	Muschenbroek.
to		4,596	
Norway Pine	.66	14,300	Bevan.
Petersburg Do.	.49	13,300	Bevan.
Fir from		13,448	Barlow.
to		11,000	
Do.		8,506	Muschenbroek.
Pitch Pine		7,818	Muschenbroek.
Norway Pine		7,287	Rondelet.
Larch		10,220	Rondelet.
Do.	.57	8,900	Bevan.

Table showing the Modulus of Elasticity of Beams pressed in the direction of their Length.

Kind of Wood.	Modulus of Elasticity in pounds.
English Oak	1,714,500
Beech	1,316,000
Alder	1,086,750
Chesnut, green	924,570
Ash	1,525,500
Elm	1,343,000
Acacia	1,687,500
Mahogany, Spanish	1,255,500
Do. Honduras	1,593,000
Teak	2,167,074
Cedar, Lebanon	486,000
Riga Fir	1,687,500
Memel Fir	1,957,750
Norway Spruce Fir	1,804,000
Weymouth Pine	1,633,500
Larch	1,363,500

Result of Experiments by George Rennie, Esq.

Base 1 inch square, length 1 inch of Elm was crushed by 1,284 pounds
" " American Pine " 1,606 "
" " White Deal " 1,928 "
" " English Oak " 3,860 "
" length 4 inches Do. " 5,147 "
3 inches " " 6 to 9 in. African Oak " 60,480 "
= 6,720 pounds per square inch.*

* This is the mean of two experiments made by Mr. A. H. Renton, with Bramah's press.

Experiments on the Strength of Woods supported at both ends.

KIND OF WOOD.	Specific gravity.	Length in feet.	Breadth in inches.	Depth in inches.	Deflection at the time of fracture in inches.	Weight that broke the piece, in pounds.	Authorities.
Oak, English, young tree	.863	2	1	1	1.87	482	Tredgold.
Do., medium quality	.748	2.5	1	1		284	Ebbels.
Do., green	.763	2.5	1	1		219	Ebbels.
Beech, medium quality	.690	2.5	1	1		271	Ebbels.
Alder	.555	2.5	1	1		212	Ebbels.
Plane tree	.648	2.5	1	1		243	Ebbels.
Chesnut, green	.875	2.5	1	1		180	Ebbels.
Ash	.753	2.5	1	1	2.38	314	Tredgold.
Elm, common	.544	2.5	1	1		216	Ebbels.
Mahogany, Spanish, seasoned	.853	2.5	1	1		170	Tredgold.
Do. Honduras, seasoned	.560	2.5	1	1		255	Tredgold
Walnut, green	.920	2.5	1	1		195	Ebbels.
Poplar, Lombardy	374	2.5	1	1		131	Ebbels.
Teak	.744	7	2	2	4.00	820	Barlow.
Willow	.405	2.5	1	1	3	146	Tredgold.
Birch	.720	2.5	1	1		207	Ebbels.
Riga Fir	.480	2.5	1	1	1. 3	212	Tredgold.
Memel Fir	.553	2.5	1	1	1.15	218	Tredgold.
Norway Fir, from Long Sound	.639	2	1	1	1.125	396	Tredgold.
Scotch Fir, English growth	.529	2.5	1	1	1.75	233	Tredgold.
Christiana White Deal	.512	2	1	1	.937	343	Tredgold.
Spruce Fir, British growth	.555	2.5	1	1		186	Ebbels.
Larch, medium quality	.622	2.5	1	1		223	Tredgold.
Red Pine	. 54	4	3	3		3780	Fincham.
Yellow Pine	.439	4	3	3		2756	Fincham.

Experiments on the Strength of Beams supported at one end.

KIND OF WOOD.	Specific gravity.	Length in feet.	Breadth in inches.	Depth in inches.	Deflection at the time of fracture, in inches.	Weight that broke the piece, in pounds.	Experimentalist.
English Oak	.922	4	2	2		266	Beaufoy.
Dantzic Oak	.854	4	2	2		196	Idem.
Beech	.700	3	2	2	11	401	Barlow.
Ash	.730	2	1	2	6	321	Idem.
Teak, old, dry	.606	5	2	2	12½	257	Idem.
Virginian Yellow Pine	.522	5	2	2	11¾	147	Peake and Barralier.
Canadian White Pine	.618	5	2	2	18¾	122	Idem.
Pitch Pine		4	2	2		270	Beaufoy.
Larch, dry	.526	5	2	2	16¼	162	Peake and Barralier.
Red Pine	.544	2	3	3		1630	Idem.
Riga Fir	.537	4	2	2		210	Beaufoy.

The following remarks respecting the strength of cast and wrought iron, with the various Tables of Experiments, are extracted principally from the elaborate work on Tubular Bridges, by Mr. Edwin Clark, to which we would refer the reader for much valuable information on this subject. A further list, showing the strength of various materials in general use, will be found useful; it is obtained from the same source.

Mr. Telford commenced his experiments upon iron by proving what force would pull asunder, lengthwise, pieces of iron from $1\frac{1}{2}$ inches to $\frac{1}{20}$th of an inch in diameter. The experiments were made upon those of the largest diameter, by means of an excellent hydrostatic machine, and in those of the smaller by attaching weights perpendicularly, and repeating them at various times.

He then made several experiments upon different diameters, from $\frac{1}{10}$th to $\frac{1}{20}$th of an inch drawn horizontally, and with different degrees of curvature; and this was performed between points 900, 225, 140, and 139 feet 6 inches apart, and was repeated 200 times. In the experiments made upon $\frac{1}{10}$th of an inch and under, the wire was drawn over pulleys; sometimes both ends were fixed, and sometimes one end only, the other having weights attached perpendicularly, to show the effects when compared with those loaded upon the curved part of the wire; these last were disposed at $\frac{1}{4}$, $\frac{1}{2}$ and $\frac{3}{4}$ divisions of the distance over which it was stretched. These experiments being completed, it was ascertained what blow would break the wire when stretched nearly horizontally and at different curvatures, which was done by dropping weights from a given height. The several wires were weighed, and the weight of 100 in length of each noted.

The result of the experiments was, that a bar of good malleable charcoal iron, 1 inch square, will suspend 27 tons, and that an iron wire, $\frac{1}{10}$th of an inch in diameter, 200 feet in length, weighing 3 pounds 3 ounces, will suspend 700 pounds; and that the latter, with a curvature or versed sine of $\frac{1}{50}$th part of the chord line, will support $\frac{1}{10}$th of the weight suspended perpendicularly, when disposed equally at $\frac{1}{4}$, $\frac{1}{2}$, and $\frac{3}{4}$, its length, and with a curvature of $\frac{1}{20}$th of the chord, it will bear $\frac{1}{3}$ of the aforesaid perpendicular weight disposed in a similar way. A wire, $\frac{1}{10}$th of an inch in diameter, drawn very tight between points, 31 ft. 6 in. apart, resisted the impulse of 20 pounds weight, falling from a height of 7 ft. 9 in.

A bar of good English malleable iron, 1 inch square, will suspend from 27 to 30 tons before it breaks, and will bear from 15 to 16 tons before its length is at all extended. With a curvature of $\frac{1}{20}$th of the length, malleable iron, besides its own weight, sustained $\frac{1}{3}$ of what broke it perpendicularly. An inch bar would therefore bear $\frac{1}{3}$ of 15 tons without deranging its parts; but it is better in practice to assume that an inch square in action should only bear 4 tons.

Table showing the Cohesive Force of Iron.

Kind of Iron.	Cohesion of square inch in pounds.	Experimentalist.
Iron Wire..................	93,964	Telford.
Swedish Iron...............	72,064	Rennie.
Do.	64,960	Telford.
English Iron	61,600	Telford.
Do.	56,000	Barlow.
Cast Iron, specific gravity, 7.716	32,700	Bevan.
Do.	19,488	Rennie.

Table showing the Extension, by a suspended Weight, of a Wrought-iron Bar, 10 *feet long and* 1 *inch square.*

Tons.	Observed extension in terms of the length.	Computed extension assumed uniform at $\frac{8}{1000000}$ of the length per ton per square inch.	Corresponding extension in fractions of the length computed at $\frac{8}{1000000}$ per ton per square inch.	Observed permanent set in terms of the length.	Observed permanent set in fractional parts of the length.
1	.000689	.0008	$\frac{1}{12500}$		
2	.000156	.00016	$\frac{1}{6250}$		
3	.000238	.00024	$\frac{1}{4156}$	.00000513	$\frac{1}{468750}$
4	.000319	.00032	$\frac{1}{3125}$	.00000283	$\frac{1}{350877}$
5	.000399	.00040	$\frac{1}{2500}$	.00000356	$\frac{1}{281030}$
6	. 00048	.00048	$\frac{1}{2083}$	.00000427	$\frac{1}{233918}$

Table showing the Extension and Permanent Set of a Cast-iron Rod, 10 *feet long and* 1 *inch square, drawn in the direction of its Length.*

Tons.	Extension per Ton.	Total Extension.	Total permanent Set.
1	.01976	.01976	. 00579
2	.02027	.04155	.001860
3	.02171	.06515	.003954
4	.02318	.09274	.007543
5	.02479	.12397	.012619
6	.02727	.16363	.020571

Table showing the Extensions of Cast-iron Rods, 10 *feet long and* 1 *inch square, deduced from numerous Experiments, and compared with observed Compression of Bars of the same Irons and the same size, cast with them for comparison.*

Extension.					Compression.				
	Weights laid on, with the corresponding Extensions, and Sets in Inches.					Mean Weights laid on, with corresponding Mean Compressions. Sets and Ratios of Weights to Compression.			
Number of Experiments.	Weights. (w)	Extensions. (e)	Sets.	$\frac{(w)}{(e)}$	Number of Experiments.	Weights. (w)	Compressions in Inches. (d)	Sets in Inches.	$\frac{(w)}{(d)}$
9	1053.77	.0090	...	117086	8	2064.745	.01875	.00047	110120
9	1580.65	.0137	.00022	115131	8	4129.49	.03878	.00226	106485
9	2107.54	.0186	.000545	113309	8	6194.24	.05978	.00400	103617
9	3161.31	.0287	.00107	110150	8	8258.98	.07879	.00645	104823
9	4215.08	.0391	.00175	107803	8	10323.73	.09944	.00847	103819
9	5268.85	.0500	.00265	105377	8	12388.48	.12030	.010875	102980
9	6222.62	.0613	.00372	103142	8	14453.22	.14163	.01405	102049
9	7376.39	.0734	.00517	100496	8	16517.97	.16338	.01712	101102
9	8430.16	.0859	.00664	98139	8	18582.71	.18505	.02051	100420
9	9483.94	.0995	.00844	95316	8	20647.46	.20624	.02484	100114
9	10537.71	.1136	.01062	92762	8	24776.95	.24961	.03220	99263
9	11591.48	.1283	.01306	90347	8	28906.45	.29699	·04300	97331
9	12645.25	.1448	.01609	87329	7	33030 80	.35341	.06096	93463
6	13699.83	.1668	.02097	82133	7	37159.65	.41149	.08421	....
4	14793.10	.1859	.02410	79576	..	....	....	....	...

Table showing the Compression of a Cast-iron Bar, 10 *feet long, and* 1 *inch Square.*

Tons.	Compression per Ton.	Total Compression.	Total permanent Set.
	Inch.	Inch.	Inch.
1	.020338	.020338	.000510
2	.021038	.042077	.002452
3	.021618	.064855	.004340
4	.021369	.085479	.006998
5	.021594	.107872	.009188
6	.021752	.130513	.011798
7	.021950	.153654	.015243
8	.022154	.177235	.018572
9	.022374	.201373	.024254
10	.022477	.224774	.028126
11	.022567	.248237	.032023
12	.022802	.273632	.037653
13	.023014	.299187	.043318
14	.023523	.329330	.052640
15	.023539	.353092	.060905
16	.024409	.390558	.080256
17	.024805	.421695	.086298

Table showing the Compression of Wrought and Cast-iron Bars, 10 *feet long, and* 1 *inch square nearly. The Experiments made by Mr. Hodgkinson.*

Cast-iron Bar. Area of Section 1.031 × 1.029.		Wrought-iron Bar. Area of Section 1.025 × 1.025.	
Weight laid on the Bar.	Decrease of length by that Weight.	Decrease of length of the Bar.	Weight producing that Decrease.
lbs.	Inch.	Inch.	lbs.
5054	.054	.052	9578
7316	.078	.073	14058
11818	.126	.130	25258
14058	.157	.154	29738
20778	.173	.174	31978
21898	.210	.214	34218

Table showing the Average Breaking-Weight of Bars 1 *inch square, and* 3 *feet long, as determined from a very extensive series of experiments by Mr. Robert Stephenson.*

Iron.	Ultimate Deflection.	Breaking Weight.
Hot blast	.789	826
Cold blast...............	.784	855
Mixtures of various Irons..	...	898

General Observations.

The tenacity of good Baltic fir is very remarkable; sound rods of this material will bear an ultimate tensile strain of 5 tons per square inch, the specific gravity of which being from $\frac{1}{2}$ to $\frac{3}{4}$ of that of water, so that it will be about $\frac{1}{2}$ or $\frac{3}{4}$ immersed when floating in that liquid; the weight may be taken generally at about 45 lbs. per cubic foot, or nearly one-tenth that of wrought-iron, while the ultimate strength amounts to one-fourth. Thus a tension-rod of wrought-iron will be $2\frac{1}{2}$ times as heavy as a tension-rod of Baltic fir of the same strength, and of four times the sectional area.

Its elasticity is about one-fifteenth that of wrought-iron; i. e. a bar one inch square is extended on $\frac{1}{150000}$th of its length per ton of direct tensile strain.

The difficulty of connecting timber longitudinally, is a complete bar to the use of deal in cases of tensile strain, in greater lengths than it is naturally produced; the balks imported vary from 40 to 60 and 70 feet in length, being from 12 to 16 inches square.

In practice, wrought-iron should not be strained beyond 10 tons per square inch, and deal $2\frac{1}{2}$ tons per square inch.

An ordinary round rod of wrought-iron, 1 inch in diameter, bears tensilely 16 tons, and weighs 8 lbs per yard.

For a round rod of any diameter, the square of the diameter, taken in greater inches, is the breaking weight in tons.

Half this quantity is the weight in lbs per yard. Thus the breaking weight of a round bar 5 inches, or 20 quarter-inches in diameter, will be 20 × 20 or 400 tons, and the actual weight will be half 400 or 200 lbs. per yard.

A rod will be perceptibly damaged by half this strain, which can never be safely exceeded, one-third being sufficient in practice.

The strength of chain-cable is thus easily arrived at, the strength of a link being double that of the bar from which it is forged.

It is usual technically to denominate chains by their diameter, thus a five-eighth chain is a chain made from a bar $\frac{5}{8}$ inch in diameter.

The following approximations will be found very convenient in estimating the weight and strength of chains, the ultimate tensile strength of the material being taken at 16 tons per circular inch, or 20 tons per square inch of section.

1. The square of the diameter in eights, will be the weight of the chains in lbs. per fathom.

2. The square of the diameter in eights, divided by 2, will be the breaking weight in tons. Thus the breaking-weight of a $\frac{5}{8}$ chain will be half 25 tons = $12\frac{1}{2}$ tons, and the actual weight will be 25 lbs. per fathom of 6 feet.

N. B.—A chain will be perceptibly damaged by half this strain, which can never be safely exceeded, one-third being sufficient in practice.

The strength of ropes is very uncertain, their size is generally denominated technically by their circumference in inches; and the following approximations will be very correct for ordinary tarred hempen rope:—

1. The square of the circumference in inches, divided by 10, will give the practical strength in tons, which will be about half their breaking-weight.

2 The square of the circumference, divided by 4, will roughly give the weight in lbs. per fathom. Thus the useful strength of a 5-inch rope will be $\frac{25}{10}$ or 2.5 tons, the ultimate strength being 5 tons; and the weight of a tarred 5-inch rope will be $\frac{25}{4}$ or $6\frac{1}{4}$ lbs. per fathom.

A rope of 10 inches in circumference, and a chain of $\frac{6\cdot3}{8}$ths diameter, will each bear practically about 10 tons, taking half the breaking-weight, and the weight of the former will be 25 lbs., and of the latter, $39\frac{1}{2}$ lbs. per fathom.

Transverse Strength of a Slab of State from the Penrhyn Quarries.

A slab of slate 2 feet 10 inches broad, 4 inches thick, and 4 feet between the bearings, failed with $24\frac{1}{2}$ tons distributed over 15 inches at the centre of the span.

A slab of cast-iron of the same dimensions would scarcely support five times as much, and would be above two and a half times as heavy. This material forms a valuable flooring for bridges.

Transverse Strength of Timber.

To avoid any anomalies in deducing the strength of large beams of timber from experiments on small battens, the following experiments were made on the transverse strength of whole balks of American red pine timber selected from the scaffolding employed in erecting the tubes.

These beams were exactly 12 inches square and 17 feet long, the distance between the bearings being 15 feet. They were broken by actual weight suspended on a scale from the centre of the beams.

Dry timber from the butt end of the balk:—

Weight of the beam, 5 cwt. 2 qrs. 5 lbs. or 36.5lbs. per cubic foot.

Breaking weight, 14.82 tons.

Dry timber from the top of the balk:—

Weight of the beam, 5 cwt. 17lbs. or 33.9lbs. per cubic foot.

Breaking weight, 13.24 tons.

Results of Experiments made with actual Weight on Materials used in the Britannia Bridge, January, 1848.

(*Brickwork.*)

	lbs. per sq. in.
No. 1. 9-inch cube of cemented brickwork (Nowell and Co.,) No. 1 (or best quality), weighing 54 lbs., set between deal boards. Crushed with 19 tons 18 cwt. 2 qrs. 22 lbs. . . .	= 551.3
No. 2. 9-inch brickwork, No. 1 weighing 53 lbs., set in cement. Crushed with 22 tons 3 cwt. 17 lbs.	= 612.7
No. 3. 9-inch brickwork, No. 3 weighing 52 lbs., set in cement. Crushed with 16 tons 8 cwt. 2 qrs. 8 lbs.	= 454.3
No. 4. 9¼-inch brickwork, No. 4 weighing 55½ lbs., set in cement. Crushed with 21 tons 14 cwt. 1 qr. 17 lbs.	= 568.5
No. 5. 9-inch brickwork, No. 4 weighing 54½ lbs., set between boards. Crushed with 15 tons 2 cwt. 12 lbs.	= 417.
Mean	521.

Note.—The three last cubes of common brick continued to support the weight although cracked in all directions; they fell to pieces when the load was removed. All the brickwork began to show irregular cracks a considerable time before it gave way.

The average weight supported by these bricks was 33.5 tons per square foot, equal to a column 583.69 feet high of such brickwork.

(*Sandstone.*)

No. 6. 3-inch cube red sandstone, weighing 1 lb. 14⅜ oz., set between boards (made quite dry by being kept in an inhabited room). Crushed with 8 tons 4 cwt. 19 lbs.	= 2043.
No. 7. 3-inch sandstone, weighing 1 lb. 14 oz., set in cement (moderately damp). Crushed with 5 tons 3 cwt. 1 qr. 1 lb.	= 128.5
No. 8. 3-inch sandstone, weighing 1 lb. 15½ oz., set in cement (made very wet). Crushed with 4 tons 7 cwt. 21 lbs.	= 1085.
No. 9. 6-inch cube sandstone, weighing 18 lbs., set in cement. Crushed with 63 tons 1 cwt. 2 qrs. 6 lbs.	= 3924.8
No. 10. 9¼-inch cube sandstone, weighing 58½ lbs., set in cement (77½ tons were placed upon this without effect = 2042 lbs. per inch, which was as much as the machine would carry).	
Average crushing weight	2185.

All the sandstones gave way suddenly, and without any previous cracking or warning. The 3-inch cubes appeared of ordinary description; the 6-inch was fine-grained, and apparently tough, and of superior quality. After fracture, the upper portion generally retained the form of an inverted square pyramid about 2½″ high, and very symmetrical, the sides bulging away in pieces all round. The average weight of this material was 130 lbs. 10 oz. per cubic foot, or 17 feet per ton.

The average weight required to crush this sandstone is 134 tons per square foot, equal to a column 2351 feet high of such sandstone.

(*Limestone.*)

	lbs. per sq. in.
No. 11. 3-inch cube Anglesey limestone, weighing 2 lbs. 10 oz., set between boards. Crushed with 26 tons 11 cwt. 3 qrs. 9 lbs.	= 6618.

This stone formed numerous cracks and splinters all round, and was considerably crushed; but, upon removing the weight, about two-thirds of its area were found uninjured.

No. 12. 3-inch limestone, weighing 2 lbs. 9 oz., set between deal boards. Crushed with 32 tons 6 cwt. 1 lb.	= 8039.

This stone also began to crack and splinter externally with 25 tons (or 6220 per inch), but ultimately bore as above.

No. 13. 3-inch limestone, weighing 2 lbs. 9 oz., set in deal boards. Crushed with 30 tons 18 cwt. 3 qrs. 24 lbs.	= 7702.6
No. 14. 3 separate inch cube limestone, arranged in a triangle, weighing 4½ oz., set between deal boards. Crushed with 9 tons 7 cwt. 1 qr. 14 lbs.	= 6995.3
All crushed simultaneously.	
Average	7579.
	7338.5

All the limestones formed perpendicular cracks and splinters a considerable time before they crushed. Weight of the material from above = 165 lbs. 5 oz. per cubic foot, or 13½ feet per ton.

The weight required to crush this limestone is 471.15 tons per square foot, equal to a column 6433 feet high of such material.

(*Single Bricks of different qualities.*)

No. 15. A single brick, No. 1 (Nowell and Co.), weighing 8 lbs., bedded flat in cement. Crushed with 17 tons 19 cwt. 1 qr. 7 lbs. .	= 1022.
No. 16. A single brick, No. 3. Crushed with 13 tons 11 cwt. 1 qr. 6 lbs.	= 750.
No. 17. A single Birkenhead brick, 9 × 4½″, weighing 7 lbs. 14 oz., bedded in cement. Crushed with 32 tons 2 cwt. 17 lbs. . . .	= 1775.8
No. 18. A single Buckley mountain brick, 9½″ × 4½″, weighing 9 lbs. 2 oz., bedded in cement. Crushed with 40 tons 13 cwt. 15 lbs.	= 2130.3

These last experiments not being on cubes, only serve for comparisons among themselves. The bricks were completely crushed into powder. The cement used in all the above experiments invariably began to crack away round the edges as soon as a very moderate weight was applied.

STRETCHED OUT, a term applied to a surface that will just cover a body, and is extended in such a manner that all its parts are in a plane, or may be made to coincide with a plane.

STRETCHER, a term applied to bricks or stones so placed in a wall that their longest side shall be parallel to the face of the wall; those bricks, on the contrary, which have their longest dimension in the heart of the work, perpendicular to the surface, are termed *headers* or *through-bricks.*

STRETCHING COURSE, in walling, a course of stones, or bricks, laid with their longest dimensions in a horizontal line parallel to the face of the wall: it is exactly the contrary of *a heading course*, where the breadths of the stones, or bricks, are laid in a straight line parallel to the face of the wall.

STRIÆ (Latin), the fillets or rays which separate the furrows, or grooves, of fluted columns.

STRIGES (from the Latin *striga*, a ridge), the channels of a fluted column.

STRIKING, STICKING, or RUNNING A MOULDING, in joinery, is the shaving away the superfluous part of the wood, till the section be of the required figure.

STRIKING is also applied to the drawing of lines by the square on the face of a piece of stuff for mortises, and cutting the shoulders of tenons, &c.

STRIKING is also used for the drawing of lines on the surface of a body.

STRIKING A CENTRE, the removal of the centre after the completion of the arch it had supported during the building, and during the time necessary for the mortar to consolidate.

STRING-BOARD, in wooden stairs, a board placed next to the well-hole, and terminating the ends of the steps. The face of string-boards follows the direction of the well-hole, whether it be prismatic or an inverted cone. String-boards are sometimes glued in several thicknesses, with the fibres of the wood running in the direction of the steps; sometimes they are wrought out of the solid, like a hand-rail, the grain of the wood being in the same direction; and they are sometimes also glued up like columns, viz., having the fibres vertical. Brackets are most frequently placed upon the string-boards, and mitred into the risers.

STRING-COURSE, a narrow continuous horizontal moulding or plat-band, projecting slightly from the face of the wall.

STRING-PIECE, the piece, or pieces, of timber, put under the flying steps of a wooden stair, for their support, and covered with the lath and plaster forming the soffit of the stair.

STRIX, (Latin,) a channel in a fluted column.

STRUCK, an architectural expression, when anything of a temporary kind is taken away, which had been used for the support of some part of the building during its erection; as the centre of a vault, &c. *See* STRIKING.

STRUTS, in a truss, are one or more pair of oblique straining-pieces, each pair tending and pressing to a point below either of their extremities, and making equal angles with the horizon, though in contrary directions. Every strut is a brace; but every brace is not a strut. Braces may meet on either side of their extremities, above or below them; but struts only meet or tend to the same point downwards, as already defined.

Struts occur most frequently in roofs, and braces in partitions. Braces, when they occur in roofs, are called *principal braces*, *auxiliary rafters*, *cushion rafters*, or *discharging braces:* when they occur in the same frame, they are used in opposition to each other; though it would be as well to have a separate term to express the idea of braces when they meet upwards, as, in this way, there could be no ambiguity of expression.

STRUTTING BEAM, or STRUT BEAM, a term used by old writers in carpentry, for what is now called *straining beam*, or *collar beam.*

STRUTTING PIECE. *See* STRAINING PIECE.

STUCCO, (from the French, *estoc.*) *See* CEMENT, MORTAR, and PLASTERING.

STUDS, (from the Saxon *studer*, a post,) the posts, or quarters, in partitions, placed eleven or twelve inches distant; the term is frequently used in London and in Somersetshire. The studs go also under the various names of *uprights* and *quarters*, in London.

STUD PARTITIONS, the same as quarter partitions.

STUD WORK, or BRICK-NOGGING, a wall consisting of brick-work, built between studs, or quarters, chiefly used in thin walls, or partitions, for greater strength than when bricks are used without studs. *See* BRICK-NOGGING.

STUFF, (from the Dutch, *stofe*,) a general term for the wood upon which joiners work.

STYLE, or STILE, the upright supports of a frame.

STYLOBATE, the substructure of a classic temple below the base of the columns, or the platform on which the building was elevated. This consisted either of a series of steps continued all round the temple, or of a podium or wall, which admitted of access to the temple at one end only.

SUB-BASE, a second base below the first or true base.

SUBNORMAL, or SUPERPENDICULAR, the distance upon the axis between the foot of the ordinate and a perpendicular to the curve, or its tangent.

In all curves, the subnormal is a third proportional to the subtangent and the ordinate; and in the parabola it is a constant quantity, being equal to half the parameter of the axis.

SUB-PLINTH, a plinth below the true plinth, and on which the latter stands.

SUB-PRINCIPALS, the same as auxiliary rafters, or principal braces.

SUMMER, a large stone, the first that is laid over columns and pilasters, in beginning to make a cross vault; or that stone, which being laid over a piedroit, or column, is made hollow, to receive the first haunce of a platband.

SUMMER, a large piece of timber, which being supported by two stone piers, or posts, serves as a lintel to a door, window, &c.

SUMMER, a beam of timber tenoned into a girder, for supporting the ends of joists on both sides of it. The distinction of the large beams of a carcase floor is, that *bressummers* are disposed in exterior walls; *girders* lie across the building; and the *summers* divide the floor in the middle, and are laid perpendicular to girders, or parallel to the bressummers.—Summers are now seldom or never employed in building.

SUMMER is also a Warwickshire term for a girder.

SUMMER-HOUSE, a house situate in a garden, or on some pleasant sequestered spot, on an estate, for the purpose of retiring to in the summer.

SUMMER-TREE, a beam full of mortises for the ends of joists to lie in, and to which the girders are framed. *See* BRESSUMMER and GIRDERS.

SUNK SHELVES, have a groove consisting of two sides, to prevent the plates from sliding off, when set up on edge.

SUPERCILIUM, in ancient architecture, the uppermost member of the cornice, called by the moderns, *corona*, *crown*, or *larmier*. It is also used for a square member under the upper torus, in some pedestals.

SUPERSTRUCT, (Latin,) to build one thing upon another.

SUPERSTRUCTURE, the upper portion of a building raised upon the foundations.

SUPPORTERS, images to bear up, or serve instead of posts, &c., in a building. The posts themselves are sometimes so called.

SURBASE, the mouldings of a room, immediately above the base, with the dado between.

SURMOUNTED ARCH, that which has its springing line below the level of the centre from which it is struck.

SURVEYING, the practice of measuring the areas and defining the boundaries of plots of land, estates, houses, &c., in such a manner as to be able to transfer a correct representation of the same to a plan showing the relative position and proportionate dimensions of the various parts with reference to each other. In other words, the plan is made to present, on a small scale, a delineation of the surface of the area surveyed.

The principal instruments employed in surveying are the theodolite and chain; the former for measuring angles, and the latter for lines. It is usual to divide the plot to be surveyed into a number of triangles, as convenient, and, when the chain only is used, which is probably the more accurate method, to measure the three sides of each triangle, which at once determines its form and dimensions. If, however, the theodolite be also used, one or more of the angles are measured thereby, and one or more sides determined by the chain; in this case, the form and dimensions of each triangle may be determined by trigonometrical formulæ. In surveying large tracts of country, it is usual to fix or determine the relative position of some of the more conspicuous points by a system of triangulation, and from these fixed points, as a basis, to determine or fill in the remainder of the plan. Several other instruments are employed in these operations, but the two above-mentioned are the principal.

SURVEYING WHEEL. *See* PERAMBULATOR.

SUSPENSION BRIDGE. This kind of construction is, perhaps, the simplest and most easily erected of all bridges; we find examples of it spoken of in remote times, and there are few countries in the world where it may not be seen under some form or other. In England we now have many splendid bridges of this description, in which the combined labours of practical experimentalists and scientific theorists have produced monuments of surprising skill and admirable daring.

The principle on which suspension bridges are constructed, is exactly the reverse of that on which the stability of arched bridges depend. In the latter case, the force of gravity is, by an ingenious arrangement, made to counteract the natural tendency of all bodies to fall towards the earth; and a *compressive* force is called into play, by which the several parts of the bridge are kept in their proper positions, provided the materials have been properly disposed, and are sufficiently strong to bear the requisite crushing force.

In suspension bridges, on the contrary, the roadway is supported by ropes or chains attached to towers and abutments, so that the *tension* of the materials employed is *principally*, although not altogether, acted upon, and the platform is sustained by the excess of their tensile powers above the weight (their own included) with which they are loaded. These bridges were not constructed to any great extent until the commencement of the present century; up to that period they were of rather a primitive character. We hear, indeed, of one built in China about the year 65 A.D., and of several suspended bridges in South America and the Indies, in which the chains were formed of ropes or barks of trees plaited or interwoven together, so that the roadway was in the form of a catenary curve; still, even in those countries we have instances of the roadway or platform being placed horizontally, and suspended from the ropes or chains by intermediate rods. Among the first Iron Suspension bridges put up in this country was the Winch Bridge crossing the river Tees near Middleton. It was merely intended for foot-passengers, being only 2 feet in width, although 70 feet long. In 1816, a Wire Suspension bridge was built over the Gala Water, of upwards of 100 feet span, at a cost of only £40; and another over the Tweed at Peebles in the following year, also of iron wire, and about the same span, for £160.

In 1820, Captain Sir Samuel Brown built a Suspension Bridge over the Tweed, in an ingenious and novel manner, for which he had obtained a patent in 1817. Instead of making the main iron chains, intended for the support of the bridge, in the form of ropes, as had been hitherto done, he constructed those chains by links of iron several feet in length, with holes formed at either end, through which he joined them together by means of bolts. This bridge, called the Union, is situate close to Berwick-on-Tweed, and has a span of 449 feet. It is supported upon 12 chains disposed in pairs, and placed one above the other 3 deep, formed by links of round iron 2 inches in diameter, and each 15 feet long, connected with one another by intermediate short links also of iron. The suspending rods are of an oval section, and are placed 5 feet apart, every one being attached to a joint of one of the three main chains, which are made to break joint, so as to admit of this arrangement. These suspension rods support the roadway, which is formed of timber. This bridge cost £50,000. In the following year, this engineer built the Newhaven Pier, which is constructed on the same principle, having three openings, each 209 feet span; and afterwards the Chain Pier at Brighton, which runs out into the sea a distance of upwards of 1,000 feet, having four openings, each 225 feet span. In the year 1823, a bridge of the kind was erected by Sir Isambert Brunel, with two spans, each 122 feet; and the year after (1824) Tierny Clarke constructed the much-admired Suspension Bridge over the Thames at Hammersmith, spanning the river by an opening of 422 feet, which has stood remarkably well.

Next in order of time is the far-famed Suspension Bridge erected by Telford over the Menai straits, for the purpose of carrying the Holyhead road, and thus connecting the Island of Anglesea with the mainland. This splendid work of art was completed in the year 1825, having been about six years in course of construction. It consists of one opening of 570 feet span. The roadway being 100 feet above the level of high-water. The chains are formed of flat bars of iron 10 feet long, $3\frac{1}{2}$ inches deep, and nearly an inch thick. There are four rows of chains, each consisting of four tiers of bars ranged one above the other, so that, in all, there are 16 chains; to these, which are passed over the tops of two lofty towers placed at either side of the straits, and fastened at either shore into the solid rock, bars an inch square are attached, 5 feet apart, for the purpose of supporting the roadway, which has two carriage-ways, each 12 feet wide, and a central footway 4 feet in width. The entire weight of this suspended platform, including the 16 chains, is about 2,186 tons. The Conway bridge, over the river Dee, is also a Suspension Bridge, and was built by Telford about the same time; it has a span of 327 feet, and likewise carries the great Holyhead road. Sir Samuel Brown then erected, in the year 1829, the Montrose Suspension Bridge over the Esk in Scotland, with a span of 412 feet, and a roadway 12 feet wide. This bridge was all but destroyed during a great storm which took place in 1838; the platform not having sufficient rigidity to withstand the unequal force of the wind. The engineer, Rendel, however, has restored the bridge, and it is thought that such a disaster cannot again take place.

In the year 1829, M. Navier, an able French engineer, to whom we are indebted for a valuable work on Suspension Bridges, constructed the Pont des Invalides, on the suspension principle, over the Seine at Paris, with a span of 236 feet, and a deflection in the catenary formed by its chains, of about 26 feet. The Fribourg Bridge, which spans the valley of the Sarine in Switzerland, is one of the most splendid wire bridges ever built. It was constructed by Mr. Challey between the years 1832 and 34. It has a span of 870 feet, and the platform is 167 feet above the surface of the water, which runs at the bottom of the valley. This platform is suspended from four iron-wire ropes, two on each side of the bridge. The ropes are composed of 80 wires, each $\frac{1}{12}$ of an inch diameter, tied up by coils of wire at regular intervals; these chain-ropes are made fast to the rock on either side, after passing over the tops of the towers. Suspension rods are then hung upon the chain-ropes, to which the joists forming the roadway are fixed; the cost of this magnificent and truly wonderful structure did not amount to more than £24,000.

SWALLOW-TAIL, a particular way of fastening together two pieces of timber, so strongly, that they cannot fall asunder. It is much the same as DOVE-TAIL.

SWELLED COLUMN. *See* COLUMN.

SYMBOLICAL COLUMN. *See* COLUMN.

SYMMETRY, (from the Greek, *συν*, *with*, and *μετρεω*, *to measure*,) the harmony, proportion, or uniformity between the parts of a building and the whole.

SYSTYLE, a building where the pillars stand thick, but not quite so thick as in the pycnostyle, the intercolumniation being only two diameters, or four modules, of the columns.

T.

TABERN, a local word for cellar.

TABERNACLE, a casket composed of marble, precious stones, or metal, placed upon the altar in churches, and employed to contain the consecrated wafer; also any casket for containing holy relics, vessels, &c. The term is further applied to decorated niches, with enriched canopies, &c.; a collection of such work is termed *Tabernacle-work*.

TABLE, or TABLET, a flat surface or panel of various forms, but usually rectangular, either plain, or charged with ornament of some kind. They are frequently made to project from the wall, and are termed *raised tables*.

The term is also applied to continuous horizontal mouldings; thus we have *bench*, *corbel*, *water tables*, *&c.*

TABLE CORBEL, a curious horizontal ornament, used, in Gothic architecture, for a cornice.

TABLE, *Projecting*, as its name imports, is a table projecting from the naked of a wall.

TABLE, *Raised*, the same as PROJECTING TABLE.

TABLE, *Raking*, one that is not perpendicular to the horizon.

TABLE, *Rusticated*, a table of which the surface is rough, from being broken with the hammer, frosted, or vermiculated.

TABLE, *Water*, one that inclines to the horizon, for throwing off water; this kind is mostly used in buttresses, and other parts of Gothic edifices.

TABLE, in perspective, the same as *the plane of the picture*, being the paper or canvass on which a perspective drawing is made, usually perpendicular to the horizon. In the theory of perspective, it is supposed to be transparent, for the more easily comprehending the subject.

TABLE OF GLASS, in glass-works, and among glaziers, a circular plate of glass, being its original form, before it is cut, or divided into squares. Twenty-four tables make *a case*.

TABLED, a term applied to anything cut into tables.

TABLET, the same as TABLE.

TABLING, a term used in Scotland for the coping of the wall of very common houses; also a method of scarfing timbers.

TACKS, small nails, for fastening and stretching cloth upon a board, &c.

TÆNIA, or TENIA, a small square fillet at the top of the architrave, in the Doric capital.

TAIL, *Swallow*. *See* SWALLOW-TAIL.

TAIL-IN, to fasten anything into a wall at one end, as the steps of a stair; this expression is similar to what, in joinery, is called *housing*.

TAIL TRIMMER, a trimmer next to the wall, into which the ends of joists are fastened, in order to avoid flues.

TAILING, the part of a projecting stone, or brick, inserted in a wall.

TAILOIR, a term used by some writers, in imitation of the French, for the ABACUS.

TALON, (French,) the same as OGEE; being either the cima-recta or cima-reversa: according to some authors, it is a kind of astragal, used as a crowning. The word is not used in England.

TALUS, or TALUT, the slope or inclination of a wall, whereby, reclining at the top, so as to fall within its base, the thickness is gradually lessened according to the height. Among workmen, this is called *battering*; and the wall itself is said *to batter;* but when the wall inclines beyond the perpendicular of its base, it is called *hanging*. The term *talus* is mostly restricted to fortifications.

TAMBOUR, (a French term, derived from the Arabic, *tambor*, a drum,) a word applied to the naked of a Corinthian or Composite capital, or to that part from which the ornaments are supposed to project.

TAMBOUR, is also applied to the wall of a circular temple, which is surrounded with columns.

TAMBOUR, a place enclosed with folding-doors, to break the current of air from without, at the entrance of churches, or other similar buildings.

TANGENT, (Latin, *tangere*, to touch,) in geometry, a line or surface which touches another without cutting it. The term is more especially applied in trigonometry to the line drawn, touching the circumference at the commencement of the arc, and terminated by the secant, which is drawn through the centre and the end of the arc.

TANK, a large vessel, or reservoir, to contain water.

TAPERING, a term expressive of the nature of a solid contained between two opposite planes inclined towards each other. Thus, the wedge, the pyramid, the frustum of a pyramid, the cone, and the frustum of a cone, are all tapering solids.

TAPESTRY, hangings of wool, silk, and other materials, and ornamented with embroidery of various kinds of needle-work, employed as decorative coverings to the walls of ancient houses.

TARRACE. *See* TERRACE.

TARRAS, or TERRAS, a strong mortar or plaster, of great use in aquatic works. *See* CEMENT, MORTAR, and PLASTER.

TASSELS, (from the French,) in common country houses, the pieces of timber that lie under the mantel-tree.

TAXIS, the same with the ancients that ORDONNANCE is with the moderns, and described by Vitruvius, as that which gives every part of a building its just dimensions, according to its uses.

TEAZE-TENON, a tenon upon the top of a post, with a double shoulder and tenon from each, for supporting two level pieces of timber at right angles to each other.

TEINT, (from the French,) a wash of any colour upon paper.

TELAMONES, the Roman term for the figures or images of men supporting a cornice or other projection. By the Greeks they were called ATLANTIDÆ, ATLASES, and PERSIANS.

TEMOIN, (from the French,) in fortification, a pillar, or mound of earth, left by the workmen in digging, to show how much has been removed, and what they are to have for their labour.

TEMONES, (from the Greek, τεμνος,) in ancient temples, the place where the image stood.

TEMPERED, a term applied to such bricks as are easily cut and reduced to a required shape.

TEMPLE, (from the Latin *templum*,) a building erected in honour of some deity, whereat the people met for religious worship. Clemens Alexandrinus and Eusebius refer the origin of temples to the sepulchres for the dead: Herodotus and Strabo will have the Egyptians to have been the first who raised temples to the gods: others say, that the portable temple, or tabernacle, made by Moses in the desert, was the first of the kind, and these hold it to have been the model of all others. The first temple erected in Greece is ascribed to Deucalion by Apollonius; as the first in Italy is said to have been built by Janus, or Faunus. In antiquity, we meet with many who would not build temples to their gods, for fear of confining them to too narrow bounds. They performed sacrifices and other religious rites in all places indifferently, from a persuasion, that the whole world is the temple of God, and that he requires no other. This was the doctrine of the Magi, followed by the Persians, Scythians, Numidians, and many other nations mentioned by Herodotus, Cicero, and Strabo. The Persians, who worshipped the sun, believed it would be injurious to his power to enclose within the walls of a temple him who had the whole world for his habitation; and hence, when Xerxes ravaged Greece, the Magi exhorted him to destroy all the temples he found. The Athenians would erect no temple to Clemency, who, they said, was to live within the hearts of men, not within stone walls. The Bithynians and Germans had no temples, but worshipped on mountains and in woods.

Temples were built and adorned with all possible splendour and magnificence; and this partly out of reverence for their respective deities, and partly to create an awe for them in those who came to pay their devotions. The temples were built after that manner which different votaries thought most agreeable to their Gods; for instance, the Doric pillars were sacred to Jupiter, Mars, and Hercules; the Ionic to Bacchus, Apollo, and Diana; and the Corinthian to Vesta; though there are instances of these being used in the same temples; such were some of those dedicated to Minerva, which had pillars of the Doric, Corinthian, and Ionic orders. Wherever a temple stood, if the situation of the place would permit, it was so contrived, that the windows, on being opened, might receive the rays of the rising sun. The front was towards the west, and the altars and statues were placed towards the other end, that the worshippers, on entering, might have their faces towards them, it being a custom among the heathens to worship with their faces towards the east. If the temples were built by the side of a river, they were to look towards the banks of it; if near the highway, they were to be so ordered, that travellers might have a fair prospect of them, and pay their devotions to the god as they passed: those built in the country were generally surrounded with groves. In the front of the temple was the porch, in which, according to Casaubon, was placed the holy water, in a vessel of stone or brass, with which all who were admitted to the sacrifices were sprinkled; beyond this porch it was not lawful for the profane or polluted to pass; this led into the body of the temple, where was the *adytum*, or sacred place, into which none entered but the priests. Belonging to each temple there was a vestry, which seems to have been a treasury both for the temple itself, and for such also as had a mind to secure their wealth in it, as was done by Xenophon, who committed his treasures to the custody of the priest of Diana, at Ephesus.

Temples are thus described by some of the ancients: first, the whole edifice; secondly, the altar on which the offerings were made; thirdly, the porch in which usually stood an altar, or an image; and lastly, the place upon which the image of the chief god was erected. This idol was originally only a rude stone; and Themistius tells us, that thus they all continued till the time of Dædalus, who first gave them feet. In after-ages, when the art of graving and carving was invented, those rude lumps were changed into figures resembling living creatures, generally men. The material of these statues, among the Greeks, was generally wood; and it has been observed, that those trees which were sacred to any particular deity, were thought most acceptable for his statues: thus, Jupiter's were made of oak; Venus', of myrtle; Minerva's, of olive; Hercules', of poplar, &c. Sometimes they were the work of the lapidary, and consisted of common or of precious stones; at other times of black stone, indicating the invincibility of the gods: marble and ivory were frequently made use of, sometimes clay and chalk; and, last of all, brass, silver, gold, and other metals. The place of the images was in the middle of the temple, where they stood on pedestals raised above the height of the altar, and enclosed with rails.

The most ordinary form given to temples was that of a long square; though sometimes they were of a circular form. Those which were of the former shape were generally twice as long as broad, and their cella had generally, on the exterior, porticos, which adorned sometimes only the front façade, sometimes both the front and back façade, and, at others, were carried all round the four sides. The enclosed part of the temple was called the *naas domos selias*, or *cella*. The front portico was termed *frons*, *pronaos*, *prodomos*, *anticum*: the back part, when it had an entrance and portico, was termed *posticum* and *opisthodomus*. Above the entablature of the two columns of the two façades was the *tympanum*, or *actos*.

The façades of temples had always an even number of columns, either four, six, eight, or ten; and from these numbers they received the names of *tetrastyle*, *hexastyle*, *octostyle*, or *decastyle*. On the two sides the columns were generally an odd number. The Grecian and Roman architects, however, were not agreed as to the disposition of the columns on the sides. When the façade had six or eight columns, the Greeks placed on each side thirteen or seventeen. Examples of this are seen in the small temple at Pæstum, in the temples of Juno Lucinia, and of Concord, at Agrigentum, in that of Jupiter Nemæus between Argos and Corinth, in that of Theseus, and the Parthenon at Athens, and in several others. The Romans, on the contrary, reckoned by the intercolumniations, and, according to Vitruvius, they gave to each side twice the number of intercolumniations of the façade, so that a temple, which had six or eight columns in front, would have on each side eleven or fifteen. Thus the temple near Mylassa had six columns on the façade, and eleven on each side; that of Fortuna Virilis, at Rome, had four in front, and seven on each side. Sometimes, however, the columns at the side are an even number, and either double, or not double, of those at the front. Thus the temple of Jupiter Panhellenius, in the island of Ægina, had six in front and twelve on each side. The temple of Ægesta in Sicily, as well as the grand temple at Pæstum, have six columns in front, and fourteen on each side. Some temples at Selinus have six columns in front, and on the sides of one of them twelve, one fourteen, and another sixteen. The greatest temple in this city had eight in front, and sixteen on each side.

Temples are classified by Vitruvius into seven different kinds, determined according to the disposition of the columns: viz., the temple *in antis*, *prostylos*, *amphiprostylos*, *peripteros*, *dipteros*, *pseudo-dipteros*, and *hypæthros*.

The temple *in antis* is the most simple in form, consisting only of the cella, with a portico formed by the projection of the side-walls beyond the end-walls of the cella, the ends of the projections being enriched with capital and base similar to a pilaster; between the antæ were two columns, one on either side of the entrance. These temples were devoid of columns on the flanks, and are termed *astylar*, or devoid of columns. The *prostyle* temple had columns only on its front or fore side. The *amphi-prostyle* had columns both before and behind, and was also tetrastyle. The *peripteral* or *peristylar* temple was surrounded on all sides by a colonnade, and, according to Vitruvius, had six columns in the front, and eleven in the flanks, including those at the angles; the space between the peristyle and walls of the cella was of the width of one intercolumniation. The number of columns in the flanks of Grecian hexastyle peripteral temples does not appear to have been regulated by the number in the fronts; it has been believed it always exceeded double that of those in the front; but in the temples of Ægina, Pæstum, Argos, Syracuse, Ægesta, and Selinus, it generally exceeds the double by two or more. Peristylar temples are of two kinds, those with a single row of columns on each side, and those which have two rows, and which are distinguished as *dipteral*. These were octostyle in the fronts, with fifteen columns in the flanks, the walls of the cella ranging with the columns at the ends which were third in order from the angles. The *pseudo-dipteral* differed from the dipteral only in omitting the innermost of the two ranges of columns which surrounded the cella. The peripteral, dipteral, and pseudo-dipteral temples all presented the same general appearance, but in the second some advantage was obtained over the first in the extended width of the fronts, but more especially in the variety of effect in shadow and perspective, and in the extension of sheltered space which was gained for ambulatories. In the third kind, the second advantage was lost, but the last was considerably increased by the clear space gained by the omission of the inner row of columns; in fact, this arrangement was similar to the first, with the exception that the space between the cella and the colonnade was twice as great.

The *hypæthral* temple was open at top, and exposed to the air. Of this latter description, some were decastyle, others pycnostyle; but they all had rows of columns within, forming a kind of peristyle, which was essential to this sort of temple. The last kind was the *monopteral* temple, which was round, and without walls, having its dome supported by columns. Sometimes, however, we find circular *astylar* temples.

TEMPLET, a mould used in masonry and brickwork, for the purpose of cutting or setting the work. When great nicety is required, two templets should be used, one for moulding the end of the work, and its reverse for trying the face. Where many stones or bricks are required to be done with the same mould, the templets ought to be made of copper.

Templet, a short piece of timber, sometimes laid under a girder, more particularly in brick than in stone buildings.

TENAILLE, (French,) in fortification, a kind of hornwork.

TEN-FOOT ROD, a rod used for measuring out grounds or long lengths in building.

TENON, (from the French *tenir*, to hold,) a projecting rectangular prism formed on the end of a piece of timber, to be inserted in a mortise of the same form.

Tenon-Saw, a saw with a brass or steel back for cutting tenons. *See* Saw.

TENSION, (from the Latin *tendo*, to stretch,) the degree that a piece of timber is strained by drawing it in the direction of its length.

TENSION ROD, a rod usually of wrought iron, employed to tie together any two parts of a structure which have a tendency to separate or be thrust asunder. Such are the tie-rods employed to tie the ends of the principals of a roof together, also such as are used to tie walls together to prevent their bulging, &c.

TEOCALLI, a name given to the ancient pyramidal structures of Mexico.

TEPIDARIUM, one of the apartments in a Roman bath.

TERM, (from the Latin *terminus*, a bound,) in Geometry, the same as *boundary*, or *limit*.

TERMINUS, a trunk, or pedestal, adorned at the top with the figure of the head of a man, woman, or satyr, whose body seems to be enclosed in the trunk, as in a sheath, which usually tapers downwards.

TERRA-COTTA, baked earth. This material has been much used in building and modelling both in ancient and modern times; many specimens of bas-reliefs and other ornaments in terra-cotta have been found in Herculaneum and Pompeii.

TERRACE, (from *terra*, earth,) an area raised before a house, or other building, above the level of the ground, for walking upon. The word is sometimes used for a balcony, or gallery.

Terrace-Roofs, those that are flat on the top.

TERRAS. *See* Tarras.

TERREPLAIN, in fortification, the platform, or horizontal surface of the ramparts.

TESSELATED PAVEMENT, a rich pavement of mosaic work, made of curious small square marbles, bricks, or tiles, called *tesselæ* or *tesseræ*. *See* Mosaic.

TESSERA, (from τεσσαρα, or τεσσερα, *four*,) a cube or die.

Tessera, a composition for covering flat roofs, recently invented.

TESTER or TESTOON, a flat canopy over a pulpit, &c.

TESTUDO, (from the Latin,) the horizontal vault of a church; an arched roof.

TESTUDINAL CEILINGS, or ROOFS, a word used by Vitruvius for such roofs as are in the form of the back of a tortoise.

TETRADORAN, a kind of bricks used by the Greeks. *See* Brick.

TETRAGON, (from τετρα, *four*, and γωνια, *a corner*,) a plain figure consisting of four sides and as many angles.

TETRAHEDRON, a regular solid comprehended under four equilateral and equal triangles.

TETRASPASTUS, (from $\tau\epsilon\tau\rho\alpha$, *four*, and $\sigma\pi\alpha\sigma\sigma\omega$, *to draw*,) a machine containing four pulleys.

TETRASTYCHE, a gallery with four rows of pillars.

TETRASTYLE, (from $\tau\epsilon\tau\rho\alpha$, *four*, and $\sigma\tau\upsilon\lambda o\varsigma$, a *pillar*,) a building, or portico, with four columns in front; or a building with four pillars on a side.

THATCH, a roof or covering formed of reeds, straw, and other similar materials.

THEATRE, (from $\vartheta\epsilon\alpha\sigma\theta\alpha\iota$, *to see*,) a building used for the performance of plays, and other scenic representations.

The magnitude of a theatre must depend upon the number of spectators, and the style in which the exhibitions are intended to be got up. It would not be easy to describe in words all the apartments necessary to the construction of a theatre, nor their uses, or proportions to each other, as these must depend upon arbitrary circumstances; but the following abstract of the report of Mr. Wyatt, the architect of the present Drury Lane Theatre, with a description of the plan, will furnish a valuable elucidation.

"In arranging the design which I submitted to the committee for rebuilding Drury Lane Theatre, and which the committee have done me the honour to adopt, I have been guided principally by the considerations which are explained under the four following heads, namely: First, the size, or capacity, of the theatre, as governed by the width of the proscenium, or stage-opening, and by the pecuniary return to be made to those whose property may be embarked in the concern. Secondly, the form or shape of the theatre, as connected with the primary objects of distinct sound and vision. Thirdly, the facility of ingress and egress, as materially affecting the convenience of those going to every part of the house respectively; as well as their lives in cases of sudden accident and alarm. Fourthly, decorum among the several orders and classes of the visitants to the theatre, as essential to the accommodation of the more respectable part of those visitants, and consequently of great importance to the interests of the theatre." [Mr. Wyatt here details, under their respective heads, the space requisite for the various departments of the theatre; and then proceeds thus to the comparative width of the stage openings.] "The annexed statement of the dimensions of the stage-opening of several large theatres will be sufficient to show, that 35 feet is a very moderate width for that opening.

[The statement alluded to by Mr. Wyatt, is as follows:

Parma, 40 feet; Turin, 39; Bordeaux, 39; Argenta, at Rome, 36; Milan, 40; San Benedetto, at Venice, 40; Theatre Francais, at Paris, 40; Theatre Italien, at Paris, 33; present Theatre at Covent Garden, 37; late Theatre in Drury Lane, 46, afterwards reduced to 33 feet.]

"And although it appears, in that statement, that the stage-opening, in the theatre that was lately burnt down in Drury-lane, was laterally two feet less than that proposed in my plan, this fact is not to be received as a criterion for the dimensions most suitable to that part of a theatre; for, in the late theatre, the stage-opening was originally 46 feet; but, upon an alteration which was subsequently made in the proscenium (for the purpose of introducing stage-doors,) the breadth was reduced to 33 feet; not because a greater breadth than 33 feet was considered to be inconvenient and improper, but because the reduction to that breadth of 33 feet afforded an opportunity of combining, with the alteration above specified, the introduction of some private boxes in a part of the proscenium which would otherwise have been lost space.

"Having assumed that the size, or capacity of the theatre, must depend principally upon the width of the scene opening, and having stated the reasons for the limit which I have applied to that opening, I have next to remark upon the size of the house, as it relates to the pecuniary return for the capital embarked in the concern. It is proposed, that the largest return which can be obtained, consistently with a due attention to the interests of the public, is the legitimate right of the proprietors, and, consequently, that (after having determined the width of the stage-opening upon a suitable scale) the most capacious form which can be possibly constructed to admit of distinct vision and sound, is the form which ought to be chosen. It appears to be a very popular notion at present, that our theatres should be very small, but if that popular notion be suffered to proceed too far, it will tend, in every way, to deteriorate our dramatic performances, by depriving the proprietors of that revenue which is indispensable to defray the heavy expenses of such a concern, and to leave a reasonable profit to those whose property may be embarked in the undertaking. It should be remembered, that the unavoidable expenses attendant on any theatre of a superior order in London, (whatever be the dimensions of that theatre,) must of necessity be very great; and that less than a certain return for those expenses cannot maintain such a theatre to any good effect. Assuming the boundary which has been described as the limit of the stage-opening, and confining the front boxes (which is absolutely necessary for purposes of vision or sound) within a given distance from the front line of the stage, it is quite unquestionable, that a segment of a circle, including three-fourths of an entire circle, contains the most capacious area which can be formed within those given points; and, therefore, if that form be also one which is well adapted to distinct vision and sound, it ought, upon the principle before stated, to be chosen in preference to any other. It should be remembered, that the remarks which I am now offering, apply to the size or capacity of the theatre, as relates to the pecuniary return for capital embarked; the subject will be hereafter considered in its relations to sound and vision; in the meantime, viewing it as the form which is capable of containing the greatest number within the given limit, I shall assume it as that which the proprietors are entitled, for their own interest, to adopt. A theatre consisting of three-fourths of a circle, with a proscenium according to my plan, which shall limit the stage-opening to 35 feet, will contain, in four different heights, 78 boxes, holding 1004 persons; with four boxes (of larger size than the rest) next to the stage on each side of the theatre, capable of containing 188 spectators, in addition to the 1004 before mentioned, amounting, in the aggregate, to 1,192 persons, or

	£	s.	d.
persons, or	£417	4	0
A pit, containing 911 persons, or	159	8	6
A two-shilling gallery for 482 persons, or . .	48	4	0
A one-shilling ditto for 284 persons, or . . .	14	4	0
Total.	£639	0	6

exclusive of four private boxes in the proscenium, and 14 in the basement of the theatre, immediately under the dress-boxes. Suppose the four private boxes in the proscenium to be appropriated to the managers, and certain other persons connected with the theatre who shall pay no rent for those boxes, the remaining 14 private boxes will let as follows: namely, the 12 smaller ones for £300 each, and the two larger ones for £500 each, for the season, (being at the rate of £23 per night for 200 nights) which, together with the foregoing amount, produces an aggregate total of £662 6s. 6d. Adverting to all the foregoing circumstances, I have no doubt that the advantages of the form which I have adopted will readily be admitted, as far as the form relates to the capacity of the theatre, and to the financial considerations attending thereon; and I shall therefore, having shown what appears to be the best form with respect to size and capacity, now proceed to the second head of the discussion, namely, the former shape of the theatre, as connected with the objects of distinct vision and sound.—1st. With reference to distinct sound, the safest method in deciding upon the shape of a theatre appears to be, to adopt a form which is known to be in itself capable of conveying sound with facility; to construct that form of materials which are of a conductive nature; and to avoid all breaks and projections on the surface of such form, which can tend to interrupt or impede the progress of the sound when once conveyed to any part of it. It is generally admitted that a circular enclosure, unobstructed by breaks and projections, possesses the power of conveying sound with facility, and that wood is the material which combines the greatest number of desirable qualities, as to conduction, resonance, &c. &c. It does not absorb the sound so much as some materials, and does not conduct it so much as others; which medium is acknowledged to be an advantage to the clear and distinct conveyance of sound. That wood is sonorous, and capable of producing soft, clear and pleasing tones, is sufficiently demonstrated by the effect of it in musical instruments.—I shall take it for granted that whatever be the form of the theatre, it ought in every part to be confined within the limit to which the voice is known to be capable of expanding: and, certainly, I hazard nothing in assuming, that the nearer the shape shall conform to those proportions which would be described by the natural expansion of the voice, the more equally the sound will be heard in all parts of the theatre. After reading Mr. Saunders's account of the experiments upon the voice, which he describes in his *Treatise on Theatres*, I was induced to try the same experiments myself, and after changing the relative positions and distances of the speaker and hearer, in a variety of ways, and after several repetitions of each experiment, the result corresponded as nearly as possible with the statement given by Mr. Saunders, and clearly proved to me, that the natural expansion of the human voice, when moderately exerted, will be in the proportion of about two-ninths farther in a direct line, than it will laterally; and that being distinctly audible on each side the speaker, at a distance of 75 feet, it will be as plainly heard at a distance of at least 92 feet in front of the speaker declining in strength behind him, so as not to be clearly heard at much more than 30 feet from his back. Upon this principle, I have in my design made the widest of the area of the theatre, upon the level of the dress-boxes, 58 feet, allowing 9 feet 6 inches for the depths of the boxes: upon that floor, a projection of 18 inches more than is given to any of the boxes above, making together, 67 feet 6 inches between the extremity of the stage on one side, and the back wall of the boxes on the opposite side. But it should be remembered, that the speaker will not at any time be placed laterally, at the very extremity of either side of the stage, and even if he were to be sometimes so situated, the distance between him and the opposite side of the house, would be eight feet within the expansion of the voice in a lateral direction, and 27 within its limits in a direct line. Referring to all the considerations connected with the foregoing remarks, I have no hesitation in believing, that the circular form is preferable to any other form. And having, upon the principles above stated, fixed a limit for the diameter of that form, I next come to those considerations connected with sound, which ought to operate upon the longitudinal dimensions of the theatre, or upon the space from the front line of the stage, to the boxes immediately facing that line.

"It has already been stated, that the natural expansion of the human voice is about 75 feet in a lateral direction on each side of the speaker; and as it is evident the space between the front line of the stage, and the boxes immediately facing that line, may at times constitute the lateral direction of the voice, according as the actor's face shall be turned more or less towards either of the sides of the theatre, the utmost distance from the front of the stage to the back-wall of the boxes facing the stage, ought not to exceed 75 feet; or the limit to which the voice is capable of expanding in its lateral direction. For if, calculating upon the actor's face being turned (as in general it would be) towards the front of the house, the distance between that part of the house and the most advanced line of the stage, were to be considered as invariably the direct line of the voice, and were accordingly to be extended 92 feet, (the expansion of the voice in a direct line,) the consequence would be, that upon a sudden turn of the actor's head, what had before been the direct line of the sound would then become its lateral direction, and those persons, sitting at the front boxes at the distance of 92 feet from the actor, would be 17 feet beyond the reach of his voice.

"There is a form approaching very nearly to that which I have chosen, which some persons might, perhaps, on the first view of it, be disposed to prefer; I mean a semicircle, with the sides continued parallel to each other, instead of converging by continuing the circular line to three-fourths of the circle, as I have done. But upon examination, this form will be found ineligible, because it involves an extension of the stage-opening to an inadmissible width, without affording any advantage as an equivalent for that defect.—I have already stated, that the extreme distance from the front line of the stage to the back-wall of the boxes facing the stage, according to my plan, is 53 feet 9 inches; in the late theatre in Drury Lane, it was 74 feet, or 20 feet 3 inches more than mine: in the old theatre in Covent Garden, (I mean as it was built in 1730,) the distance between the front of the stage and the back of the wall of the front boxes, was 54 feet 6 inches, or 1 foot 3 inches more than mine: in the old Opera House, built by Sir John Vanburgh, in the Haymarket, it was 66 feet, or 12 feet 3 inches more than mine.—In most of the foreign theatres, it is very much greater than in my plan. At Milan it is 78 feet, or 24 feet 3 inches more: in the theatre of San Carlos, at Naples, it is 73 feet, or 19 feet 3 inches more: at Bologna it is 74 feet, or 20 feet 3 inches more: in the present theatre of Covent Garden, it is 69 feet 8 inches, or 15 feet 11 inches more. The advantages of which difference between the theatre now building in Drury Lane, and those I have just mentioned, in point of distinct sound, are obviously not less than they are with respect to vision, and they are in both so evident, that they need not be here detailed. It may be right to remark, that the theatre at Bourdeaux is exactly of the form which I have chosen; and that theatre is always quoted as one in which the voice is better heard than in almost any theatre in the world.—Before I conclude this part of the subject, I shall mention one more point, which bears very seriously upon the distinctness of sound in a theatre, namely, the uniform depth from the front to the back of the boxes throughout the house: it has hitherto been invariably the practice in our theatres, to carry the boxes facing the stage to a much greater depth than those on the sides of the theatre; and, by so doing, to produce a great difference between the form of the wall immediately at the back of the boxes, and that of the breast-work, or front of those boxes.

"Having stated my observations with respect to the advantages in point of sound which I conceive to be attendant on the circular form, I shall now offer a few remarks upon its comparative and positive merits with respect to vision. In entering on this branch of the subject, I should wish to anticipate a question, which may possibly arise in the minds of some persons, why we should not, in the form of our theatres, adopt the semicircle, which was generally in use among the ancients, and which has evidently great advantages with respect to vision? The answer to this is, that the semicircle requires either that the stage-opening should be of enormous width, or that the size of the house should be extremely small, and therefore it is inadmissible in our theatres. It is inadmissible on the first point, namely, the enormous width of the stage as to opening, for the reasons which have been already shown (under the first head) upon that subject: and it is equally so upon the second point, because it is impossible to maintain a good theatre in this metropolis upon such a revenue as would accrue from an extremely small house. So long as the public taste for spectacle shall continue (and it is not likely to cease) all the objections to increasing the stage opening, and with it the magnitude and expense of the scenery, must remain in force. The Greeks and Romans, in their theatres, made use of scarcely any change of scenes, and their performances were given gratis to the public; consequently, their theatres were not subject to many of those considerations which are attached to ours. Under these circumstances, therefore, the semicircle is totally inadmissible for a principal theatre in London. The oval and the horse-shoe, as well as some flat-sided forms, have been supposed to be very advantageous in point of vision; but it is evident, that in the oval, a large proportion of the spectators must be placed with their backs inclining towards the scene, and that in all of them (if the house be not of extremely small dimensions) the front boxes must be at a great distance from the stage; for, in proportion as the sides shall approximate each other, the front must recede, provided the circumference be not varied.

"The fact is, there is no object connected with the formation of a theatre, which, in all its bearings, is of more importance than that that part of the house which faces the scene should be within a moderate distance of the stage; unless that be the case, it is obvious that a very large proportion of the spectators must be excluded from a clear and distinct view of that play of the features which constitutes the principal merit of the actor in many of the most interesting scenes. If the actor's merit in that particular be not fairly appreciated, he must, of course, be deprived of a proportionate share of the applause which might otherwise be bestowed on him, and this mortifying want of encouragement, bringing with it a gradual and progressive defect of zeal and emulation, cannot fail in the end to reduce the number of good actors, and materially to injure the state of dramatic performances.

"For the sake of argument, let it be supposed for a moment, that an oval, or horse-shoe, or flat-sided figure, is the best for side-vision, and the fact will then be, that, although in adopting either of those forms, provision may be made for the better accommodation of spectators sitting on the sides of the theatre, that accommodation will be given to them at a serious expense to those sitting in the front, for, while it will enable those who may sit on the sides of the house to see a greater proportion of the stage in cases of spectacles, (though not in ordinary,) those who are placed in the front will be proportionately excluded from that distinct view of the actor's countenance which is not less desirable than to be within the reach of his voice. But in point of fact, the oval, horse-shoe, or flat-sided theatre, is not so well calculated even for side-vision, as that which I have chosen; for there is one consideration of very great importance to each of these forms, and which appears entirely to have escaped observation, although obvious on reflection, namely, that although in either of them, the spectators who sit in the front row of the boxes on each side of the house, may be enabled to see rather more of the stage when extended to an extraordinary depth, those who sit in the back-seats in all the boxes above stairs, (which it should be remembered constitute in point of extent the greater part of the house,) will see considerably less of the stage than in a theatre of circular form; where, of course, the sides of the theatre will, from their swelling-shape, recede from the stage much more than in either of the others; for nothing can be more unquestionably true, than that the more the boxes on each side shall advance towards the centre-line of the theatre, the more must they necessarily overhang the stage, and all the objects on the stage; and that the more they shall overhang those objects, the more perpendicular the rays of sight (especially from the upper part of the boxes) must become, and, consequently, the less those who sit on the back-rows of the upper boxes will be able to see of the performance on the stage. In proportion as the point of sight shall be at a greater distance from the stage, the visual rays will have an oblique direction towards the stage; and a greater proportion of the breadth, as well as depth of the stage, than appears in the plan, will be opened to view in all situations. However, the comparative advantage which has been stated, namely, of seeing one-fifth more of the breadth of the stage, will belong to the circular form, a fact which I wish to impress upon the mind of the reader. There is an exemplary instance of this in the House of Commons; for, from the second row of seats on the side-gallery, (taking a position opposite the side of the table, or speaker's chair,) it is impossible to see the speaker, or any part of the floor of the house, although the whole of the seats on the opposite side of the house, upon a level with the speaker, and even below him, (being farther removed from the point of sight,) are perfectly visible; whence it is evident, that the more the position of the spectator shall recede from a perpendicular point with respect to the objects below him, the more those objects will be opened to his view: and while it is thus clear, even for the purposes of side-vision, that the oval, horse-shoe, or flat-sided theatre, is inferior to the circular form, it is, on the other hand, impossible for prejudice itself to resist the proof, that in the form I have chosen, namely, three-fourths of a circle, a much larger proportion of the whole house will be placed immediately in front of the scene, than could be the case in either of the other three forms which have been named. Impressed by the importance of all the foregoing considerations, I determined to adopt, in my design for a theatre, the form I have described; and although I was aware at the time when my drawings and model were first made, that a certain proportion of the spectators in the boxes nearest to the stage, would have but an imperfect view of the stage, I considered that as an unavoidable inconvenience in all theatres, and not greater in that projected by me, than all others; while on the other hand, the form which I had chosen, possessed many advantages which could not be derived from any other shape.—The angles, however, to which I allude, in the boxes nearest to the stage, having appeared to several persons, who saw my model, as an imperfection to the design, and those persons seeming to view the defect more in its positive than in its comparative bearing upon the perfection of a theatre, I was led to reconsider, most attentively, this particular part of the design; and after a great deal of reflection, and a variety of experiments, I determined to alter the shape of that part of the theatre adjacent to the stage, by opening the proscenium from the back, instead of from the front of the boxes. The scene (excepting in cases of spectacle) is seldom extended in depth beyond 30 feet from the front line of the stage.

"In the theatre of Parma, (which is particularly celebrated both for sound and vision,) the frontispiece of the stage-opening is placed at a distance of no less than 40 feet from the termination of the spectatory, for the purpose of opening a view of the scene to the spectators sitting nearest to the stage; and the width of the stage-opening in that theatre, with a view to the same desirable object, is extended to 39 feet, exceeding by 4 feet the width which is given to that opening of my design.

"In discussing this subject, I have hitherto confined myself to those considerations connected with the form of the theatre, which appertain directly to the two primary objects of distinct sound and vision; and I trust, that I have shown completely, that there is no admissible form so well calculated to secure those objects, as that which I have adopted in my design. But there is another consideration of great importance, which appertains to the form which I have chosen, and which does not relate to either of the objects above mentioned; namely, its decided superiority over every other form in point of beauty, for a circle is a form which will never weary or distress the eye.

"In building our early theatres in this country, little attention seems to have been bestowed upon the means of favouring sound or vision: in the form of those theatres, their sides were either entirely parallel, or diverging but little from each other; and if those theatres had not been confined to very small dimensions (such as would not be consistent with the present population and condition of the metropolis) there can be no doubt that their form would have been found to be extremely defective. The first gradation of improvement in this respect, appears to have been the introduction of the oval, and the horse-shoe, by rounding of the angles of the former shape, and thus we have been approaching gradually to that form which I now propose, and which deviates as little from the Greek and Roman amphitheatres, as the state of circumstances will admit. The original theatres of Drury Lane and Covent Garden, as well as the old Opera House, and Foote's theatre in the Haymarket, were all flat-sided; the latter (never having been rebuilt) is so to this day. The late theatre in Drury Lane was nearly oval, and the present Opera House is in the form of a horse-shoe.

"There is one other point in a great degree connected with the form and proportions of the theatre, to which I must advert, before I entirely conclude this part of the subject; namely, the height of the ceiling. In forming my design, it has been my object to avoid raising the ceiling beyond the proportion which I think it ought, for the sake of the symmetry, to bear to the open area which it is to cover: that proportion is, in my opinion, about three-fourths of the diameter of that area, but not less. I do not believe that the height of the ceiling can in any degree injure or affect the sound of the voice in the lower parts of the theatre; it may materially assist in conducting the sound into those parts of the house which are nearest to it: but it must, in every theatre, be much too high to act as a reverberator, or sounding-board, to the lower parts of the house. If this were not the fact, the voice would be quite indistinct and inaudible in a cathedral church, where the roof is at a vast height: the form of that roof, not calculated for direct reverberation of sound, and the person uttering the sound at the reading-desk, placed in a situation by no means so well calculated to convey the sound of his voice generally among his auditors, as that in which an actor upon the stage is placed: yet we know, that even under all these circumstances, the voice is heard in most of the cathedral churches quite as well as it is in many chapels; which is a positive proof that a low ceiling is not essential to the strength and clearness of sound in a theatre. If it were necessary to support this opinion, the whispering gallery in St. Paul's cathedral would serve as an additional proof, that sound may be distinctly heard in a large enclosed area (provided that area be in itself so constructed as to facilitate the conveyance of sound) without any direct reverberation from above; the great height of the dome above the floor of the whispering gallery, together with the large aperture in the centre of the dome itself, are sufficient to demonstrate, that the extraordinary effect of sound in the whispering gallery, is in no degree produced by reverberation from above. Under this conviction, I have been influenced in the height at which I have fixed the ceiling, by the proportion which appeared to me to be most in symmetry with the area to be covered by that ceiling. I feel confident, that upon a serious and impartial attention to the facts and deductions contained in the foregoing pages, it will be admitted, that the form which I have adopted is the best form: 1st, as to size and capacity; and 2nd, as to distinct sound and vision."

The following are the Dimensions of the Interior of Drury Lane Theatre.

The stage-opening, 35 feet.

The widest part of the area, upon the level of the dress boxes, 58 feet.

Depth of the dress boxes, 9 feet 6 inches.

Depth of the three upper tiers of boxes, 8 feet.

From the front line of the stage to the front of the dress boxes, in the widest part, 44 feet 3 inches.

Theatre, among the ancients, a building encompassed with porticos, and furnished with seats of stone, or marble, disposed in the area of a semicircle, and ascending, by degrees, over each other, for the use of the spectators to behold the performances. The orchestra, or place where the musicians performed, was situate in front of the spectators. The stage, or place where the actors performed, was called *the orchestra*. The area beyond this was called *the proscenium*, or *pulpitum*. At the extremity of the proscenium stood *the scena*, a large front, adorned with the orders of architecture; and, behind, was the place where the actors made themselves ready, called *the postscenium*. *See* Amphitheatre.

THEODOLITE, an instrument for taking angles, whether in a horizontal or in a vertical plane.

If 29 half-degrees of the horizontal circle be taken for the length of an arc on the vernier, and this arc be divided into 30 equal parts, the vernier will show to a single minute, by observing when a coincidence takes place between a division of the vernier and one of the horizontal circle, or limb.

THEOREM, (Greek,) a proposition which requires to be demonstrated.

THEOTHECA, (Greek, θεος, *god*, and θήκηα, *repository*,) the receptacle for the consecrated host; it is of various forms and sizes, but usually of the most costly materials. The same as *Monstrance* or *Remonstrance*.

THOLE, the knop or scutcheon in the midst of a timber vault.

THOLOBATE, that part of a building on which a cupola is raised; the base of a cupola.

THOLUS, the name given to buildings of a circular form. Vitruvius employs the term to signify the roof of a circular building.

THOROUGH FRAMING, the framing of doors and windows: a term not much used at present.

THOROUGH-LIGHTED ROOMS, those which have windows on two opposite sides.

THRESHOLD OF A DOOR, the sill. *See* Sill.

THROAT. *See* Gorge, and Gula.

THROATING, the channel cut on the underside of a stone, &c., to prevent the further passage of rain, which is here collected, and drips off the building.

THROUGH-STONE, a bond stone; one which runs through the heart of the work.

TIE, (from the Saxon, *tian*, to bind,) a timber, string, chain, or iron rod, connecting two bodies together which have a tendency to diverge from each other. The tie-beams, diagonal ties, and truss-posts, are ties. Braces may act either as ties or straining-pieces: straining-pieces are preferable to ties, for these cannot be so well secured at the joints as straining-pieces.

Tie-Beam, the beam which connects the bottom of a pair of principal rafters, and prevents them from bursting out the wall. *See* Tie and Truss.

Tie-Rod. *See* Tension-Rod.

TIERCE POINT, the vertex of an equilateral triangle. Arches, or vaults, of the third point, which the Italians call *de terzo acuto*, are such as consist of two arcs of a circle intersecting at the top.

TIGE, a term used by the French for the shaft of a column.

TILE, (from the Saxon, *tigle*,) an artificial stone, or broad thin brick, made of dried earth, and burnt in a kiln, used in covering buildings. *See* Brick.

Tiles have various names, according to their surface, shape, or situation.

Those of a rectangular form, with a plane surface, are denominated *plane tiles* and *crown tiles*: their dimensions are about 10½ inches long, 6 inches broad, and five-eighths of an inch thick. A plane tile weighs from 2 lb. to 2½ lb.

Those of a cylindric form are denominated *ridge tiles, roof tiles*, or *hip tiles*, and are used in covering the ridges of houses. Their dimensions are, in length, about 12 inches, in breadth 10, and in thickness five-eighths of an inch. The weight of a ridge tile is about 4½ lb. Tiles which are placed on the angle formed by the two sloping sides, are called *hip tiles*.

Tiles to be placed in gutters, have a form adapted to their situation: the weight of a gutter tile is the same as that of a ridge tile.

Tiles of a rectangular outline, with a surface both concave and convex, are denominated *pan tiles;* these have no holes, but are hung on the lath, by means of a ledge, formed in their making, at their upper ends: they are usually 14½ inches long, and 10 broad. They weigh from 5 lb. to 5¼ lb.

Tile-Creasing, two rows of tiles placed horizontally under the coping of a wall, and projecting about three inches from the surface, for discharging the rain-water therefrom.

Tiles, Encaustic, decorative tiles formed of different-coloured clays, arranged so as to form a variety of patterns. The ground is usually red, and this being stamped with some pattern, the recess is filled in with clay of various colours, frequently white, the whole being afterwards glazed over with a yellow glaze. Frequently each tile presents a complete pattern, but at other times a pattern is composed of four or more tiles arranged in juxtaposition. Such tiles are mostly used in ecclesiastical buildings, and are often interspersed in regular order amongst tiles of a plainer description, by which means their beauties are more fully displayed.

TILING, the act of laying tiles for the covering of a building, which may be done either with plane tiles or pan tiles. Plane tiling is preferable to pan tiling. Plane tiles are laid at a 6-inch gauge, with or without mortar; and pan tiles at an 11 or 11½ inch gauge, though some use a gauge of 12 inches, but this distance is too great.

From the frequent repairing of tiled roofs, and their fiery appearance, slating has now become the general covering, and tiling is seldom used except for common cottages, sheds, and out-houses, as being more expensive to keep in repair than slating.

TIMBER, (from the Saxon, *timbrian*, to build,) in carpentry, a piece of wood for supporting some part or parts of the building, or to give strength to any part thereof.

Timbers, in a building, support parts of the fabric in three different ways, viz., by lateral strain, by tension, and by compression.

Timber, wood felled and seasoned for the purpose of building. Many kinds of woods are useful for building purposes, but those most frequently employed are oak, fir, and pine; but before entering into the peculiar properties of these, it will be as well to give some idea of the structure and growth of trees in general.

Upon observing the transverse section of the stem or trunk of a tree, the wood will be found to be composed of numerous concentric layers or rings, which are more or less defined in different trees. Where the rings are well defined, they will be found to consist of two parts, the outer being hard, compact, and of a dark colour, while the inner is of a lighter tint, more soft and porous. In the centre of the tree is the pith, and on the exterior the bark, and it will be observed, that the concentric rings become more soft, and contain more sap as they recede from the pith, the more compact layers nearest the pith being termed heart-wood.

The structure of a tree appears to be composed of minute vessels for conveying nutriment from the roots; the space between these vessels being occupied by cells, which are engaged in performing the function of secretion. The vessels in the growing tree convey the sap in a liquid state from the roots to the leaves, whence it descends in a less liquid state through the bark, and is at last deposited in an altered state between the bark and the last year's wood, forming a new layer of bark and sap-wood, the old bark being pushed outward, and the inner layers being compressed, probably in an equal degree. The sap begins to ascend in the spring of the year, and flows principally through the annual rings next the bark, which contain most sap-wood. In its ascent, it would appear to dissolve some part of a substance which had accumulated in the vessels during the preceding winter, for the nourishment of the buds, leaves, and new wood; and this accounts for the viscous state of the sap on its descent. As the leaves expand, the sap ceases to flow, and the bark again adheres to the wood, and, from the middle of June to the middle of August, there appears to be a pause in vegetation; but after this period, the sap again begins to flow.

As this process goes on from year to year, the fluid parts of the interior of the wood, are absorbed by the new wood and leaves, and the vessels through which they flow, being pressed more closely together by the growth of new wood, become harder and harder, until at last the sap-wood is converted into heart-wood; for it would appear, that there is nothing of the character of solid fibres in wood, the more compact parts being composed solely of the linings of the vessels and cells deprived of their moisture, and packed closely together. When trees arrive at this stage of existence, that is to say, when the sap-wood has become heart-wood, and the greater part of the moisture has been expelled, they are in a fit state to be felled for the purposes of building. The best time for felling is in mid-winter or midsummer; for in the former the sap has ceased to flow, and in the latter it is expended in the production of leaves. Besides the concentric rings, another series of lines may be observed with more or less facility in the sections of various trees;

these lines radiate from the centre, and are termed medullary rays; they produce that beautiful flowered appearance in the oak, to which the name of silver grain has been given.

It will not be necessary here to treat of the seasoning of timber, as that subject has been treated on in another place. *See* SEASONING OF TIMBER.

If timber be properly seasoned, and kept in a dry situation, with a free circulation of air, it will last for several centuries, but even under the most favourable circumstances it gradually deteriorates, it loses its elastic and coherent properties, and becomes brittle at last. If it be kept immersed in water, it will also last a very considerable period; but it is not uninjured, for if it be taken out and dried, it becomes brittle, splits, and cracks in every direction. Alternate changes of dryness and moisture is very injurious to timber, and under such conditions it rapidly decays, as may be observed in the upper part of piles driven in a tidal river, viz., that part which is contained between high and low water. Moisture, combined with a certain degree of heat, about 45 degrees, will gradually decompose timber, especially when exposed to the air. This rot is usually divided into two kinds, the wet and dry rot; these, however, are both produced by the same causes, the only difference being that the former takes place when there is a free evaporation, the latter when the evaporation is imperfect; the one takes place when there is a free circulation of air, the other when the air is confined.

The best method of preserving timber, and preventing decay from any of the above causes, is by proper seasoning, but it must be thoroughly seasoned, partial seasoning being of little avail. A coating of paint, tar, or other preparation, will help to defend the wood from injury by external causes, but will be of no service if any moisture remain in the interior, for it will only prevent its escape, and thus hasten decay. Paint is also useless, unless fresh coats be repeatedly applied, for it is as liable to decay as the timber itself, and therefore requires to be constantly renewed. If the paint be sanded over, it will be found much more durable than common painting. A very good preparation consists of linseed oil and tar put on boiling, the wood being first thoroughly heated; this will sink into the wood, and close up all the pores. Charring the wood will be found an excellent method, and is in many respects better than some of the above. No composition should, however, be applied till the timber has been well seasoned, for to inclose the natural juices of the wood, is to render its rapid decay certain.

Description of Woods.—Of oak there are several kinds, two of which belong to England—the common British oak, and the sessile-fruited oak. The first is found in the temperate parts of Europe, and is that which is commonly met with in the south of England. The wood has often a reddish tinge, and the larger septa are very numerous, producing large flowers; the grain is tolerably straight and fine, and free from knots. It splits freely, and makes good laths for plasterers and slaters; and is decidedly the best kind of oak for joists, rafters, and for any other purposes where stiff and straight-grained wood is required. The second kind is found in the temperate parts of Europe, and in the north of England; it is of a darker colour than the preceding, and the larger septa are fewer in number; the grain is smooth and glossy. It is heavier, harder, and more elastic, and is apt to warp and split in seasoning; it is tough, and difficult to split.

The Dursault oak is a native of France and the south of England, but it is not so strong nor of so firm a texture as the above. The wood of the Austrian and American species is not very valuable; the former being comparatively soft and the latter coarse-grained. The mountain red oak, from Canada, is useful for many purposes, but is light and spongy, and not very durable. The white oak, also from America, is more valuable, being tough and pliable, and more durable than the other species.

The colour of oak is a fine brown of various shades; that inclined to red is the most inferior kind. The transverse septa are usually large and distinct, but are smaller and less distinct in the stronger kinds of wood. The texture is alternately compact and porous.

Oak is particularly adapted for situations exposed to the weather, and makes the best wall-plates, ties, templets and king-posts, but is liable to twist and warp when drying.

Beech is not much used for building, and soon rots in damp situations; in dry situations it is more durable, but is liable to be injured by worms; it is best adapted for piles and other works where it is constantly immersed in water. It is stronger and tougher than oak, but not so stiff. The colour is whitish-brown, of different shades; the texture is very uniform, and the septa smaller than in oak.

Alder has much the same qualities as beech, being very durable in water, but rotting when exposed to damp, and subject to worms in a dry state. The colour is reddish yellow of different shades, and nearly uniform; the texture is very uniform, with larger septa of the same colour as the wood. It is soft, and works easily.

Of plane trees, that from America is very durable in water, but they are not much used for building purposes. The colour and structure is similar to that of the beech, but in this case the septa are more numerous.

Chesnut may be used in many places as a substitute for oak, the wood is hard and compact; when young it is tough and flexible, but when old it is brittle and often shaky. It does not shrink and swell much, and is easier to work than British oak, and contains only a small proportion of sap wood.

The wood of chesnut is so much like that of oak, that it has frequently been mistaken for it; it has, however, no large transverse septa, and in old wood the sap-wood is whiter, and the heart-wood browner, than in oak.

Ash is superior to any other British timber for its toughness and elasticity; it is tolerably durable in a dry situation, but soon rots when exposed to damp or alternate changes of wet and dry. It is too flexible for the timbers of buildings, and in old trees is of a brittle nature. The colour is oak brown, the veins being darker than in oak; in young trees, however, the colour is lighter. The texture is alternately compact and porous, the rings being strongly marked; there are no large septa.

Elm is not much used for building; it is very durable in water, as also when perfectly dry, but will not stand exposed to the weather. It is difficult to work, but not liable to split; it twists, shrinks, and warps much in drying. The heart-wood is generally darker and redder than that of oak, and the sap-wood of a yellowish or brownish white; it is porous and cross-grained, but has no large septa.

The common acacia is very durable; it is equal or superior to oak in stiffness and toughness, and is very valuable for fencing. The colour is a greenish yellow, with a slight tinge of red in the pores, and is, in structure, alternately compact and very porous, so that the rings are very distinct; it has no large septa.

There are several species of poplars, of which the Lombardy, black, and common white, are mostly esteemed. They are all very durable when preserved in a dry state; and the aspen or trembling poplar will last a considerable time exposed to the weather. They are not well adapted for large timbers, but are well fitted for flooring, where there is no great wear, they do not take fire readily.

The colour is of a yellowish or brownish white, one side of the annual rings being a little darker than the other. The wood is of a uniform texture, and has no large septa.

Red or yellow fir is the produce of the Scotch fir, and is common in the north of Europe, in Scotland, Russia, Denmark, Sweden, Norway, and Lapland. It is very durable; and its lightness and stiffness render it superior to any other material for beams, girders, joists, rafters, and framing in general. It is also much used for joiners' work, both external and internal, being cheaper and more readily worked than oak. The wood from cold climates is stronger than that from warmer situations. The colour is of a reddish or honey-yellow, and of various degrees of brightness; the layers are well marked, the one part being soft and light-coloured, the other hard and dark: in the best timber the rings are thin, not more than $\frac{1}{10}$th of an inch in thickness. The inferior kinds have thick annual rings; in some kinds the dark parts of the rings are of a honey-yellow, the wood, heavy, and filled with soft resinous matter, feels clammy, and chokes the saw. In other inferior kinds it is spongy, contains less resinous matter, and leaves a woolly surface after the saw.

White fir, or deal, is the produce of different varieties of spruce fir, and is imported from the north of Europe, and from America. Of Norway spruce, a great quantity is imported from Christiana in deals and planks, which are very highly esteemed. The American wood is not so resinous as that from Norway; it is tougher, less heavy, and generally more liable to twist in drying. It is of two kinds, white and black spruce, the latter producing the best wood. White deal is very durable in a dry state, and is much used for internal joiners' work.

The colour is yellowish or brownish white; the hard part of the annual ring a darker shade of the same colour, often has a silky lustre, especially in the American and British-grown kinds. Each annual ring consists of two parts, the one hard and the other softer. The knots are generally very hard. The clear and straight-grained kinds are often tough, but not very difficult to work, and stand extremely well when properly seasoned.

The Weymouth, or white pine, is a native of North America, and is imported in large logs, often more than 2 feet square, and 30 in length: it is one of the largest and most useful of the American pines. The wood is light and soft, and is said to stand the weather tolerably well. In joinery it is much used for mouldings and other work, where clean straight-grained wood is desirable; but it is not durable, nor fit for large timbers, being very liable to take the dry-rot. The colour is brownish yellow, and the texture more nearly uniform than that of any other of the pine species, and the annual rings not very distinct.

The pitch pine is a native of Canada. It is very resinous and heavy, but not very durable: it is also brittle when very dry. It is of a redder colour than the Scotch pine, feels sticky, and is difficult to plane.

The silver fir is a native of the mountains of Siberia, Germany, and Switzerland, and is common in British plantations. The wood is of a good quality, and much used on the continent both for carpentry and ship-building. The harder fibres are of a yellow colour, compact and resinous; the softer nearly white. It is light and stiff, and does not bend much under a considerable load; consequently floors constructed of it remain permanently level. It is subject to worm.

Of the larch there are three species; one European, and two American. The wood is extremely durable in all situations, even when exposed to damp and weather; it is adapted for both internal and external work, and especially for flooring boards, which are subject to much wear; also for doors, shutters, &c.

The wood of the European larch is generally of a honey-yellow colour, the hard part of the annual rings of a redder cast; sometimes it is brownish white. In common with the other species of pine, each annual ring consists of a hard and soft part. It generally has a silky lustre, and its colour is browner than that of the Scotch pine, and it is much tougher. It is more difficult to work than Riga or Memel timber, but the surface is better when once it is attained. It bears driving bolts and nails better than any other kind of resinous woods. When it has become perfectly dry it stands well, but warps much in seasoning.

The following table, showing the comparative strength, stiffness, and toughness of various woods, taking English oak at 100 as a standard, is compiled from Tredgold, from whose work the above observations are principally extracted:—

Name of Wood.	Strength.	Stiffness.	Toughness.
Common English Oak	100	100	100
Riga Oak	108	93	125
American Oak	86	114	64
Dantzic Oak	107	117	99
Beech	103	77	138
Alder	80	63	101
Plane Tree	92	78	108
Sycamore	81	59	111
Green Chesnut	68	54	85
Ash	119	89	160
Elm	82	78	86
Unseasoned Acacia	95	98	92
Spanish Mahogany	67	73	61
Honduras Mahogany	96	93	99
Walnut	74	49	111
Teak	109	126	94
Abele Poplar	86	66	112
Lombardy Poplar	50	44	57
Cedar	62	28	137
Foreign Fir	80	114	56
Mar Forest Fir	61	49	76
English-grown Fir	60	55	65
Christiana Deal	104	104	104
American White Spruce	86	72	102
British-grown Norway Spruce	70	81	60
Weymouth Pine	95	99	103
Pitch Pine	3	82	92
Larch	103	79	134

For further information on this head, see STRENGTH OF MATERIALS.

TIMBER BRIDGE. *See* WOODEN BRIDGE.

TIMBER MEASURE, 43 solid feet make a ton of timber, and 50 feet a load.

TIMBER PARTITIONS, are board and brace, or quarter or stud partitions. Board and brace partitions are made of narrow boards, or battens, with a thin board between every two battens inserted into their edges: the batten is about half the width of a board.

TIN, a very useful metal, found principally in Cornwall. It is of a silvery-white colour, with a very slight shade of yellow; it is very soft and malleable.

TING, a Chinese temple. *See* CHINESE ARCHITECTURE.

TINNING. The process of covering other metals with tin for the purpose of preventing rust or oxydation. The practice was very commonly adopted in mediæval metal-work.

TOMB. The custom of interring the dead seems to be more ancient than that of burning, and in many countries we find that great pains were taken to preserve them by embalming and similar methods. The practice of burning the bodies would seem to be of later date, and at no period of time universal; under these circumstances, however, the ashes were usually preserved with great care in some structure set apart for that especial purpose. Great reverence has always been shown for the bodies of the departed; a feeling which has been exhibited in different manners, according to the time and place: the interment would appear to have been always connected with some religious rite. In some places, the bodies were simply inhumed or deposited in the earth without any erection above them, save that of a tumulus of earth; in others, they were embalmed at great expense, and placed in structures of greater or less magnificence; whilst in others again they were deposited in natural caves or excavations beneath the surface of the earth.

Perhaps no people have ever expended greater care upon their dead than the Egyptians, a fact which may be readily accounted for by the tenets of their religion. This nation was accustomed to adopt both the latter practices, as is manifest by their building those vast structures, the pyramids, which have been proved to have been erected for the purpose, as well as by the existence of an extensive range of excavations below the surface of the ground. Of the latter, as well as of the pyramids, will be found an account under the article EGYPTIAN ARCHITECTURE, and of the PYRAMIDS, under that article.

Many sepulchral grottos have been found in the plains of Etruria. They are hollowed out of a rock, sometimes disposed in the form of a cross, or with three wings, and sometimes squared in different proportions. Doors have been formed to lead from one grotto to another; sometimes they are above each other. These grottos are not very deep, and the interior is often adorned with paintings. In Campania, also, several tombs have been discovered, containing Etruscan vases. They are represented as being formed by an enclosure of cut stones, and covered with a sort of roof or flagstone shelving on both sides. The dead body was stretched out on the ground, the feet turned towards the entrance of the sepulchre, and the head ranged against the wall, from which were suspended, by bronze nails, vases of terra-cotta, whilst others of a similar kind were disposed around the body.

At Agrigentum, the tombs are a sort of troughs ranged one above another, sometimes arched, or chambers with rent-holes in the roof, only two inches apart from each other. In some parts of Greece and Italy are sepulchral chambers excavated in the rock, and formed like a bell, as at Amphissa. In the valley of Ispica, in Sicily, Denon found tombs, formed out of a hollow stone, upwards of 5 feet long and 15 inches wide.

Tumuli, or large mounds of earth, are of very ancient date, and are to be found in various situations. They are frequently found encompassed by a large square wall, as that of Alyattes in Lydia, of Ægyptus in Arcadia, and of Phocus in Ægina besides many others in Greece and Asia, and in western Scythia. In one, with a circular wall, which was opened between Smyrna and Pergamus, were found galleries and chambers. One of the tumuli in the plain of Athens having been opened, was found to contain a chamber finely constructed of large blocks of stone, in which was a vase of terra-cotta, with figures and inscriptions.

Of a similar kind, though of smaller dimensions, were those mounds which are termed barrows, and which are common in many parts of Europe and Asia. "The Russians, in effecting a practicable road to China, discovered, in fifty degrees north latitude, between the rivers Irtish and Obalet, a desert of very considerable extent, overspread in many parts with tumuli or barrows." One of the largest of these barrows was opened by the Russian government, and was found to contain the body of a prince. "After removing a very deep covering of earth and stones, the workmen came to three vaults constructed of stones of rude workmanship. That wherein the prince was deposited, which was in the centre, and the largest of the three, was easily distinguished by the sword, spear, bow, quiver and arrow which lay beside him. In the vault beyond him, towards which his feet lay, were his horse, bridle, saddle, and stirrups. The body of the prince lay in a reclining posture upon a sheet of pure gold, extending from head to feet, and another sheet of gold of the like dimensions was spread over him. He was wrapped in a rich mantle, bordered with gold, and studded with rubies and emeralds. His head, neck, breast, and arms naked, and without any ornament. In the lesser vault lay the princess, distinguished by her female ornaments. She was placed reclining against the wall, with a gold chain of many links set with rubies round her neck, and gold bracelets round her arms. The head, breast, and arms were naked. The body was covered with a rich robe, but without any border of gold or jewels, and was laid on a sheet of fine gold, and covered over with another. The four sheets of gold weighed forty pounds. The robes of both looked fair and complete, but, upon touching, crumbled into dust." The tombs near Pergamus in Asia Minor are cones of earth with chambers or vaults constructed in the interior. The tomb of Anthridates in the Crimea, is an immense tumulus of hemispherical form, constructed with huge masses of stone of an irregular shape, heaped together without the aid of cement of any kind. This kind of construction is the same as that to be found at Tyrus and Mycene, and is supposed to have been of very ancient date. *See* PELASGIAN ARCHITECTURE.

The Romans do not seem to have adopted this kind of sepulchre, for although tumuli have been discovered in this country containing articles of Roman workmanship, yet our best antiquaries do not allow such to have been the burial-places of the Romans themselves, but rather of Romanized Britons, or of Britons engaged in their service. The general characteristics of a Roman place of interment in Britain, appear to consist simply of the plain grave, with one or more stone pillars bearing an inscription, and sometimes a sculptured device. At Chatham hill in Kent, a Roman sepulchre was discovered, of which the walls were composed of rubble-stone and hard mortar; the wall first discovered was 30 feet in length, and intersected by three apartments with their walls. One apartment which was complete, was 9 feet 3 inches by 7 feet 3 inches, with the inside of the walls covered with fine white plaster, on which were painted stripes of black and red. The urn containing the ashes of the deceased, was deposited on a pavement within the sepulchre, and round it were several vessels of different size and shape, pateræ, &c. A Roman sepulchre, discovered about two hundred and fifty yards from the wall of the city of York, was an oblong room with a ridged roof, covered with hollow Roman tiles; it was about 3½ feet long within, and contained several urns all standing on a tiled pavement. A burial-vault was discovered in Oxfordshire, which in the part explored was 20 feet long by 18 wide, and 8 high from the planking-stones. The human remains were laid in partitions of a dissimilar width, which crossed the vault from east to west, and were built with Roman red tiles, about 8½ inches square. The partitions were 2½ feet deep, and generally about the width of modern graves. Roman urns and other vessels were discovered among the rubbish. There were two tiers of sepulchral recesses, and above were a range of planking tiles covered with mortar and sand, in which was set tesselated work, supposed to have formed the flooring of a temple." In the year 1807, a Roman vault containing a scarcophagus, was discovered in the suburbs of York. The sarcophagus, which contained a skeleton, was cut out of a single grit-stone, and covered with a blue flagstone; its length was 7 feet; breadth 3 feet 2 inches; depth 1 foot 6 inches; thickness 4 inches. Near the vault, an urn of red clay was discovered, containing ashes and fragments of burnt bones. Stone coffins of a similar character, containing bones accompanied by urns, &c., have frequently been discovered. Coffins of brick also occur.

The tumuli, not unfrequently discovered in this island, are to be attributed for the most part to the Britons, as is often evidenced by the weapons, &c. found within them. The Saxons, however, it is probable, still continued the practice, though not for a very long period; their barrows are distinguished from the British by being devoid of any remains of garments, &c.; they are found in clusters, and are of the bell-shaped form. Those with cistvaens, urns, cups, beads, weapons in wooden scabbards, bosses of shields, &c. are British. The cistvaens, just mentioned, consist of three or four stones placed edgeways, and covered by another at the top. Several Saxon barrows are still to be seen in Lower Saxony. The custom of interring the body commenced to be practised by the Saxons, in all probability, upon their conversion to Christianity: their coffins were either of wood or stone, the latter being reserved for persons of wealth and influence; they were at first made of several stones, set round with one at the bottom, and one for a cover at the top, similar to the British cistvaens, but they were afterwards formed of a single stone, hollowed out, with a slab for a cover. In the earlier periods, the bodies of all persons were interred in the cemetery which surrounded the church, but in a short time, persons of rank, and ecclesiastics, began to be buried within the church; and, in such cases, the top of the coffin was generally level with the pavement, of which, indeed, it formed a part.

After a time, the tombs began to assume a different form, and became gradually of a more costly and imposing character. From the plain stone chest we come to that with a coped covering; and then we find the lid sculptured with some ornament, most frequently with a cross, plain or floriated. Next, we arrive at the raised tomb, which became more and more ornamented; and at last we have them covered with rich canopies, and embellished with the most minute and delicate carving. Some tombs in our larger churches and cathedrals still exist as specimens of the most elaborate workmanship of our ancient artificers. Stone tablets, inlaid with brass, were for some time common; the brasses which were engraved, represented the deceased in his usual costume, sometimes surrounded with a canopied niche, also of engraved brass, let into the slab, and usually having a border of inlaid brass round the edge of the slab, containing an inscription relative to the title of the deceased. Floriated crosses, and other figures, were sometimes inlaid in a similar manner; and, occasionally, the brasses were enriched with coloured enamel. Remains of brasses are very common, few old churches being without them.

During the whole of this period, burials in the church-yard were still common, tombs within the church being reserved for the great and noble. The church-yard stones were, of course, of a more simple description, being either of wood or stone, and most usually in the form of a cross, varying, however, greatly in design and outline.

After the Reformation, sepulchral monuments, together with architecture, began to decline in taste and execution; in design, they follow the prevailing style of architecture; and we find Italian details gradually introduced. Effigies were common; and it is not uncommon to find, during the Stuart period, effigies of an entire family on one tomb. Brasses were still prevalent, though of less beautiful design and workmanship. After this, the Italian, or rather Elizabethan style, was thrown aside, and we find groups of sculpture, of classic design, more or less successful, some of very extensive dimensions; in fact, at one time, size seems to have been the principal recommendation, as will be evident to any one visiting our cathedrals, where he cannot but lament the introduction of huge monstrosities, equally vicious in design and execution; and for the sake of these, too, he will see windows and arches blocked up, delicate workmanship defaced, and the whole effect of a grand design marred, if not destroyed. The ill taste displayed in the designs, and the monstrous adulation portrayed in the inscriptions of the monuments of the last century and a half, is enough to shock the feelings of any man who pretends to modesty or common sense. We are glad to see a better taste reviving in the present day.

Mr. Gough has classified the tombs of this country under eight different heads as follows:—

1st Form.—Coffin-shaped stone, prismatic and plain at the top.

2nd Form.—Prismatic and carved at the top, with crosses plain and fleury, as that of Theobald, Archbishop of Canterbury, in 1160, and that of Bishop Glanville, near the altar in Rochester Cathedral.

3rd Form.—Tables with effigies or sculpture, as that of Robert Duke of Normandy, in Gloucester Cathedral, with effigy cross-legged, in a coat of mail, A. D. 1134; King John, in Worcester Cathedral, 1213; Prelates in pontifical habits, first in half-relief, afterwards complete effigies, as Herbert Walter, Archbishop of Canterbury, 1205; Knights and nobles in armour, &c., as Longspee, Earl of Salisbury, 1226.

4th Form.—Tombs with festoons or arches over them, as those of Henry III., Edward I., Queen Eleanor, Edward the Black Prince, Henry IV., &c. This class was succeeded by more lofty tombs, with arches, crochets, pinnacles, finials, &c.

5th Form.—Tombs in chapel burial-places, consisting mostly of open screens, with doors, altar, monuments, piscinas, niches, &c., several of which are seen in the cathedrals of Wells, Salisbury, Exeter, &c.

6th Form.—Inlaid with brass, representing figures of the deceased, and inscriptions either in cameo or intaglio. These are mostly of the 14th century. Many fine specimens are engraved and published by Cotman.

7th Form.—Against walls, which chiefly occur since the Reformation.

8th Form.—Detached buildings, as domes, obelisks, columns, and equestrian statues.

TONDINO, a round moulding, representing a ring. *See* Torus.

TONGUE, (from the Saxon *tung*,) a projecting part on the edge of a board, to be inserted in a groove ploughed in the edge of another. Instead of a tongue wrought out of the edge of the solid board, sometimes both the edges to be joined are ploughed, and a tongue is made equal to the sum of the depths of both grooves, and being inserted into one of them, they are then driven home to each other. It is very difficult to glue two edges that are grooved and tongued together, unless the tongue be made very slack, on account of the difficulty of rubbing them. Work that is tongued should not be fastened with glue; white-lead and oil should be used in preference.

TOOLS, (from the Saxon *tol*,) implements used by artificers in the reduction of any material to its intended form.

The tools employed by the different professions of artificers in building are chiefly carpenters' tools, bricklayers' tools, joiners' tools, masons' tools, slaters' tools, and tilers' tools.

The bricklayers' tools have already been described under the article Bricklayer, it only remains here to give the reference to the Plate:

Figure 1.—The *trowel.*

Figure 2.—The *brick-axe.*

Figure 3.—The *square.*

Figure 4.—The *bevel.*

Figure 5.—The *jointing-rule.*

Figure 6.—The *jointer.*

Figure 7.—The *hammer.*

Figure 8.—The *raker.*

Figure 9.—The *line-pins.*

Figure 10.—The *rammer.*

Figure 11.—The *pickaxe.*

Figure 12.—The *camber-slip.*

Figure 13.—The *banker*, with the *rubbing-stone* placed upon it.

The carpenters' tools having been more slightly noticed, we shall here show their uses as they are referred to in the Plate.

Figure 1.—The *axe*, used in chopping timber by a reciprocal circular motion, with the cutting edge of the axe in a vertical plane.

Figure 2.—The *adze*, used in chopping timber by a reciprocal motion in a given plane, which is generally that of a vertical plane, but with the cutting edge describing a cylindric surface.

Figure 3.—The *socket-chisel*, used in mortising large timbers; and as the mortise is commonly bored by the auger, the chisel is generally less than the breadth of the mortise.

Figure 4.—The *mortise-gauge*, with a double tooth, made temporarily to serve only for the framing in hand.

Figure 5.—The *square*, used in forming right angles, and taking any kind of angles by observing the numbers on the sides of the square.

Figure 6.—The *plumb-rule*, used in setting work perpendicular.

Figure 7.—The *level*, used in setting work horizontal by means of the double square.

Figure 8.—The *auger*, for boring pin-holes, or holes in mortises, for the more easy cutting with the socket-chisel.

Figure 9.—The *hook-pin*, used in drawboring, or in bringing the parts of a large frame together.

Figure 10.—The *crow-bar*, for moving large pieces of timber.

References to Joiners' Tools. See Joinery.

Plate I. *Figure* 1.—The *jack-plane; a* the stock; *b* the tote, or handle, which being open on one side, is called *a single tote; c* the iron; *d* the wedge; *e* the orifice, where the shavings are discharged. *See* Plane.

Figure 2.—The *trying-plane.* The parts are the same as those of the jack-plane, except that the hollow of the tote is surrounded with wood, and on this account it is called *a double tote.*

Figure 3.—The *smoothing-plane*, without a tote, the hand-hold being at the end of the plane.

Figure 4.—The *iron.* No. 1, Front view of the cover for breaking the shavings, screwed on the top of the iron, to prevent the tearing of the wood. No. 2, Front of the iron without the cover, showing the slit for the screws which fasten the cover to the iron. No. 3, The profile of the iron and cover screwed together.

Figure 5.—The *wedge*, for lightening the iron. No. 1, The longitudinal section of the wedge. No. 2, Front, showing the hollow below, for the head of the screw.

Figure 6.—The *sash-fillister*, for throwing the shavings on the bench; *a* head of one stem; *b* tail of the other; *c* iron; *d* wedge; *e* thumb-screw, for moving the stop up and down; *f f* fence for regulating the distance of the rebate from the arris. *See* Plane.

Figure 7.—The *moving-fillister*, for throwing the shavings on the bench. No. 1, Right-hand side of the plane: *a* brass stop; *b* thumb-screw of ditto; *c d e* tooth; the upper part *c d*, on the outside of the neck, and the part *d e*, passing through the solid of the body, with a small part open above *c* for the tang of the iron tooth; *f f* the guide of the fence. No. 2, Bottom of the plane turned up: *a* the guide of the stop; *f f* the fence, showing the screws for regulating the guide; *g g* the mouth and cutting edge of the iron.

Figure 8.—The *plough*, being the same in every respect as the sash-fillister, except the sole, which is a narrow iron. *See* Plane.

Figure 9.—The *mallet.*

Figure 10.—The *hammer.*

Figure 11.—The *side hook*, for cutting the shoulders of tenons.

Figure 12.—The *work-bench: a* the bench-hook; *b b* the screw-cheek; *c c* handle of the screw; *d* end of the guide.

Plate II. *Figure* 1.—The *stock*, into which is fixed a *centre-bit.*

Figure 2.—No. 1, The *gimlet;* No. 2, The lower part, at full size.

Figure 3.—No. 1, The *bradawl;* No. 2, The lower end turned edgewise; No. 3, The lower end turned sideways.

Figure 4.—No. 1, The *paring chisel;* No. 2, The lower end turned edgewise with the basil.

Figure 5.—The *mortise chisel.* No. 1, The side; No. 2, The front; No. 3, The lower end, with the basil.

Figure 6.—The *hand saw. See* Saw.

Figure 7.—The *tenon saw;* generally backed with iron.

Figure 8.—The *sash saw;* generally backed with brass.

Figure 9.—The *compass saw*, for cutting in the direction of a curve-line.

Figure 10.—The *key-hole saw: a* the pad, in which is inserted a spring and two screws for fixing the saw to any length.

Figure 11.—The *square: a b c* the outer square; *d e f* the inner square; *a d e* the stock, or handle; *b c f e* the blade.

Figure 12.—The *movable bevel: a b* the stock; *b c* the blade.

Figure 13.—The *gauge: a a* the stem; *b b* the head, which moves; *c* the tooth, for cutting a sharp line on the surface of the wood. *See* Gage.

Tools, *Masons'*, are: 1. The *peck*, or *cavil*, for breaking and dressing the stone to any determinate size. 2. *Points*, from $\frac{1}{8}$ to $\frac{1}{4}$ of an inch, for quickly reducing the prominent parts of a stone.

3. The *chisel*, from half an inch to two inches in breadth.

4. The *tool*, from two inches to two and a half or three inches in breadth.

5. The *mallet.*

As points will reduce the solid more than chisels, so will a narrow chisel reduce the solid more than a broad one; but the broader the chisel, the smoother the work; and hence broad chisels, or tools, are always used in the finishing of work. The tools here enumerated belong to the journeyman; but the master requires many others of a more extensive nature, as cranes, and other machines for hoisting up stones.

Tools, *Plasterers'*. *See* Plasterer.

TOOLS.

BRICKLAYERS TOOLS.

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Fig. 11.

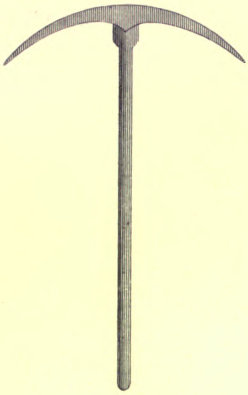


Fig. 2.

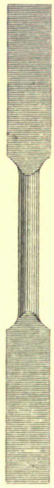
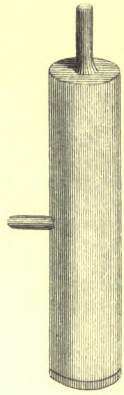


Fig. 1.

Fig. 10.



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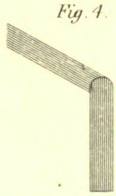


Fig. 9.

Fig. 3.

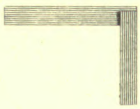
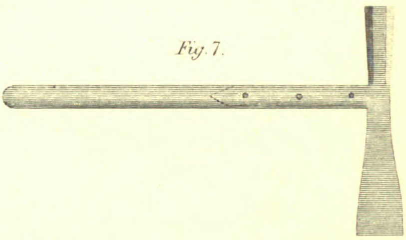


Fig. 7.



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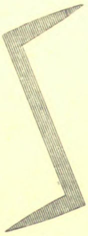

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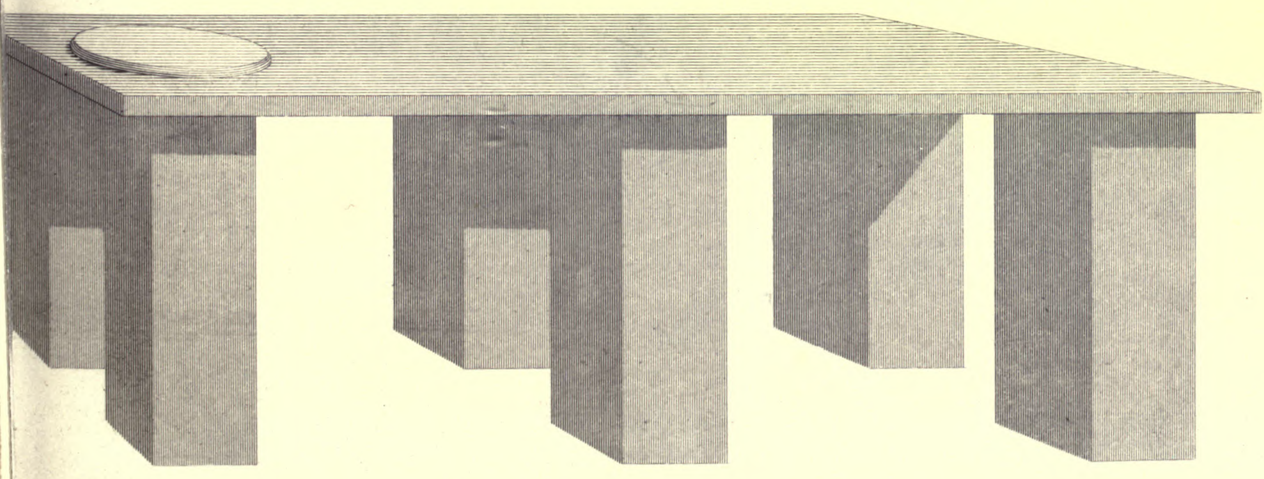
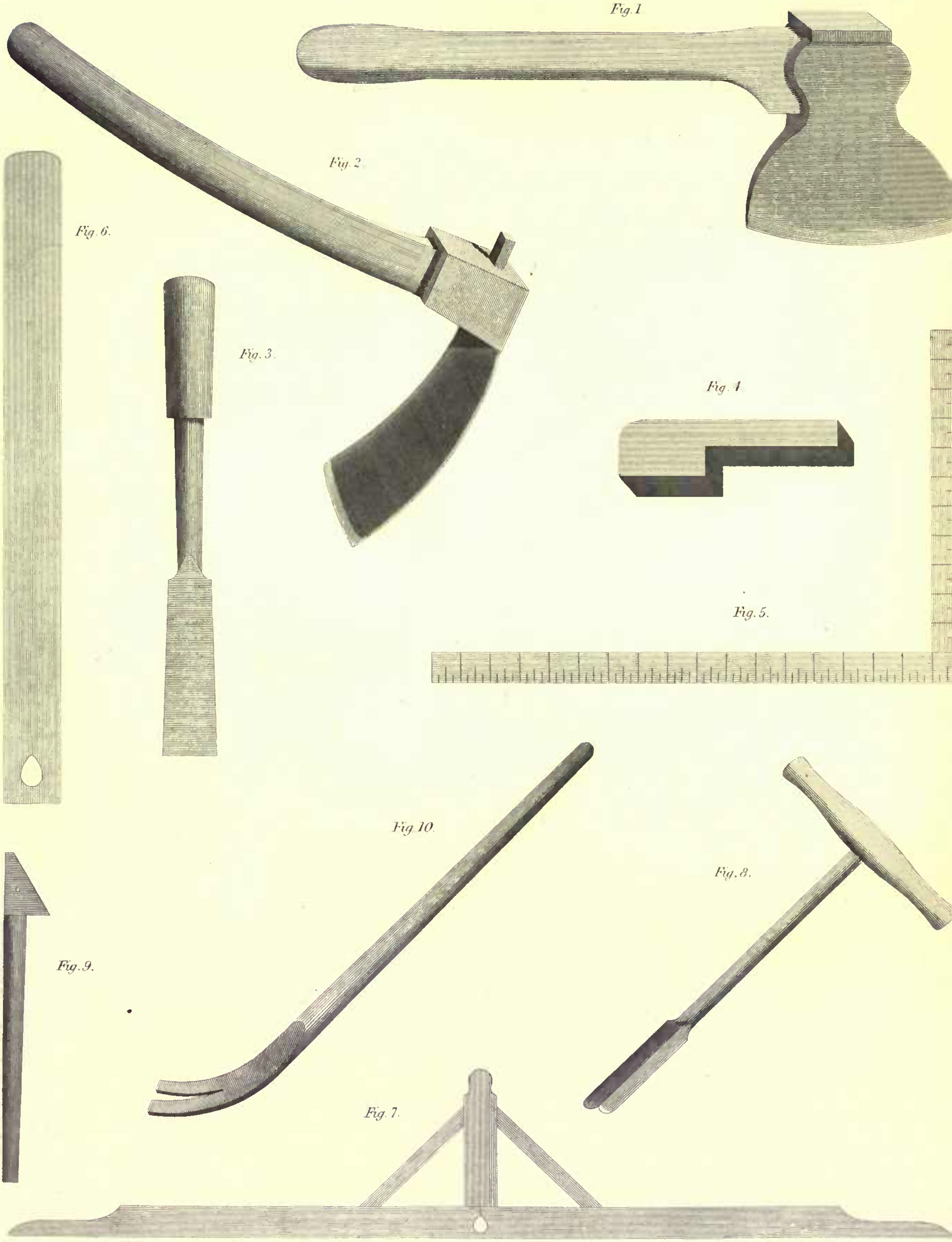
Fig. 12.

Fig. 13.



TOOLS.

CARPENTER'S TOOLS.



Drawn by M. A. Nicholson.

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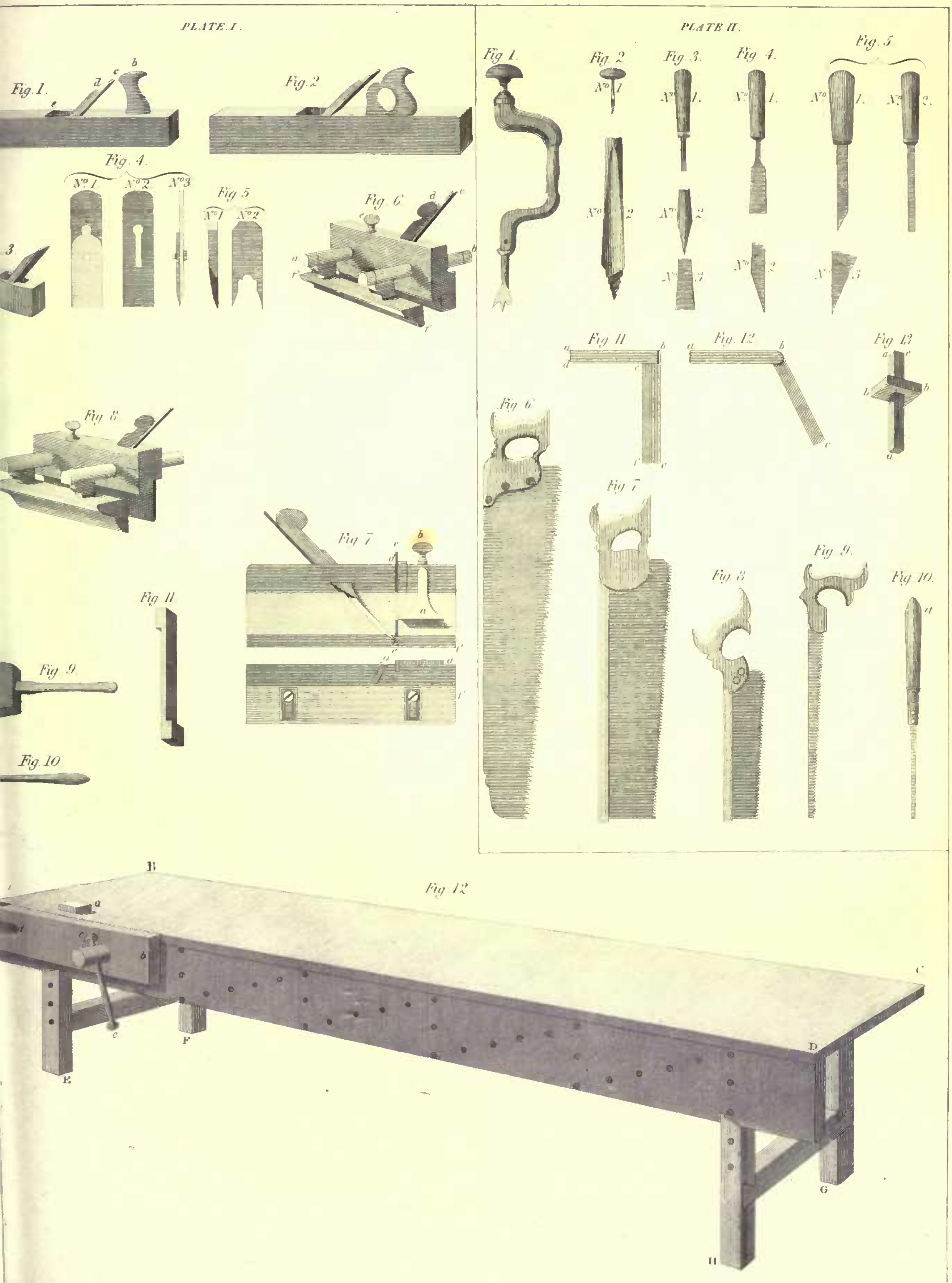
TOOLS.

BELONGING TO JOINERS.



Tools, *Plumbers'*. *See* Plumber.

Tools, *Slaters'*. *See* Slating.

Tools, *Tilers'*, are: 1. The *lathing hammer*, with two guage marks; one mark is placed at 7 inches, the other at 7½. This tool is used both for lathing and tiling.

2. The *lathing staff*, of iron, in the form of a cross, to stay the cross laths, and clinch the nails.

3. The *tiling trowel*, to take up the mortar and lay it on the tiles. It differs from the brick trowel in being longer and narrower.

4. The *bosse*, made of wood, with an iron hook to hang on the laths, or on a ladder for holding the mortar and tiles.

5. The *striker*, a piece of lath about ten inches long, for separating and taking away the superfluous mortar at the breeches of the tiles.

6. The *broom*, to sweep the tiling after it is strook.

TOOTH, the iron or steel point in a guage, which marks the stuff in its passage, or draws a line parallel to the arris of the piece of wood.

Tooth Ornament, a sculptured ornament common in and characteristic of buildings of the early English style of architecture. It consists of a sculptured flower of four leaves, disposed in a pyramidal form; the centre, where the leaves join, projecting above the general surface, to which it is applied as a decoration. It is commonly inserted in hollow mouldings, disposed either at intervals, or more frequently in close proximity one to the other. Its origin is naturally derived from the junction of two Norman zig zag mouldings meeting at an arris. *See* Dog-tooth Moulding.

TOP BEAM, the collar-beam of a truss: it has also been called *wind-beam*, or *strut-beam*. Collar-beam is now generally used, the other names being either antiquated or not much employed. *See* Collar-Beam.

Top Rail, the uppermost rail of a piece of framing, or wainscoting, as its name imports.

TORSEL, or Torsil (from the French *torse*,) a piece of wood laid into a wall, for the end of a timber, or beam, to rest on. *See* Tassels.

TORUS, or Tore, (Latin,) a large moulding, of a semicircular section, used in the bases of columns. The only difference between an astragal and a torus is in size, the astragal being small, and the torus large.

Torus for a Bulwark, a large semicircular moulding, used in the base of a fortified edifice.

TOWER, a building of great height in proportion to its horizontal dimensions, usually forming an adjunct to a larger building, and employed as a belfry, stronghold, watch, or beacon. Amongst the Romans, structures of this kind do not seem to have been very numerous; and when employed, they were not very lofty: they were of various forms. In the castles of the feudal ages, towers were very necessary; the keep usually consisted of a large square tower, with smaller ones at the angles, which were generally elevated above the central one. Sometimes, however, the keep is circular, and occasionally of irregular forms. Towers are also common at the entrances of other positions in fortifications. Churches are seldom found without an addition of this nature, either with or without a pyramidal spire. Church towers are sometimes detached from the main building, but most frequently adjoining; they are of various forms, designs, and proportions, and are found in every position, except at the east end of the chancel. Cathedrals and larger churches frequently have more than one tower, the most usual number being three, one at the intersection of nave and transept, and two others at the west end; sometimes the transepts are flanked with towers, as at Exeter. Smaller churches have only one tower which is variously situated, but as a rule, at the west end of nave, or in cruciform churches at the intersection. *See* Castle, Church, Cathedral, Gothic Architecture, and Round Tower.

TOWN, (from the Saxon, *tun*,) a collection of houses, walled round about for the defence of its inhabitants.

During the feudal system, when many inhabitants lived together, a wall surrounding their habitations was necessary, and now, though this system is abolished, and the surrounding walls have either gone to ruin, or have been taken down to extend the boundaries for habitation, the collection of houses still retains the name of *town*.

Town-Hall, a public hall in which the business of a town is transacted. It answers in some respects to the ancient basilica.

TRABS, (from the Latin *trabs*, a beam,) in ancient carpentry, those beams which are now called *wall-plates*, or *rising-plates*, for supporting the rafters.

TRACERY. That kind of pattern traced in the head of a Gothic window or panel by the divergence and intersection of the mullions.

The origin of this kind of work is to be observed in the works of the close of the 12th century, from which period it was gradually developed into its more perfect form. At a very early period it became customary to enclose two small arches within one larger one; and when this form came to be applied to windows, it must naturally have been observed that the tympanum, or blank space, contained between the larger arch and the heads of the smaller ones, offered a very favourable opportunity for increasing the lighting area by perforating it either wholly or partially: in fact, it appeared to form part of the window; and the idea of making it really so must readily have occurred to many persons; as a blank space, it is heavy, and rather offensive to the eye.

The first advance towards the development of tracery then occurred in this way; the tympanum was relieved by being pierced with an aperture in the form of a circle, quatrefoil, or some other simple figure, and sometimes the spandrels were treated in a similar manner. To this method of perforation the name of *plate*-tracery has been applied, while that in which the sides of the adjacent openings are always parallel, so that the patterns of the openings appear to be formed by the intersection of bars, is termed *bar*-tracery. This latter form arose, naturally enough, from the former, by the multiplication of the piercings, or apertures, till at last the plate disappeared, save what was just sufficient to separate the openings. Sometimes we find bar and plate tracery in the same window, which shows one stage in the development of the former.

At first, the bar-tracery was disposed in simple geometrical patterns, to which the name of *geometrical*-tracery has been given. This term, however, is scarcely appropriate, as all tracery is described geometrically, although not composed of the more common or regular geometrical figures, such as circles, squares, triangles, &c., of which the so-called geometrical tracery was mostly composed. The *flowing*-tracery is designed with greater freedom, and curve-lines of variable curvature are made to flow gracefully one into the other, branching off in various directions, and forming, in their progress, an infinite variety of patterns, the apertures so produced being, for the most part, in the shape of a leaf. Regular geometrical figures are sometimes found combined with the last system. As we near the Perpendicular period, the curves gradually become straight, the bars assume a vertical position, and are at last divided horizontally by transoms.

In all the above instances, the practice of cusping the various figures is very common, such ornamentation being seldom omitted. When the tracery is of a complicated character, we find a sort of subordination observed amongst the less significant members; thus, the principal compartments of a window are divided by large bars, consisting of a large assemblage of mouldings, of which only a portion are employed in the bars which form the sub-divisions.

The Gothic buildings of France are noted for a peculiar form of tracery, termed *flamboyant*, from its flame-like appearance. It is similar to some examples of our flowing-tracery, but differs in this, that the leaf-like openings always terminate in a sharp point at the top, and thus assume rather the appearance of flames.

Tracery is employed, not only in windows, but also in screens, panels, &c., even when not pierced.

TRAIL, a running, or continuous, enrichment of leaves or flowers, with their tendrils or stalks, &c. Such enrichment is common in Gothic mouldings.

TRAMMEL, a rod of wood or metal, having sliding pieces, to which are affixed points, with which to describe large circles, or set off long distances.

TRANSEPT, that portion of a cruciform church which extends across the main body of the building, and usually separates the nave and choir. Thus, the nave and choir running from west to east, the transept will have its direction from north to south, and in the plan forms the shorter arms of the cross, projecting more or less beyond the nave and chancel aisles. Sometimes double transepts occur east and west of each other, as at Canterbury and Lincoln cathedrals; occasionally we find one at the extreme west, as at Ely; and also at extreme east, as at Durham and Peterborough. *See* Cathedral, Church.

TRANSITION, a term applied to certain classes of architectural examples, which appear to form a connecting link between two well-defined styles. It is especially applied to those buildings which are intermediate between the Norman, or Romanesque, and the Pointed styles. *See* Gothic Architecture.

TRANSOM, (from the Latin *transenna*, a cross beam,) in joinery, a horizontal piece, framed across a double-lighted window. When a window has no transom, it is called *a clear story window.*

Transom, a horizontal mullion, dividing a window into two stages in height. Transoms were not generally in use previous to the Perpendicular period of Gothic architecture, but are occasionally found in spire-lights of both Early English and Decorated buildings, where they seem to have been requisite for the purpose of strengthening the window. They are also very common in domestic buildings of all periods, and in those of later date almost universal, the lights beneath being usually arched and cusped.

TRANSTRA, the horizontal timbers in the roof of Roman buildings.

TRANSVERSE, (from the Latin *trans*, over, and *verto versus*, to turn,) lying in a cross direction.

Transverse Strain, the strain against a piece of timber side-ways, by which it is more easily bent, or broken, than when compressed, as a straining-piece, or drawn in a direction of its length, as a tie.

TRANSYTE, a narrow or triforial passage.

TRAPEZIUM, (from τραπέζιον,) a plane figure with four unequal sides and angles. As every rectilinear figure may be divided into as many triangles, wanting two, as the figure has sides; a trapezium, which is a right-lined figure of four sides, may be divided into two triangles by a diagonal. Therefore, to find the superficial content, find the area of each triangle, and the sum of these areas is that of the trapezium.

TRAVELLING-CRANE, a very useful machine for hoisting materials in the erection of a building. It consists of a crab fixed on a carriage, which is movable upon rails to any part of a building where it may be required.

TRAVERSE, (from the Latin *traversus*,) to plane a board in a direction transverse to the fibres, in order to straighten it in that direction.

Traverse, a gallery or loft of communication, such as those found in large churches.

TREAD OF THE STEP OF A STAIR, the horizontal part of the step.

TREBEATION, the same as Entablature.

TREFOIL, an ornament much used in Gothic architecture, consisting of a figure of three cusps disposed within a circle, and enclosing a space similar in form to the three-leaved clover. Trefoils, however, are not invariably disposed within a circle; any cusped figure which encloses a tri-lobed space is termed a trefoil, even if it have only two cusps.

TRELLIS WORK, a reticulated framing, made of thin bars of wood, used in rural architecture. Any reticulated work.

TRESSEL, or Trussel. *See* Trussel.

TRIANGLE, (from the Latin *tres*, three, and *angulus*, a corner,) a plane figure of three sides, and consequently as many angles. In measuring, all rectilinear figures must be reduced to triangles; and in constructions for carpentry, all frames of more than three sides must be reduced to triangles, to prevent a revolution round the angles.

TRIANGULAR COMPASSES, such compasses as have three legs, or feet, by which any triangle, or three points, may be taken off at once. *See* Instruments.

TRICLINIUM, a hall, or apartment, used by the ancients. *See* Cyzicene.

TRIFORIUM, the gallery contained in the space between the vault and timber-roof of the aisles of a church; presenting towards the interior a continuous arcade, situate between the lower arcade and the clere-story.

TRIGLYPHS, (from τρεῖς, *three*, and γλυφάς, *a channel*, or *furrow*,) the tablets in the Doric frieze, chamfered on the two vertical edges, and with two channels in the middle called glyphs, or carvings. In the Grecian Doric, the triglyph is placed upon the angle; but in the Roman, the triglyph next the angle is over the centre of the column.

TRIGONOMETRY, (from τρεῖς, *three*, γονια, *a corner*, and μετρεω, *to measure*) the art of measuring the unknown parts of a triangle, from the remaining parts being given.

Trigonometry, is either *Plane*, or *Spherical*. *Plane* trigonometry is the arts of measuring the unknown parts of a plane rectilinear triangle. This, on many occasions, might be of considerable use to the architect and engineer, in ascertaining certain distances and dimensions, which might otherwise be very inconvenient to obtain. Indeed, it is founded upon such obvious principles, that when once understood it can never be forgotten.

Every triangle consists of six parts, *viz.* the three sides and the three angles: any three of these six parts, except the three angles, being given, the rest may be ascertained.

Definitions.

Definition 1.—The chord of an arc is a straight line, A B, joining its two extremities.

Definition 2.—The sine of an arc is a straight line, B C, drawn from one extremity perpendicular to the diameter drawn through the other extremity of the arc, A B.

Corollary.—Hence, the sine of an arc is the same as the sine of its supplement; the supplement being an arc of such dimensions as will, together with the original arc, make an arc of 180°, or, in other words, a semicircle: thus, an arc of 120° is the supplement of an arc of 60°, and *vice versa*, because 60° + 120° = 180°. Similarly, the complement of an arc is an arc of such dimensions as, together with the original arc, to make an arc of 90°; thus, an arc of 50° is the complement of an arc of 40°, and *vice versa*.

Definition 3.—The tangent of an arc is a straight line, A D, drawn from one extremity of the radius, A C, perpendicular to the same, A C, terminated at the other extremity by a continued radius drawn through the other extremity, B, of the arc A B.

Definition 4.—The secant of an arc is a straight line, D C, passing through one extremity of the arc and the centre, and terminated by the tangent, which passes through the other extremity.

The versed sine is that part of the radius which is intercepted between the foot of the sine and the beginning of the arc.

The co-tangent and co-secant are respectively the tangent and secant of the complement.

Definition 5.—The sine, tangent, or secant of an angle, is the same as that of the arc intercepted.

As trigonometry is chiefly performed by proportion, and as all proportion consists of multiplication or division, or both, and since multiplication and division is best performed by logarithms, we shall here give a short sketch of the nature and construction of logarithms.

The sum of the logarithms of any two numbers, x and z, is the logarithm of their product. Let X be the logarithm of x, and Z the logarithm of z; then taking the exponents of the power of a constant root for the logarithm, we have $x = a^{X}$, and $z = a^{Z}$.

Therefore $x z = a^{X} a^{Z} = a^{X + Z}$; therefore X + Z is the logarithm of $x z$; that is the sum of the logarithms of any two numbers is the logarithm of their product.

Corollary.—Hence, if $x = z$ the logarithms of x^2 is 2 X or of $z^2 = 2$ Z.

In the same manner the logarithm $x y z$ will be found to be X + Y + Z, and consequently the logarithm of $x^3 = 3$ X; therefore, universally, the logarithm of a power is the logarithm of the root multiplied by the index of the power.

The difference of the logarithms of any two numbers, x and z, is equal to the logarithm of their quotient; since $x = a^{X}$ and $z = a^{Z}$, therefore $\frac{x}{z} = \frac{a^{X}}{a^{Z}} = a^{X - Z}$; therefore, X—Z is the logarithm of $\frac{x}{z}$.

The logarithm of the nth root of any number, x, is the logarithm of that number divided by n.

Since $x = a^{X}$; by taking the nth root of both sides, we have $x^{\frac{1}{n}} = a^{\frac{X}{n}}$; but $\frac{X}{n}$ is the logarithm of $x^{\frac{1}{n}}$. And in the same manner we find the logarithm of the nth power of any number, x, is n times the logarithm of that number, for $x = a^{X}$; raise both sides to the nth power, then will $x^n = a^{nX}$; therefore n X is the logarithm of x^n.

To determine two such functions of two quantities, $x + 1$ and $z + 1$, so that if the same operation be separately performed upon $x + 1$ and $z + 1$, and upon their product, the sum of the functions of $x + 1$ and $z + 1$, may be equal to the function of their product:

I. That is, $\phi\,(x + 1) + \phi\,(z + 1) = \phi\,[(x + 1)\,(z + 1]] = \phi\,(1 + x + z + x z)$.

II. Assume $\phi\,(1 + x) = a + b x + c x^2 + d x^3 +$, &c.

III. Therefore, $\phi\,(1 + z) = a + b z + c z^2 + d z^3 +$, &c. And by the same operation we obtain,

$$\text{IV. } \phi\,[1 + (x + z + x z)] = a + \begin{matrix} b x \\ b z \end{matrix} + (b + 2c)\,x z + \begin{matrix} c x^2 \\ c z^2 \end{matrix} \begin{matrix} (2c + 3d) \\ (2c + 3d) \end{matrix} \begin{matrix} d x^2 \\ x^2 z \\ x z^2 \end{matrix} +, \text{\&c.}$$

and by adding No. II. and No. III. together, we obtain,

$$\text{V. } \phi\,(1 + x) + \phi\,(1 + z) = 2a + \begin{matrix} b x \\ b z \end{matrix} + \begin{matrix} c x^2 \\ c z^2 \end{matrix} - \begin{matrix} d x^2 \\ d z^2 \end{matrix} +, \text{\&c.}$$

Then comparing the co-efficients of IV. and V. we obtain,

$$a = o,\ b = b,\ c = -\frac{b}{2},\ d = \frac{b}{3},\ e = -\frac{b}{4}, \text{ \&c., whence we obtain,}$$

$$\text{VI. } \phi\,(1 + z) = b\,(z - \frac{z^2}{2} + \frac{z^3}{3} - \frac{z^4}{4} + \text{\&c.,}) \text{ which is the logarithm of } 1 + z.$$

Let M $= b$, substitute $-z$ for x, in the series VI. and we obtain,

$$\text{VII. } L'\,(1 - z) = M\,(-z - \frac{z^2}{2} - \frac{z^3}{3} - \frac{z^4}{4} -, \text{\&c.})$$

Subtract No. VII. from No. VI. and we obtain,

$$\text{VIII. } L'\,(1 + z) - L'\,(1 - z) = 2M\,(z^1 + \frac{z^3}{3} + \frac{z^5}{5} + \frac{z^7}{7} +, \text{\&c.,}) \text{ or,}$$

IX. $L'\,\frac{1+z}{1-z} = 2\,M\,(z + \frac{z^3}{3} + \frac{z^5}{5} + \frac{z^7}{7} +, \&c.)$

In VI. substitute $\frac{\dot{x}}{x}$ for z, and we obtain,

X. $L'\,\frac{x+\dot{x}}{x} = M\left(\frac{\dot{x}}{x} - \frac{\dot{x}^2}{2\,x^2} + \frac{\dot{x}^3}{3\,x^3} - \frac{\dot{x}^4}{4\,x^4} +, \&c.\right)$ or,

XI. $L'\,(x+\dot{x}) - L'\,x = M\left(\frac{\dot{x}}{x} - = \frac{\dot{x}^2}{2x^2} + \frac{\dot{x}^3}{3x^3} - \frac{\dot{x}^4}{4x^4} +, \&c.,\right)$ and, by transposition, we obtain,

XII. $L'\,(x+\dot{x}) = L'\,x + M\left(\frac{\dot{x}}{x} - \frac{\dot{x}^2}{2x^2} + \frac{\dot{x}^3}{3x^3} -, \&c.\right)$

In IX. substitute $\frac{\dot{x}}{x}$ for z, and we obtain,

$L'\,\frac{x+\dot{x}}{x-\dot{x}}\ 2\,M\left(\frac{\dot{x}}{x} + \frac{\dot{x}^3}{3x^3} + \frac{\dot{x}^5}{5x^5} + \frac{\dot{x}^7}{7x^7} +, \&c.\right)$

In IX. for z substitute $\frac{v-1}{v+1}$, and we obtain,

XIII. $L'\,v = 2\,M\left(\frac{v-1}{v+1} + \frac{(v-3)^3}{3\,(v+1)^3} + \frac{(v-1)^5}{5\,(v+1)^5} + \frac{(v-1)^7}{7\,(v+1)^7} +, \&c.\right)$

This series will always converge, whatever be the value of v; but as v is greater, the degree of convergency becomes less, and, therefore, the logarithms of small numbers may be easily found; but, in the computation of large numbers, the calculation would extend to too great a length to be of any practical utility. In order, therefore, to save trouble, it becomes necessary to derive the logarithm of one number from that of another.

In XIII. for v substitute $v + 1$, and we obtain,

XIV. $L'\,(1+v) = 2\,M\left(\frac{v}{1\,(v+2)} + \frac{v^3}{3\,(v+2)^3} + \frac{v^5}{5\,(v+2)^5} +, \&c.\right)$

In IX. substitute $\frac{x}{2-x}$ for z, and we obtain,

XV. $L'\,\frac{1}{1-x} = 2\,M\left(\frac{x}{2-x} + \frac{x^3}{3\,(2-x)^3} + \frac{x^5}{5\,(2-x)^5} +, \&c.\right)$

In XIII. let $v = \frac{z+\dot{z}}{z}$, and we obtain,

XVI. $\frac{z+\dot{z}}{z} = 2\,M\left(\frac{\dot{z}}{1\,(2z+\dot{z})} + \frac{\dot{z}^3}{3\,(2z+\dot{z})^3} + \frac{\dot{z}^5}{5\,(2z+\dot{z})^5} +, \&c.,\right)$ therefore,

XVII. $L'\,(z+\dot{z}) - L\,z = 2\,M\left(\frac{\dot{z}}{(2z+\dot{z})} + \frac{\dot{z}}{3\,(2z+\dot{z}^3)} +, \&c.\right)$ therefore,

XVIII. $L'\,(\,z+\dot{z}\,) = L'z + 2\,M\left(\frac{\dot{z}}{(2\,z+\dot{z})} + \frac{\dot{z}^3}{3\,(2\,z+\dot{z})^3} +, \&c.\right)$

Practical Example.

The logarithm of 18 being 1.255273, to find the logarithm 19 by the series XIX.

Here $z = 18, \dot{z} = 1$;

therefore, $L'\,19 = L\,18 + 2\,M\left(\frac{1}{37} + \frac{1}{3\,(37)^3} + \frac{1}{5\,(37)^5} +, \&c.\right)$

$= L'\,19 + 2 \times .4342945\left(\frac{1}{37} + \frac{1}{3\,(37)^3} + \frac{1}{5\,(37)^5} +, \&c.\right)$

$2 \times .4342945 = .868589 \qquad (37)^2 — 1369.$

```
                (1369)   ( 3)
37) .868589 ( .023475  (. 17
    74         1369     ----
    ----       -----      5
    128        9785     ----
    111        9583
    ----       -----
     175        202
     148       -----
    -----
      278
      259
    -----
       199
       185
      ----
        14
      ----
 .023475
       5
 -------
 .023480 sum
```

add 1.255273 the log. 18.

the sum 1.278753 is the logarithm of 19.

To find the logarithm of 2 from *Series* XIX. Here $z=1$ and $z=1$, and by substituting the numbers, the series becomes

$$\text{Log. } 2 = 0+.86858896\left(\frac{1}{3}+\frac{1}{3.3^3}+\frac{1}{5.3}+\frac{1}{7.3^7}+\&c.\right)$$

work, therefore, as follows:

3) .86858896			
9) .28952965	÷ 1	=	.28952965
9) 3216996	÷ 3	=	.1072332
9) 357444	÷ 5	=	71488
9) 39716	÷ 7	=	5673
9) 4412	÷ 9	=	490
9) 490	÷ 11	=	44
54	÷ 13	=	4

.30102996 which is the logarithm of 2 nearly. By only adding .00000004, we should have .30103, which is the number to be found in the common tables of logarithms. And lastly, by reverting the series,

$$\text{L}'\,(1+x) = \text{M}\left(x-\frac{x^2}{2}+\frac{x^3}{3}-\frac{x^4}{4}+,\ \&c.\right) \text{ we obtain}$$

$$x = 1 + \text{A}x + \frac{\text{A}^2x^2}{1.2} + \frac{\text{A}^3x^3}{1.2.3} + \frac{\text{A}^4x^4}{1.2.3.4} +,\ \&c., \text{ which}$$

is the value of the number x when the logarithm of x is given. Here $\text{A} = \frac{1}{\text{M}}$.

Trigonometrical Formulæ.

The circumference of a circle being divided into 360 degrees, of which 90° forms a right angle, affords us a ready means of connecting angular space with lines, for the dimensions of an angle will vary directly as the arc, and inversely as the radius. Thus if we make the sides containing any angle of equal length, and measure the width of the opening, as also the length of either side, we shall be able to find the number of degrees contained by the angle. Now we know with sufficient accuracy for all practical purposes, the number of times which a radius is contained in its circumference, which is 2 × 3.14159, &c.; and by this proportion, we shall be enabled to find our angle.

For instance, suppose the width of the opening to measure 52.359 feet, and the length of the side 100 feet, then 100 × 3.14159 = 314.159 gives the length of the semicircumference, or an arc of 180°. Then $\frac{314.159}{52.359} = 6$ gives the number of times which the arc to be found, is contained in an arc of 180°; therefore $\frac{180°}{6} = 30°$ is the measure of the angle required.

The following Table gives the value of the sine, cosine, &c. in terms of each other, so that if one be given, the other may be found.

$$\text{Sin. A} = \sqrt{1-\cos.^2\text{A}};$$
$$\text{Cos. A} = \sqrt{1-\sin.^2\text{A}};$$
$$\text{Vsin. A} = 1-\cos.\ \text{A};$$
$$\text{Tan. A} = \frac{\sin.\ \text{A}}{\cos.\ \text{A}};$$
$$\text{Cot. A} = \frac{\cos.\ \text{A}}{\sin.\ \text{A}} = \frac{1}{\tan.\ \text{A}};$$
$$\text{Sec. A} = \frac{1}{\cos.\ \text{A}} = \sqrt{1+\tan.^2\text{A}}$$
$$\text{Cosec. A} = \frac{1}{\sin.\ \text{A}} = \sqrt{1+\cot.^2\text{A}}$$

The following numerical values of the sine, cosine, tangent, and secant, of 30° 45° 60° 120° are of frequent use. They are calculated to radius = 1.

30°.

The chord of 60° = 2 sin. 30°
But chord of 60° = rad. = 1.

$$\therefore \sin 30 = \frac{1}{2}.$$

$$\text{Cos. } 30 = \sqrt{1-\sin.^2 30} = \sqrt{1-\frac{1}{4}} = \frac{\sqrt{3}}{2}.$$

$$\text{Tan. } 30 = \frac{\sin.\ 30}{\cos.\ 30} = \frac{\frac{1}{2}}{\frac{\sqrt{3}}{2}} = \frac{1}{\sqrt{3}}.$$

$$\text{Sec. } 30 = \frac{1}{\cos.\ 30} = \frac{1}{\frac{\sqrt{3}}{2}} = \frac{2}{\sqrt{3}}.$$

45°

Since sine of an arc = cosine of its compliment;

$$\therefore \sin.\ 45 = \cos.\ \overline{90-45} = \cos.\ 45.$$

But $\sin.^2 45 + \cos.^2 45 = 1$;

$$\therefore 2\sin.^2 45 = 1;\ \text{or } \sin.\ 45 = \frac{1}{\sqrt{2}} = \cos.\ 45.$$

$$\text{Tan. } 45 = \frac{\sin.\ 45}{\cos.\ 45} = \frac{\sin.\ 45}{\sin.\ 45} = 1$$

$$\text{Sec. } 45 = \frac{1}{\cos.\ 45} = \frac{1)}{\frac{1}{\sqrt{2}}} = \sqrt{2}.$$

60°

$$\text{Sin. } 60 = \cos.\ \overline{90 - 60} = \cos.\ 30 = \frac{\sqrt{3}}{2}.$$

$$\text{Cos. } 60 = \sin.\ \overline{90 - 60} = \sin.\ 30 = \frac{1}{2}.$$

$$\text{Tan. } 60 = \frac{\sin.\ 60}{\cos.\ 60} = \frac{\frac{\sqrt{3}}{2}}{\frac{1}{2}} = \sqrt{3}.$$

$$\text{Sec. } 60 = \frac{1}{\cos.\ 60} = \frac{1}{\frac{1}{2}} = 2.$$

120°

Since the sine of an arc = sine of its supplement, and the cosine of an arc = — cosine of its supplement;

$$\text{Sin. } 120 = \sin.\ 60 = \frac{\sqrt{3}}{2}.$$

$$\text{Cos. } 120 = \cos.\ 60 = -\frac{1}{2}.$$

$$\text{Tan. } 120 = \frac{\sin.\ 120}{\cos.\ 120} = \frac{\frac{\sqrt{3}}{2}}{-\frac{1}{2}} = -\sqrt{3}.$$

$$\text{Sec. } 120 = \frac{1}{\cos.\ 120} = +\frac{1}{-\frac{1}{2}} = -2.$$

The above, as we observed, are calculated for a circle whose radius = 1, but if we require their value in a circle of any other radius, it can be readily obtained, for we have this rule to transform formulas, computed to a radius unity, into others computed to a radius (r); write, for sin. A, cos. A., &c. $\frac{\sin.\ A}{r}$, $\frac{\cos.\ A}{r}$ &c., and the values of the sin. A, and cos. A, &c. so found, will be in terms of the radius (r).

Also if we know the numerical values of sin. A, and cos. A, to radius unity, and we wish to have them to a radius (r), we must multiply the numerical value by (r);

For $\frac{pn}{r} = \sin.\ A$; $\therefore pn = r \sin.\ A$

or sin A to radius $r = r \times \sin.\ A$ to rad. = 1.

Ex. Find the numerical value of sin. 30 to rad. 10.000.

sin. 30 to rad. unity $= \frac{1}{2} = .5$;

$\therefore$ sin. 30 to rad. 10.0000 = 10.000 × .5 = 5000.

We may here observe, that in any right-angled triangle, the sine of one of the acute angles $= \frac{\text{altitude}}{\text{hypothenuse}}$, the cosine $= \frac{\text{base}}{\text{hypothenuse}}$ and the tangent $= \frac{\text{altitude}}{\text{base}}$.

The sine and cosine of any two unequal arcs of the same circle being given; to find the sine of any multiple of the lesser arc.

Let E K be any arc of a circle, which being divided into two arcs, E F the less and F K the greater, draw the radii E C, F C, and K C; make F D equal to F E, and join D E cutting C T at L: draw E M, L O, F G, and D H, perpendicular to C K, cutting C K in M, O, G, and H: parallel to C K draw D S, cutting L O at S, and L N cutting E M at N: then let r = C E = C F = C K, let the arc F K be called B, and the arc E F be called A; then F G is the sine of B, C L the cosine of A, C G cosine of B, and E L the sine of A: then, by similar triangles,

C F : F G : : C L : L O, that is,

$$r : \sin' B : : \cos' A : LO = \frac{\sin' B \times \cos' A}{r}.$$

Again, by similar triangles,

C F : C G : : E L : E N, that is,

$$r : \cos' B : : \sin' A : EN = \frac{\cos' B \times \sin' A}{r}.$$

Now E M = sin' (A + B) = N M + E N = L O + E N; therefore, by addition,

$$\sin' (B - A) = \frac{\sin' B \times \cos' A + \cos' B \times \sin' A}{r}$$

Again, D H = sin' (B — A) = L O — E N; therefore, by subtraction,

$$\sin' (B - A) = \frac{\sin' B \times \cos' A - \cos' B \times \sin' A}{r}.$$

These formulæ may be simplified by putting $r = 1$, thus:

Form. 1. $\sin' (B + A) = \sin' B \times \cos' A + \cos' B \times \sin' A$.

Form. 2. $\sin' (B - A) = \sin' B \times \cos' A - \cos' B \times \sin' A$;

add these formulæ together, and we obtain,

Form. 3. $\sin'(B + A) + \sin' (B - A) = 2 \times \sin' B \times \cos' A$;

therefore, $\sin' (B + A) = 2 \times \cos' A + \sin' B - \sin'(B - A)$.

Let $B = (n - 1)$ A; then will

$\sin' n A = 2 \times \cos' A \times \sin' (n - 1) A - \sin' (n - 2) A$, which is a general theorem.

Now in this general theorem, let n be put successively equal to 1, 2, 3, 4, &c., and we obtain,

s' 1 A = s' A.
s' 2 A = 2 × c' A × s' A.
s' 3 A = 2 × c' A × s' 2 A — s' A.
s' 4 A = 2 × c' A × s' 3 A — s' 2 A.
s' 5 A = 2 × c' A × s' 4 A — s' 3 A, &c.

where s' signifies the sine of the quantity that follows, and c' the cosine of the quantity that follows it.

In the last article, put $2 A = a$; $\therefore A = \frac{a}{2}$.

$$\therefore \sin.\ a = 2 \sin.\frac{a}{2}.\cos.\frac{a}{2};$$

$$\text{and } \cos.\ a = 1 - 2 \sin.^2\frac{a}{2} = 2 \cos.^2\frac{a}{2} - 1,$$

by which formulas we find the sine and cosine of an arc in terms of the sine and cosine of half the arc.

A great variety of formulas may be deduced from the general formulas; the following are the most important:

Adding 1 and 2 together—

sin. (A + B) + sin. (A — B) = 2 sin. A cos. B.

And similarly, also, we have—

cos. (A + B) + cos. (A — B) = 2 cos. A cos. B,
sin. (A + B) — sin. (A — B) = 2 sin. B cos. A,
cos. (A — B) — cos. (A + B) = 2 sin. A sin. B.

Let $A+B=m$, and $(A-B)=n$;

$$\therefore A=\frac{m+n}{2} \text{ and } B=\frac{m-n}{2}, \text{ and}$$

$$\sin. m+\sin. n=2\sin.\frac{m+n}{2}.\cos.\frac{m-n}{2}$$

$$\cos. m+\cos. n=2\cos.\frac{m+n}{2}.\cos.\frac{m-n}{2}$$

$$\sin. m-\sin. n=2\sin.\frac{m-n}{2}.\cos.\frac{m+n}{2}$$

$$\cos. n-\cos. m=2\sin.\frac{m+n}{2}.\sin.\frac{m-n}{2}.$$

Again—

since $\sin.(A+B)=\sin. A\cos. B+\sin. B\cos. A$
and $\sin.(A-B)=\sin. A\cos. B-\sin. B\cos. A$

therefore,

$$\sin.(A+\,)\sin.(A-B)=\sin.^2A\cos.^2B-\sin.^2B\cos.^2A$$
$$=\sin.^2A(1-\sin.^2B)-\sin.^2B(1-\sin.^2A)$$
$$=\sin.^2A-\sin.^2B$$
$$=(\sin. A+\sin. B)(\sin. A-\sin. B)$$

$\cos.(A+B)=\cos. A\cos. B-\sin. A\sin. B$
$\cos.(A-B)=\cos. A\cos. B+\sin. A\sin. B$

$$\cos.(A+B)\cos.(A-B)=\cos.^2A\cos.^2B-\sin.^2A\sin.^2B$$
$$=\cos.^2A(1-\sin.^2B)-(1-\cos.^2A)\sin.^2B$$
$$=\cos.^2A-\sin.^2B=(\cos. A+\sin. B)\times(\cos. A-\sin. B).$$

Again—

$\sin.(A+B)=2\sin. A\cos. B-\sin.\overline{A-B}$
$\cos.\ A+B\ =2\cos. A\cos. B-\cos.\overline{A-B}$

Hence, if we have three arcs, $A+B$, A, and $\overline{A-B}$, given in arithmetic progression, the sine and cosine of $A+B$ may be found from the sines and cosines of A and $A-B$. Thus, to find $\sin. A+B$, multiply $\sin. A$ by $2\cos. B$, and $\sin. A-B$ by $(-1,)$ the sum of the products will be $\sin. A+B$; and to find $\cos. A+B$, multiply $\cos. A$ by $2\cos. B$, and $\cos. A-B$ by (-1), and add the results together. The expression $2\cos. B-1$, is called the scale of relation; and $\sin. A+B$, $\sin. A$, and $\sin. A-B$ are called terms of a recurring series.

Since $\sin.(A+B)+\sin.(A-B)=2\sin. A\cos. B$,
and $\cos.(A+B)+\cos.(A-B)=2\cos. A\cos. B$.

For B put a, and for A put $n\,a$;

$$\therefore A+B=n\,a+a=\overline{n+1}.a$$
$$A-B=n\,a-a=\overline{n-1}.a;$$

$\therefore \sin.(n+1)a+\sin.(n-1)a=2\sin. n\,a\cos. a$
and $\cos.\overline{n+1}\,a+\cos.(n-1)\,a=2\cos. n\,a\cos. a.$

Let $n=2$; $\therefore n+1=3$, and $n-1=1$

Therefore,

$$\sin. 3a+\sin. a=2\sin. 2a\times\cos. a=2(2\sin. a\cos. a)\cos. a$$
$$=4\sin. a\cos.^2a=4\sin. a(1-\sin.^2a)$$
$$=4\sin. a-4\sin.^3a;$$
$$\therefore \sin. 3a=3\sin. a-4\sin.^3a$$

and $\cos. 3a+\cos. a=2\cos. 2a\cos. a.$

$$=2(2\cos.^2a-1)\cos. a.$$
$$=4\cos.^3a-2\cos. a.$$
$$\therefore \cos. 3a=4\cos.^3a-3\cos. a.$$

These formulas for $\sin. 3a$, and $\cos. 3a$, give the values of the sine and cosine of triple the arc in terms of the sine and cosine of the simple arc.

128

To find the sine and cosine of an arc in terms of the sine of twice the arc.

$$\cos.^2A+\sin.^2A=1$$
$$2\sin. A.\cos. A=\sin. 2A;$$
$$\therefore \cos.^2A+2\sin. A\cos. A+\sin.^2A=1+\sin. 2A;$$
$$\text{and } \cos.^2A-2\sin. A\cos. A+\sin.^2A=1-\sin. 2A.$$

$$\therefore \cos. A+\sin. A=\pm\sqrt{1+\sin. 2A}$$
$$\cos. A-\sin. A=\pm\sqrt{1-\sin. 2A}$$

$$\therefore \cos. A=\tfrac{1}{2}\left\{\sqrt{1+\sin. 2A}\pm\sqrt{1-\sin. 2A}\right\}$$
$$\sin. A=\tfrac{1}{2}\left\{\sqrt{1+\sin. 2A}\pm\sqrt{1-\sin. 2A}\right\}$$

When A is $<45°$, $\cos. A$ is $>\sin. A$, and we must use the upper signs; but when $A>45°$, $\sin. A$ is $>\cos. A$, and we must use the lower signs.

These values for $\cos. A$ and $\sin. A$ are termed formulas of verification; for, by means of them, we are enabled to test or verify the accuracy of results obtained by other processes.

Thus, to find $\sin. 15°$,

$$\sin. 15=\sin.(45-30)=\sin. 45\cos. 30-\sin. 30\cos. 45$$
$$=\frac{\sqrt{3}}{2\sqrt{2}}-\frac{1}{2\sqrt{2}}=\frac{\sqrt{3}-1}{2\sqrt{2}}$$

Then, in the formula, let $A=15$;

$$\therefore 2A=30 \text{ and } \sin. 2A=\frac{1}{2} \text{ and } \overline{1+\sin. 2A}=\frac{3}{2}, \overline{1-\sin. 2A}=\frac{1}{2};$$

$$\therefore \sin. 15=\frac{1}{2}\left(\sqrt{\frac{3}{2}}-\sqrt{\frac{1}{2}}\right)=\frac{\sqrt{3}-1}{2\sqrt{2}},$$ the same result as before.

The utility of the preceding formulas may be shown in finding the numerical values of some arcs.

$$\sin.(45+A)=\sin. 45\cos. A+\sin. A\cos. 45$$
$$=\frac{1}{\sqrt{2}}(\cos. A+\sin. A).$$
$$\cos.(45+A)=\cos. 45\cos. A-\sin. 45\sin. A$$
$$=\frac{1}{\sqrt{2}}(\cos. A-\sin. A).$$

Let $A=30$; $\therefore \cos. A=\frac{\sqrt{3}}{2}$, and $\sin A=\frac{1}{2}$;

$$\therefore \sin. 75=\frac{\sqrt{3}+1}{2\sqrt{2}}, \text{ and } \cos. 75=\frac{\sqrt{3}-1}{2\sqrt{2}}.$$

Next let $A=90$; $\therefore \cos. A=0$, and $\sin. A=1$

$$\therefore \sin. 135=\frac{1}{\sqrt{2}}, \text{ and } \cos. 135=-\frac{1}{\sqrt{2}}.$$

To find the sine and cosine of 18° and 36°

$$5\times 18°=90°;\ \therefore 3\times 18°=90°-2\times 18°$$
$$\therefore \cos.(3\times 18°)=\cos.(90°-2\times 18°)=\sin.\overline{2\times 18°}$$

But $\cos.\overline{3\times 18}=4\cos.^3 18-3\cos. 18,$
$\sin.\overline{2\times 18}=2\sin. 18\cos. 18;$

$\therefore 4\cos.^3 18-3\cos. 18=2\sin. 18\cos. 18.$

Let $8=x$;

$$\therefore 4(1-x^2)-3=2x, \text{ or } 4x^2+2x=1$$
$$\therefore x^2+\frac{x}{2}+\frac{1}{16}=\frac{1}{4}+\frac{1}{16}=\frac{5}{16}$$
$$\therefore x=\frac{\sqrt{5}-1}{4}=\sin. 18=\cos. 72.$$

But,

$$4(1-x^2) = 4 \cos.^2 18 = 2x + 3 = \frac{\sqrt{5}-1}{2} + 3 = \frac{5+\sqrt{5}}{2}$$

$$\sqrt{1-x^2} = \cos. 18 = \frac{\sqrt{5+\sqrt{5}}}{2\sqrt{2}}$$

THEOREMS. (*The figures, as marked on the Plate, are according to the numbers of the Theorems.*)

Theorem 1.—*The sides of any plane triangle are as the sines of the angles opposite to them.*

Figure 1.—Let A B C be a triangle; upon B C let fall the perpendicular A D: from B A and C A take B E and C H, equal to each other; on B, with the radius B E, describe the arc E F, cutting B C at F; on C, with the radius C H, describe the arc H I cutting B C at I; draw E G and H K parallel to A D, cutting B C at G and K; then will E G be the sine of the arc E F, or of the angle E B F; and H K will be the sine of the arc H I, or of the angle H C I: now, let B E and C H be called radius, denoted by R, and let E G be called the sine of angle B, and H K the sine of angle C; then, by similar triangles,

B A : A D : : B E or C H : E G.

Again, by similar triangles,

A D : A C : : H K : H C or B E;

therefore,

B A : A C : : H K : E G;

that is,

B A : A C : : sin' C : sin' B.

Therefore, the sides of triangles are as the sines of their opposite angles.

Theorem 2.—*In any plane triangle, as the sum of the two sides is to their difference, so is the tangent of half the sum of the opposite angles to the tangent of half their difference.*

Figure 2.—Let A B C be a plane triangle; from B C cut off B D equal to B A, and join A D; bisect the angle A B C by the straight line B E; then will B E also bisect A D; let F be the point of section, and let B E meet A C in E; through F draw F G parallel to A C, cutting B C in G; then by similar triangles, B C E and B G F,

B G : G C : : B F : F E.

But D C is the difference of the sides B A and B C; and because D F : F A : : D G : G C; but D F and F A are equal, whence D G and G C are equal; therefore, D G or G C, is half the difference of the sides; now half the difference of the sides, added to the lesser side, is half the sum of the sides. It is evident, that B A D is half the sum of the angles C A B and B C A, and D A C is half their difference; now, by considering A F as radius, B F will be the tangent of the angle B A F, or B A D, and F E the tangent of the angle F A E, or D A C; therefore, as B G, half the sum of the two sides, is to G C, half their difference, so is B F, the tangent of the half sum of the opposite angles, to F E, the tangent of half their difference; and, consequently, as the sum of the two sides is to their difference, so is the tangent of the half sum of the opposite angles, to the tangent of half their difference.

Theorem 3.—*In any plane triangle, if a perpendicular be let fall upon the longest side from the opposite angle; then, as the sum of the segments of the longest side, or base, is to the sum of the other two sides, so is the difference of the sides to the difference of the segments of the base.*

Figure 3.—In the triangle A B C, left fall the perpendicular A E upon B C; about A as a centre with the distance, A C, of the shortest side, describe a circle: produce B A to meet the circumference in G; then will B G be the sum of the two sides, and B F their difference; also, B E and E C are the segments of the base, and B D their difference; now, by the property of the circle, B G × B F = B C × B D;

whence, B C : B G : : B F : B D;

that is, as the longest side, B C, is to B G, the sum of the other two sides, so is B F the difference of the sides, to B D, the difference of the segments of the base.

When two angles of a triangle are given, the third angle is found by subtracting the sum of the two given angles from 180°, or two right angles; and, consequently, if one of the acute angles of a right-angled triangle be given, the remaining angle will be found, by subtracting the acute angle from 90; for, in this case also, two angles are given, *viz.*, one of the acute angles and the right angle; and these being subtracted from two right angles, or 180, the other acute angle will be found.

Various propositions might be given, but the preceding are sufficient for every case of plane trigonometry.

The analogies of plane trigonometry may easily be deduced from those of spherical trigonometry; the former being particular cases of the latter.

Proposition.—The sum, s, and difference, d, of two quantities, x and y, being given; to find the quantities themselves.

$$\text{Let } x + y = s$$
$$x - y = d$$

add these equations together, and $2x = s + d$ or $x = \frac{s+d}{2}$; subtract these equations from each other, and $2y = s - d$, or $y = \frac{s-d}{2}$; whence x, the greater of the two quantities, is half the sum and difference of these quantities; and y, the lesser, is half of the difference between the sum and difference; or, in other words, the half sum added to the half difference, gives the greater quantity; and the half sum subtracted from the half difference, gives the lesser quantity.

Solutions of the three cases of oblique-angled triangles.

Every plane triangle consists of six parts, the three sides and the three angles; three of these parts must always be given, and of these given parts one at least must be a side; to find the remaining three parts.

Case 1.—*Two angles and a side being given, to find the remaining sides.*

As the sine of the angle opposite the given side is to the sine of the angle opposite the required side, so is the given side to the required side.

In the oblique-angled triangle, A B C, given the angle A 59°, the angle C 52°15′, and the side A B 276.5, to find A C and B C.

We shall find

angle B = 180° − (52° 15′ + 59°) = 68° .45,

as the sine < C 52° 15′	9.89801
is to sine of < B 68° 45′	9.96942
so is the side A B 276.5	2 44170
	12.41112
to the side A C 325.9	2.51311

To find B C.

As the sine of < C 52° 15′	9.89801
is to the sine of < A 59°	9.93307
so is A B 276.5	2.44170
	12.37477
to B C..........299.8	2.47676

GEOMETRICAL CONSTRUCTION.

From a scale of equal parts draw A B = 276.5, and by the protractor, or line of chords, make angle A 59°. Now the triangle cannot be constructed without having the angle B;

therefore subtract the sum of angles A and C from 180° which gives angle B, that is 180—(59°+52° 15′) or 180—111° 15′ = 68.45 = angle B; make angle B 68° 45′, then A C and B C being measured by the same scale as A B, will give their respective lengths.

Case 2.—*Two sides, and an angle opposite to one of them, being given; to find the other two angles and the remaining side.*

As the side opposite the given angle
is to the side opposite the required angle
so is the given angle
to the required angle.

Example.—In the oblique-angled triangle A B C, obtuse at B, given A C 318 yards, B C 195 yards, and the angle A 32° 40′, to find the angles B and C, and the side A B.

Construction.—Draw A C = 318 from a scale of equal parts; make angle A = 32° 40′; with the distance 195 equal parts and the centre C describe an arc cutting A B at B, and join B C; the angles B and C will be found by the protractor, or line of chords, and the side A B by the same scale from which the other two sides were taken.

By Calculation.

As the side B C, 195	2.290035
is to the side A C, 318	2.502427
so is the sine' A, 32° 40′	9.732193
	12.234620
to the sine of B, 61° 40′	9.944585

But since the tables give only acute angles, and the angle required is obtuse, and the sine of any angle is the same as the sine of its supplement,
therefore 180—61° 40′ = 118° 20′ = angle B.

Note.—When the given side opposite to the given angle is greater than the other given side, the angle opposite to such other given side, or the angle to be first found, is always acute, and is found by proportion; but when the side opposite to the given angle is less than the other given side, the opposite angle may either be acute or obtuse.

To find the side A B.

As the sine of A 32° 40′	9.732193
is to the sine of C 29°	9.685571
so is B C 195	2.290035
	11.975606
to A B 175.15	2.243413

Case 3.—*Given the two sides and the included angle; to find the other two angles, and the third side.*

As the sum of the two sides
is to their difference,
so is the tangent of half the sum of the opposite angles
to the tangent of half their difference.

Having by this proportion found the difference of the angles of the base, then half of the sum added to the half difference, gives the greater angle, and half of the sum diminished by the half difference gives the lesser angle.

Example.—*For the triangle* A B C, *given the side* A C 919.95, *the side* A B 500 *feet, and the contained angle* A 36° 52′; *to find the angles* B and C, and the side B C.

Construction.—Make the angle B A C = 36° 52′; make A B = 500 from a scale of equal parts, which set from A to B; from the same scale transfer 919.95 from A to C, and join A C; then the side A C will be found upon the line of equal parts, and the angles B and C by the protractor, or line of chords.

By calculation, to find the angles.

Now 919.95 + 500 = 1419.95 the sum of the sides, and 919.95 — 500 = 419.95 their difference; the three angles are 180° from which subtract angle A 36° 52′, and there will remain 143° 8′, divided by 2, gives 71° 34′ for half the angles at the base: then

As A C + B C, 1419.95	3.152273
is to A C — B C, 419.95	2.623198
so is the tang' ½ (B — C), 71° 34′	10.477162
	13.100360
to the tangent of ½ (B — C) 41° 35′	9.948087

Then 71° 34′ + 41° 35′ = 113° 9′ = angle B
and 71° 34′ — 41° 35′ = 29° 59′ = angle C.

To find the side B C.

As the sine of C, 29° 59′	9.698751
is to the sine of A, 36° 52′	9.778119
so is A B. 500	2.698970
	12.477089
to B C, 600.26	2.778338

Case 4.—*Given the three sides of a triangle, to find the angles.*

From the angular point opposite the greater side, draw a perpendicular to that side, dividing it into two segments; then
As the base, or sum of the two segments of the base,
is to the sum of the other two sides,
so is the difference of the sides
to that of the segments of the base:
add half the sum of the segments of the base, and half their difference will give the greater segment: while the half sum subtracted from half the difference, will give the lesser segment.

Example.—*In the triangle* A B C, *given the side* A B, 562, A C 800, *and* B C 320; *to find the angles.*

Construction.—Draw the straight line A C = 800 equal parts from any scale; with a radius of 562 equal parts, and the centre A describe an arc at B, and with a radius of 320 and the centre C′ describe another arc, cutting the former at B; join A B and B C; then measure the angles by a protractor, or line of chords.

Now A B + B C =562 + 320 = 882 the sum of the sides, and A B — B C=562—320=242 their difference; then

As the base, or longest side, 800	2.903090
is to the sum, 882, of the sides	2.945469
so is the difference, 242, of the sides	2.383815
	5.329284
to A C—A D 266.81, the difference of the segments of the base	2.426194

then 133.405 is the half difference
and 400 is half the base;

therefore 533.405 is the greater segment of the base
and 266.595 is the lesser segment.

Then, to find the angle C B D.

As B C, 320	2.505150
is to C D, 266.6	2.425860
so is the sine of 90°, or radius	10000000
	12.425860
to the sine of C B D, 56° 25′	9.920710

To find the angle A B D.

As A B, 562	2.749736
is to A D, 533.405	2.727057
so is the sine of 90°	10.000000
	12.727057
to the sine A B D, 71° 39′	9.977321
then adding C B D = 56° 25′	
gives the whole angle A B C = 128° 4′	

then 90 — 71° 39′ = 18° 21′ = angle A
and 90 — 56° 25′ = 33° 35′ = angle C.

From three parts of a triangle, including at least one side as a part given, the other three remaining parts have been found upon general principles; but when the triangle is right-angled, other solutions, more simple for general practice, may be given; these are founded upon the following proportions:

Let A B C be a right-angled triangle, right-angled at B; upon A B take any radius, A D; with A as a centre, and the radius A D, describe an arc, D G, cutting A C at O; draw D E and O F parallel to B C, cutting A C at E, and A D at F; then, by the definitions given, A C or A D is the radius, E D is the tangent, G F the sine, A F the cosine, and A E the secant of the arc C D. Now the sine, cosine, tangent, &c. of an arc, being the same as the sine, cosine, tangent, &c. of an angle drawn from the centre through the extremities of the arc, the following proportions result by similar triangles, A D E and A B C.

A D : D E : : A B : B C; that is, as a radius
is to the tangent of angle, A,
so is the base, A B,
to the perpendicular, B C.

By similar triangles, A F G and A B C,
A F : F G : : A B : B C; that is,
As the cosine of angle A,
is to the sine,
so is the base, A B,
to the perpendicular, B C.

So that having the angle, A, and the side, A B, given, the side B C may be found by either of these analogies; or, having the sides or legs A B and B C, angle A can easily be found.

By similar triangles, A E D and A C B,
A E : E D : : A C : C B; that is,
As the secant
is to the tangent
so is the hypothenuse, A C,
to the perpendicular, C B;
or, by similar triangles, A G F and A C B,
A G : G F : : A C : C B; that is,
As radius
is to the sine of angle, A,
so is the hypothenuse, A C,
to the perpendicular, C B.

So that having the angle, A, and the hypothenuse given, the perpendicular, B C, may be found; or, the angle, A, may be found from having the perpendicular and the hypothenuse given.

We shall now proceed to show the use of these analogies by examples.

In making any side radius, the other sides are sines, or tangents, of their opposite angles; when either of the legs, or sides, containing the right angle, is made radius, the other leg becomes a tangent of the opposite angle, and the hypothenuse the secant of that angle, and not of an opposite angle.

When the hypothenuse is made radius, the three sides are sines of their opposite angles; in this case the hypothenuse of the sine 90° is equal to the radius, and is therefore a constant quantity, its logarithm being 10.00000.

The radius, sine, tangent, or secant, being written upon any side, or supposed to be written, is called by the name of that side. Then,
As the name of any side
is to the name of any other side,
so is the former
to the latter side.
And the same analogy obtains on the contrary.

In analogies for finding the parts of a right-angled triangle, one of the terms, or names, may always be the radius, which will lessen the labour of the operation.

To exemplify what has been said:

If radius, or r, be written upon the leg A B, the other leg, B C, will be the tangent of angle A, and A C will be the secant of angle A. Therefore upon B C write t'A, which signifies the tangent of A, which will be the name of the side B C; also upon the hypothenuse A C, write sec' A, which signifies the secant of angle A, or name of the hypothenuse A C.

Again, when the leg B C is made radius, A B becomes the tangent of the opposite angle, C, and the hypothenuse the secant of angle C. Therefore, upon B C write r, and upon A B write t' C, and upon A C write sec' C; then *radius* is the name of the side B C, *tangent of* C is the name of the side A B, and *secant of* C is the name of the hypothenuse, or side, A C.

Lastly, when the hypothenuse A C is made radius, the legs A B and B C become the sines of their opposite angles; therefore, if r be written upon A C, write s' C, signifying *sine of angle* C, upon A B, and s' A, *signifying sine of angle* A, upon A B; then *radius* is the name of A C, *sine of* C the name of A B, and *sine of* A the name of B C.

It must be remembered, that whatever be the given parts, and whatever the parts required, any side of the right-angled triangle may be made radius, except when the two legs are given to find the acute angles, and this will furnish a method of proving the result. Therefore, if two of the sides be given, radius, being always constant, must always be one of the parts concerned; whence, if the two legs be given to find the angles, one of the legs must be made radius.

To find a Side.

As the term, or name on the given side
is to that on the required side,
so is the given side
to the side required.

And to find an Angle.

As the side made radius
is to the other given side,
so is radius
to the term or name upon that side.

Note.—From this property of a plane triangle, that the three angles are together equal to two right angles, or 180°, the following very useful corollaries arise.

Corollary 1.—When two angles of a triangle are given, the third is also said to be given; for it is the supplement of the other two, and may be found by subtracting their sum from 180°.

Corollary 2.—When one angle of a triangle is given, the sum of the other two may be found, by subtracting the given angle from two right angles, or 180°.

Corollary 3.—If one angle of a triangle be right, the other two are acute, and together make another right angle; and, if one of the acute angles be given, the other is also given, being the complement of the other given one, or what it wants of 90°.

Problem I.—*Given the angles and hypothenuse of a right-angled plane triangle, to find the base and perpendicular.*

Example 1.—In the triangle A B C, right-angled at B, suppose the angle, C, 55° 30′, and the hypothenuse, A C, 121 yards; required the sides A B and B C.

Geometrically.

Draw the indefinite line B C, and from the point C, with the chord of 60°, describe an arc, upon which lay off the quantity of the angle C, 55° 30′; then place the hypothenuse 121 equal parts from C to A, and from A let fall a perpendicular to B. Measure the sides A B and B C on the scale from which A C was taken.

By Calculation.

The hypothenuse A C being radius, then A B is the sine of the angle C, and B C the sine of angle A, or cosine of angle C. Hence,

To find A B.

As radius	10.000000
is to sine of C, 55° 30′	9.915994
so is A C, 121	2.082785
to A B, 99.719	1.998779

To find B C.

As radius	10.000000
is to cosine of C, 55° 30′	9.753128
so is A C, 121	2.082785
to B C, 68.535	1.835913

The base, B C, being radius, then A B is the tangent, and A C the secant of the angle C. Hence,

To find A B.

As secant of C, 55° 30′	10.246872
is to tangent of C, 55° 30′	10.162866
so is A C, 121	2.082785
to A B, 99.719	1.998779

To find B C.

As secant of C, 55° 30′	10.246872
is to radius	10.000000
so is A C, 121	2.082785
to B C, 68.535	1.835913

The perpendicular, A B, being radius, then B C becomes the tangent of the angle A, or the cotangent of the angle C; and A C becomes the secant of angle A, or cosecant of angle C. Hence,

To find A B.

As cosecant of C, 55° 30′	10.084006
is to radius	10.000000
so is A C, 121	2.082785
to A B, 99.719	1.998779

To find B C.

As cosecant of C, 55° 30′	10.084006
is to cotangent of C, 55° 30′	9.837134
so is A C, 121	2.082785
to B C, 68.535	1.835913

General Rule for Gunter's Scale.

Extend the compasses from the first term to the second; that extent will reach from the third to the fourth term; observing to take the line marked *Num.* for feet, yards, miles, &c., the line marked S. for sines of angles, and that marked T. for tangents. The radius is 90° of sines, and 45° of tangents.

Example 2.—In the triangle A B C, right-angled at B, let the hypothenuse, A C, be 1045 feet, and the angle, A, 35° 56′; what is the length of the base and perpendicular?

Example 3.—A ship, from latitude 20° 30′ north, sailed N.W. by N. 235 leagues; what is her departure from the meridian, what her difference of latitude, and what the latitude come to?

Example 4.—Suppose one end of a rope, 350½ fathoms long, fixed at the top of an eminence, and the other end brought down to the plane below, so that its direction make with the plane an angle of 50° 40′; required the perpendicular height of the eminence, and the space of the level covered by the rope.

Problem II.—*Given the angles and one side, to find the hypothenuse and other side.*

Example 1.—In the right-angled triangle A B C, right-angled at B, let the angle at A be 35° 30′, and the side A B 294 feet; required the base, B C, and the hypothenuse, A C.

Geometrically.

Make A B = 294; at the point A make an angle of 35° 30′ from the line of chords; and from B raise the perpendicular B C. Measure B C and A C severally, by taking them in the compasses, and applying them to the scale from which A B was taken; then

By Calculation.

The hypothenuse, A C, being radius,

To find B C.

As cosine of A, 35° 30′	9.910686
is to sine of A, 35° 30′	9.763954
so is A B, 294	2.468347
to B C, 209.7	2.321615

To find A C.

As cosine of A, 35° 30′	9.910686
is to radius	10.000000
so is A B, 294	2.468347
to A C, 361.13	2.557661

The base being radius,

To find B C.

As cotangent of A, 35° 30′	10.146732
is to radius	10.000000
so is A B, 294	2.468347
to B C, 209.7	2.321615

To find A C.

As cotangent of A, 35° 30′	10.146732
is to cosecant of A, 35° 30′	10.236046
so is A B, 294	2,468347
to A C, 361.13	2.557661

The perpendicular, A B, being radius,

To find B C.

As radius	10.000000
is to tangent of A, 35° 30′	9.853268
so is A B, 294	2.468347
to B C, 209.7	2.321165

To find A C.

As radius	10.000000
is to secant of A, 35° 30′	10.089314
so is A B, 294	2.468347
to A C, 361.13	2.557661

Example 2.—In the triangle A B C, right-angled at B, suppose the base, B C, 374½ yards, and the angle, A, 52° 8′; required the other side, A B, and the hypothenuse, A C.

Example 3.—Suppose a ship sail S. W. by W. until she has made 409 miles of southing; required the distance sailed, and also how far she is west from the meridian of the place sailed from.

Example 4.—Observing the sun's altitude to be 30° 45′, and the shadow of a tree at the same time to fall 70 feet 3 inches distant from the tree, on the horizontal plane; what is the height of the tree, and what will be the length of a rope to reach from the extremity of the shadow to the top of the tree?

PROBLEM III.—*Given the hypothenuse and one side, to find the angles and the other side.*

Example 1.—In the right-angled triangle A B C, right-angled at B, let the hypothenuse, A C, be 350 feet, and the perpendicular, A B, 245 feet; required the angles, A and C, and the base, B C.

Geometrically.

Draw B C indefinitely toward C; at the point B make A B = 245, from a scale of equal parts, perpendicular to B C; and from the same scale take A C = 350; place one foot of the compasses in A, and the other, extending to the base, will cut it in C; then the angles are measured on the line of chords.

By Calculation.

The hypothenuse A C being radius,

To find angle C.

As A C, 350	2.544068
is to B A, 245	2.389166
so is radius	10.000000
to sine of C, 44° 25′ 37″	9.845098

To find B C.

As radius	10.000000
is to cosine of C, 44° 25′ 37″	9.853786
so is A C, 350	2.544068
to B C, 249.95	2.397854

The perpendicular, A B, being radius,

To find angle A.

As A B, 245	2.389166
is to A C, 350	2,544068
so is radius	10.000000
to secant of A, 45° 34′ 23″	10.154902

To find B C.

As radius	10.000000
is to tangent of A, 45° 34′ 23″	10.008688
so is A B, 245	2.389166
to B C, 249.95	2.397854

The base, B C, being radius,

To find itself.

As tangent of C, 44° 25′ 37″	9.991312
is to radius	10.000000
so is A B, 245	2.389166
to B C, 249.95	2.397854
As secant of C, 44° 25′ 37″	10.146214
is to radius	10.000000
so is A C, 350	2.544068
to B C, 249.95	2.397854

The side B C may also be found, independently of the angles, by means of the known property of a right-angled triangle; that the square of the hypothenuse is equal to the sum of the squares of the two sides.

For, since $AC^2 = AB^2 + BC^2$, it follows, that $BC^2 = AC^2 - AB^2 = (AC + AB) \cdot (AC - AB)$; and therefore $BC = \sqrt{(AC + AB) \cdot (AC - AB)}$

Or, $\text{Log. } BC = \dfrac{\text{Log. } (AC + AB) + \text{Log. } (AC - AB).}{2}$

From which B C is easily determined.

Example 2.—Suppose the hypothenuse of a right-angled triangle be 274.5 yards, and its base 196.25; what are the two acute angles?

Example 3.—Suppose a ship sailed between south and east 510 miles, and thereby made her difference of latitude, or southing, 315 miles; upon what course did she sail?

Example 4.—A ship sailed from latitude 49° 30′ north, between the south and west, 135 leagues, till, by a good observation, she is found in latitude 45° 15′; required the course on which she sailed.

PROBLEM IV.—*Given the base and perpendicular, to find the angles and hypothenuse.*

Example 1.—In the right-angled triangle A B C, right-angled at B, let the perpendicular, A B, be 650 feet, and the base, B C, 420 feet; required the acute-angles, A and C, and the hypothenuse, A C.

Geometrically.

Make B C = 420, taken from a scale of equal parts; from B raise the perpendicular A B = 650; from the same scale join A C to complete the triangle; then, with 60° taken from the line of chords, describe arches round the angles A and C; and their measures, applied to the same line of chords, will give the quantity of each angle.

By Calculation.

The base, B C, being radius,

To find angle C.

As B C, 420	2.623249
is to A B, 650	2.812913
so is radius	10.000000
to tangent of C, 57° 7′ 52″	10.189664

To find A C.

As radius	10.000000
is to secant of C, 57° 7′ 52″	10.265427
so is B C, 420	2.623249
to A C, 773.88	2.888676

The perpendicular A B being radius,

To find angle A.

As A B 650	2.812913
is to B C 420	2.623249
so is radius	10.000000
to tangent of A, 32° 52′ 8″	9.810336

To find A C.

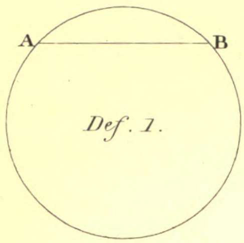
As radius	10.000000
is to secant of A, 32° 52′ 8″	10.075763
so is A B, 650	2.822913
to A C, 773.88	2.888676

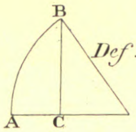
The hypothenuse, A C being radius,

To find itself.

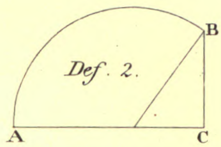
As sine of C, 57° 7′ 52″	9.924237
is to radius	10.000000
so is A B, 650	2.812913
to A C, 773.88	2.888676

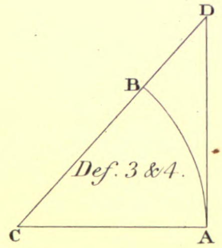
TRIGONOMETRY.





Def. 2.





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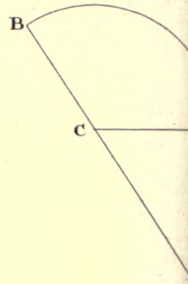
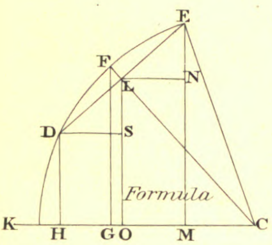
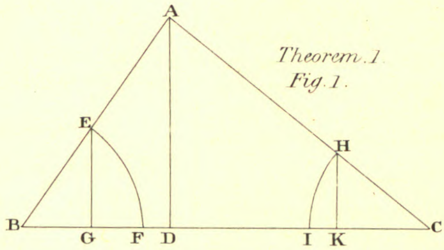
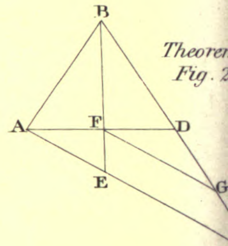




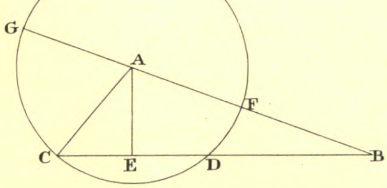
Theorem. 1
Fig. 1.



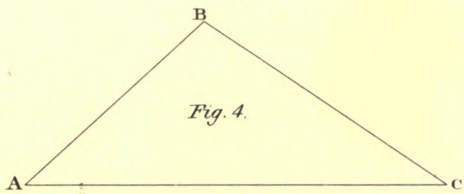
Theorem
Fig. 2



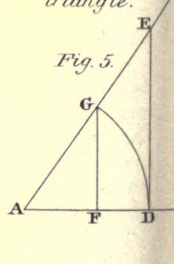
Theorem. Fig. 3.



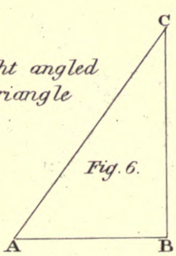
Obtuse angled triangle
Cases 1 2 3. 4.

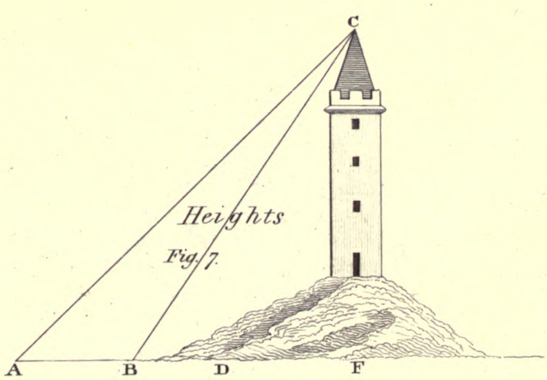


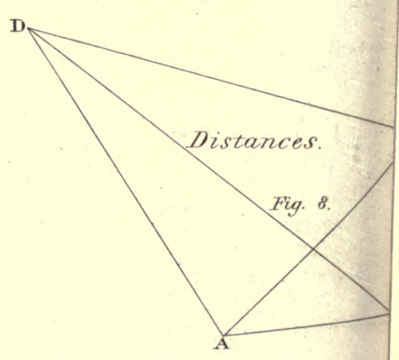
Right angled
triangle.



Right angled
triangle







As sine of A, 32° 52′ 8″	9.734573
is to radius	10.000000
so is BC, 420..............................	2.623249
to AC, 773.88..............................	2.888676

The hypothenuse may also be found, independently of the angles, for $AC = \sqrt{AB^2 + BC^2}$; from which AC is easily determined.

Example 2.—In the rectilinear triangle ABC, rectangular at B, suppose the side AB 495.45 yards, and the side BC 560.5 yards; what are the acute angles, A and C?

Example 3.—Suppose three towns so situated, that A lies $35\frac{3}{4}$ miles south from B, and C lies $50\frac{1}{4}$ miles west from B; the bearing of A from C, and of C from A are required.

Example 4.—When the sun shines, if a steeple, 196 feet high, project a shadow 237 feet 9 inches, on the horizontal plane, what is the sun's altitude at that time?

With respect to taking angles by the theodolite, when we are not obliged to cross zero, subtract the less number of degrees from the greater, which will give the angle. But if we are under that necessity, subtract the greater number from 360 and add the less to the remainder for the angle.

Thus, suppose the index to stand at 145° in looking at one point or object, and at 253° in looking at another; or, suppose first at 253°, and then at 145°, then, in either case, 253° — 145° = 108° for the angle contained between the two objects.

Again: suppose the index stands at 254°, and we are obliged to cross zero in order to come to the other object, and then the index to stand at 15°; or suppose the index stands at 15° in looking at the first object, and at 254° in looking at the second, then, in either of these cases, 360°—254° + 15° = 106° + 15° = 121°.

Figure 7.—To find the height of an inaccessible object.

Let C be the apex of a steeple, standing on the summit of a hill, and let AB be a straight line parallel to the horizon, so that the point C may be seen by a spectator from the points A and B, at a convenient distance from the eye above ground: let AB be 367 feet, the angle BAC = 44° 30′, and the angle CBD = 51° 20′; it is now required to find the height of the summit C, of the steeple above the horizon.

By subtracting 51° 20′ from 180°, a remainder of 128° 40′ is left for the angle ABC; and since the three angles of a plane triangle are equal to two right angles, the third angle ACB may be found by subtracting the sum of the two angles CAB and CBA from 180°, viz. 44° 30′ + 128° 40′ = 173° 10′ from 180°, which will leave a remainder of 6° 50′; so that in the right-angled triangle all the angles and one side are given, by which to find the side BC. Now, as the sides of a plane triangle are as the sines of the opposite angles,

	Thus,	or thus.
As sine of BCA 6° 50′....log. =	10‘924520 ..	9‘075480
is to sine of BAC, 44° 30′..log. =	9‘845662 ∴	9‘845662
so is AB, 367 feet........log. =	2‘564666 ..	2‘564666
to BC, which is 2,162 feet..log. =	3‘334848 ..	12‘410328
		9‘075480
		3‘334848

In the right-angled triangle AFC, right-angled at F, we have the hypothenuse, BC, and the acute angle, CBF: therefore, making the hypothenuse radius, the sides are as the sines of their opposite angles. Wherefore,

	Thus,	or thus.
As rad. sine of 90°......log. =	10‘...... =	10‘000000
is to sine of 51° 20′......log. =	9‘892536 =	9‘892536
so is 2,162 feet..........log. =	3‘334848 =	3‘334848
to CF, which is 1688 feet..log. =	3‘227384 ..	13‘227384
		10‘000000
		3‘227384

Figure 8.—To find the distance between two inaccessible objects.

Two inaccessible objects, D and C, are both visible from each of the two places A and B, whose distance is known, and each of which is visible from the other. Required the distance CD.

Observe the $< CAD = a$, and $< DAB = \beta$ from A,
and $< DBC = a$, and $< CBA = \beta$ from B.

Let $AB = a$,

Then, if we can find DA and AC, or DB and BC, the problem is reduced to this; find the third side when the other two sides and the angle included by them are given.

$$\text{Now, in } \Delta\ CBA, \frac{CA}{AB} = \frac{\sin.\ CBA}{\sin.\ ACB} = \frac{\sin.\ \beta}{\sin.\ ACB.}$$

$$\text{But } ACB = 180\ (ADC + CAB) = 180 - (\beta + a + \beta)$$

$$\therefore \sin.\ ACB = \sin.\ (a + \beta + \beta)$$

$$\therefore CA = \frac{a \sin.\ \beta}{\sin.\ (a + \beta + \beta)}.$$

$$\text{and in } \Delta\ DBA \frac{DA}{AB} = \frac{\sin.\ ABD}{\sin.\ ADB} = \frac{\sin.\ (a + \beta)}{\sin.\ ADB}$$

$$ADB = 180 - (ABD + BAD) = 180\ (a + \beta + \beta);$$

$$\therefore \sin.\ ADB = \sin.\ (\beta + \beta + a);$$

$$\therefore AD = a \frac{\sin.\ (a + \beta)}{\sin.\ (\beta + \beta + a)}.$$

And thus knowing AC and AD, and $<$ CAD, we may, by means of a subsidiary angle compute CD.

TRILATERAL, (from the Latin *tres*, three, and *latus*, a side,) a plane figure, or solid angle, having three sides.

TRIM, (from the Saxon *trimman*, to build,) in general, signifies to fit; as, *to trim up*, is to fit up.

TRIMMED: when a piece of work is fitted between two others previously executed, it is said to be *trimmed in* between them; thus, a partition wall is said to be trimmed-up between the floor and the ceiling; a post between two beams, a trimmer between joists, &c.

TRIMMED, is also applied to the putting of anything into shape, by cutting it away by degrees until it be of the proposed form.

TRIMMED-OUT, an expression applied to the trimmers of stairs, when brought forward to receive the rough strings.

TRIMMER, a small beam, into which the ends of several joists are framed. Beams of this kind are either stair-trimmers, hearth-trimmers, or tail-trimmers.

TRIMMING JOISTS, the two joists into which each end of the trimmer is framed. The distance of the trimming-joists, when employed in fire places, must be such as to take in not only the fire place, but the flues on each side of it. Trimming-joists ought to be stronger than the other joists, on account of the support they have to give.

TRINE DIMENSIONS, the dimensions of a solid, including length, breadth, and thickness; the same as *three-fold dimensions*.

TRIPARTITION, (from the Latin *tres*, three, and *pars*, a part,) the division of a number by three.

TRIPOD, or Tripos, (from τρεῖς, *three*, and πȣς, *a foot*,) in antiquity, a three-legged seat from which the priests delivered their oracles.

TRIPTIC, or Triptych, a tablet in three divisions, of which the two outer fold over the centre one, by means of hinges, and form a cover to it. Triptics are employed to adorn the altars of churches over which they are placed; when open, they exhibit a painting, or representation, of some sacred subject.

TRISECTION, (from the Latin *tres*, three, and *seco*, to cut,) the division of anything into three equal parts; as the trisection of an angle, &c.

TROCHILUS, (from τροχος, *a wheel*,) an annular moulding, of which the section through the axis of the column is concave; more commonly denominated *scotia*. Its situation is generally between two tori. *See* Scotia, and Mouldings.

TROCHOID, (from τροχος, *a wheel*, and ειδος, *shape*,) a figure described by rolling a circle upon a straight line, with a pin or point in the circumference upon a fixed plane, in, or parallel to, the plane of the moving circle. *See* Cycloid.

TROPHY, (τροπαῖον, from τροπὴ, *to put an enemy to flight*,) in architecture, an ornament representing the trunk of a tree, charged around its circumference with military weapons, colours, and instruments of music.

TROUGH, (from the Saxon *troh*,) a vessel in the form of a rectangular prism, open on the top, having five sides enclosed for holding water.

Trough-Gutter, a gutter in the form of a trough, placed below the dripping eaves of a house, in order to convey the water from the roof to the vertical trunk, or pipe, by which it is discharged. They are only used in common buildings and out-houses. In buildings of the better class, the water-way is formed behind a blocking-course.

TROWEL. *See* Tools.

Trowel-point, a method of enrichment, applied to some mouldings of Norman and Byzantine character, such as to give them the appearance of having been indented with the point of a trowel.

TRUGG, a tray to carry mortar in.

TRUNCATED, (from the Latin *trunco*, to cut short,) signifies that quality of a solid by which the upper portion is cut off parallel to the base of the solid. Thus the frustum of a pyramid, cone, sphere, &c., is said to be truncated.

Truncated Cone, one which has the upper part cut off the frustum of a cone. *See* Cone.

Truncated Pyramid, one which has the upper part cut off; the frustum of a pyramid.

TRUNK, (from the French *trompe*, a long tube,) a vessel open at each end for the discharge of water, rain, &c.

Trunk, (from the Latin *truncus*, the body of a tree,) that part of a pilaster which is contained between the base and the capital.

TRUSS, (from the French *trousse*,) a frame of timbers so disposed, that if suspended at two given points, and charged with one or more weights in certain others, no timber would press transversely upon another, except by timbers exerting equal and opposite forces.

When one or more exterior timbers of a frame, suspended from two given points, are propped by the disposition of interior timbers at certain points in each of the exterior pieces, so as to resist the pressures of several weights, each acting upon one of the said points, without any tendency to bend or break any timber employed in the construction; the frame is called *a truss*, and each of the exterior timbers so propped in their length, are said to be *trussed*.

It is a principle in every such frame to have as few quadrangles as possible; all the interstices, or openings, should be triangles; and the intersections of the timbers should be as direct as possible, because oblique pressures exert prodigious strains, which require strong timbers of large scantlings to withstand them, and these would press upon the abutments so much as to make the truss sag by the compression of the intermediate joggles. Wherever two oblique thrusts press to the same point, no transverse timber should be interposed; for the shrinking of the transverse piece will also make the truss liable to sag. A truss of any extension may be made with a series of triangles composed of very short timbers; but then it will be necessary that every two adjoining triangles have the same common side, otherwise transverse strains will be produced. A truss may also be made of very short timbers, by making them balance each other by their position only.

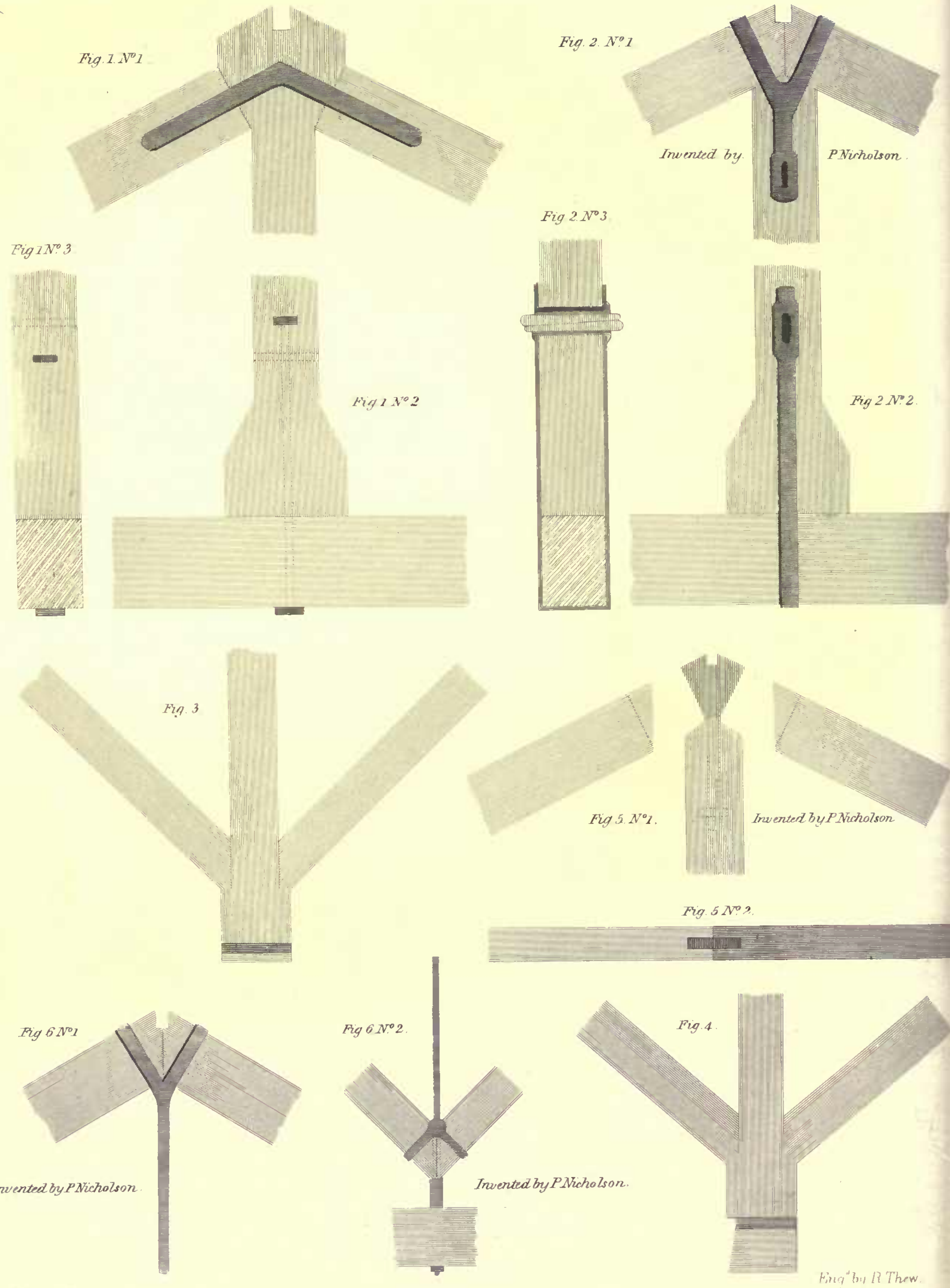
Trusses are used for several purposes in building, as in partitions for supporting the floor above, to prevent it from communicating its pressure to the floor below, which may also be hung to the truss; particularly when there are neither bearing partition, nor trussed girders, which are shallow trusses, put between the ceiling and the floor, in order to stiffen the platform for walking upon. A roof of any considerable extent cannot be executed without one or more trusses; nor yet the centre of a bridge, or large vault.

Trusses employed in roofs and centerings, are placed from eight to ten feet distance in the clear, and in equidistant vertical planes. They may also be employed in the inclined sides of a roof, having their plane parallel to that of the covering, to counteract the pressure of the rafters downwards, and keep the lateral force thereby occasioned from acting upon the walls.

In all regular trusses, inclined timbers stand in pairs for mutual resistance, or counteraction. The names of the timbers which most frequently occur in trussed work are as follow: all inclined timbers are called *braces;* braces which either meet, or have ther direction to a point below their extremities, are called *struts;* hence every strut is a brace, but every brace is not a strut; those braces which form the exterior part of the truss, are called *principal rafters:* braces under the principal rafters, and parallel to them, are called *principal braces*, *discharging braces*, *auxiliary rafters*, or *cushion rafters*. Beams have various names, according as they have a higher or lower situation in the truss, or according as they perform the office of a tie or straining-piece; a beam acting as a tie, is therefore called a *tie-beam;* of which description it is always the lowest; a beam extending above the tie-beam, between a pair of principal rafters, is called a *collar-beam*, or simply a *collar*, or *straining-beam*, which name indicates its use; when a beam terminates the upper part of a truss, it is called *a camber-beam*, because it is made to slope in a small degree both ways from its middle towards each extreme on the upper edge; beams placed above the tie-beam, between a pair of posts, are called *straining-beams.* Posts when employed in trusses, stand always in pairs, except there be one in the middle: every such post is called by the general name of *truss-post:* when the head of a truss-post stands at the apex of a pair of principal rafters, it is called *the middle-post*, *crown-post*, or *king-post:* a pair of truss-posts, each of which is placed equidistant from the middle or ends of the truss, are called *side-posts:* when there is no crown-post in a truss, but one or more pairs of side-posts, the pair next the middle are called *queen-posts.* The annexed Plate shows the various parts of a truss in detail, together with various methods of connecting them together.

TRUSS.

PLAT



Drawn by P Nicholson

Eng^d by R Thew.

Figure 1.—No. 1. The top of the king-post, with part of the principals, and a strap connecting the three members.

No. 2. The method of joining the king-post with the tie-beam, and of screwing it up.

No. 3. The edge of the king-post, and a section of the tie-beam.

Figure 2.—Another method of joining the principals, king-post, and tie-beams.

No. 1. Parts of the principal rafters and king-post secured together by a branched strap.

No. 2. The method of strapping the king-post and tie-beam.

No. 3. Parts of the king-post and tie-beam, showing the method of wedging them.

Figure 3.—The method of forming a joggle, when the thick part at the bottom of the king-post is not sufficient for receiving the shoulder of the struts at right angles to their directions.

Figure 4.—A similar method, with a little variation.

Figure 5.—No. 1. Another method of joining the principals and king-posts by means of an iron dovetail, which is received into a mortise in the head of each principal.

No. 2. View from the top of the principals, showing the head of the wedge.

Figure 6.—Method of securing the tie-beam and principals when the king-post is made of an iron rod.

No. 1. The principals, with a part of the iron king-rod, and the hanging up of the tie-beam.

No. 2. The struts fixed to the iron king-rod, and the hanging up of the tie-beam.

TRUSS PARTITION, a partition with a truss consisting generally of a quadrangular frame, two braces, and two queen-posts, with a straining-piece between the queen-posts, opposite the top of the braces.

TRUSS POSTS. *See* TRUSS.

TRUSSED BEAM, TRUSSED GIRDERS, or GIRDING BEAMS. *See* GIRDERS.

TRUSSED-RAFTER-ROOF, a roof which has no principal trusses, but which is composed entirely of trussed rafters. Such roofs are not uncommon in churches of the 12th or 13th centuries; they have a very pleasing perspective effect.

TRUSSELS, or TRESSELS, (from the French *tresteau*,) props for the support of anything, the under surface of which is horizontal; each trussel consists of three or four legs, attached to a horizontal part. When the trussels are high, the legs are sometimes braced. Trussels are much used in building for the support of scaffolding, and by carpenters and joiners for ripping and cross-cutting timber, and for many other purposes.

TRUSSING PIECES, those timbers in a roof that are in a state of compression.

TRY, (from the French *trier*, to bring to a test,) to plane a piece of stuff by the rule and square only.

TUBE, (from the Latin *tubus*, a pipe,) a substance perforated longitudinally, generally quite through.

TUBULAR BRIDGE. *See* IRON BRIDGE.

TUDOR ARCHITECTURE, considered in a general sense, is that style of architecture which prevailed during the Tudor dynasty. It is necessary, however, that the application of the term should be somewhat limited; for it cannot be expedient to adopt one title for so many and widely-different styles as those prevailing during that period; amongst which may be enumerated the late Perpendicular Gothic, the mixed or Elizabethan style, in which Italian details were introduced in buildings otherwise Gothic, and the Italian as practised by Inigo Jones and his cotemporaries.

As to the precise limitation of the term, there seems to be but little agreement amongst writers upon the subject; some applying it to buildings of the late Perpendicular style, in which ornamental details were profusely introduced, and which is, by other writers, designated as Florid Gothic. Under this signification, Ecclesiastical as well as Domestic and Civil structures are included; and of these, Henry VII.'s chapel, at Westminster, forms a characteristic example. The application of the term is strictly correct with respect to chronology, but is rather inconvenient as regards systematic arrangement, based upon peculiarities of style; and, besides this, there are so few important examples of this particular class, as scarcely to warrant the formation of a distinct style; they may be fairly considered as modifications of the Perpendicular.

Other writers would divide the style thus denominated into two divisions, Early and Late Tudor, the former term including the buildings just alluded to, and the latter being applied to those into which Italian details are introduced, and which are otherwise distinguished as Elizabethan. This plan we shall now adopt to a certain extent, excluding, however, the ecclesiastical buildings, which we include under the Perpendicular style, and conceding the term Tudor entirely to buildings of a domestic character. This arrangement, we must confess, is not without its objections; and we are inclined to think that the distinction between the first and second class of buildings is sufficiently great to entitle them to distinct designations, and, therefore, that the title of Elizabethan may be appropriately applied to the latter, to mark out a peculiar and separate style. We shall have before us, then, for consideration, the Early Tudor, and the Elizabethan or Late Tudor, styles.

The reign of Henry VII. introduced a new mode of living, and with it a new style of domestic architecture. With his marriage, the feuds between the houses of York and Lancaster came to an end, and a long season of internal peace seemed about to follow the troublous times of the preceding monarchs. Previous to this period, domestic architecture can scarcely be said to have had any existence; the mansions that had been erected were rather military than domestic, more like fortresses than dwellings. Now, however, with a prospect of peaceful times before them, men began to look for convenience rather than strength in their private mansions, and elegance began to be preferred to security. The halls of this and the following reign contained little of the fortified character of their predecessors beyond the battlements with which the walls were surmounted, and these, indeed, appear to have been preserved more for ornament than use: the thickness of the walls was reduced, the size of the windows enlarged, and the other arrangements influenced by the requirements for comfort and convenience rather than of security.

We know little of Henry VII.'s buildings of this class; of the palace erected by him at Shene or Richmond, not a vestige now remains, but some particulars concerning it are given in the Survey of 1649, when it was offered for sale by the Commissioners of Parliament. It abounded with bay-windows of capricious design, with rectangular and semicircular projections: and was adorned with many octagonal towers, surmounted with bulbous cupolas of the same plan, having their angles enriched with crockets.

Henry VIII. was not only a great builder himself, but encouraged his nobles to follow his example; so that there was no lack of examples in his reign. Henry, himself, is said to have built or repaired the following mansions:—

Beaulieu, or Newhall, Essex.

Hemsdon, Herts, originally built by Sir John Oldhall, temp. Edward IV.

Ampthill, Bedfordshire.

Nonsuch, Surrey.

York Place, Whitehall, Westminster.

Bridewell and Blackfriars, London, for the reception of the emperor Charles V.

St. James's, Westminster.

Kimbolton, Huntingdonshire, the jointure of the divorced Queen Catherine of Arragon.

Sheriff Hutton, Yorkshire, given for the residence of Henry, Duke of Richmond, the king's natural son.

King's Langley, Herts.

When the monarch set himself so vigorously to work in building and repairing, it is no matter of surprise to see his courtiers following in the same steps; and, accordingly, we find that many and sumptuous were the mansions erected by them. Foremost in such works stands Wolsey, amongst whose principal buildings may be enumerated Hampton Court Palace; York House, afterwards Whitehall; his episcopal residence at Esher, Surrey; the college of Christchurch, Oxford, and another at Ipswich. Edward Stafford, Duke of Buckingham, erected a magnificent palace at Thornbury, Gloucestershire; Charles Brandon, Duke of Suffolk, one at Grimsthorpe, Lincolnshire; the Duke of Norfolk, and his son, the Earl of Surrey, those of Kenninghall, Norfolk, and Mount Surrey, near Norwich. Amongst others may be mentioned Haddon Hall, Derbyshire; Coudray, Sussex, destroyed by fire in 1793; Hever Castle, Kent; Gosfield Hall, Essex, perfect; Hengreave Hall, Suffolk, perfect; Layer Marney, Essex, now in ruins; Raglan Castle, Monmouthshire, in ruins; Hunsdon House, Herts, rebuilt; South Wingfield, Derbyshire, dilapidated; Hill Hall, Essex; Wolterton, East Barsham, Norfolk, in ruins.

The plan of the larger mansions of this period was quadrangular, comprising an inner and base court, between which stood the gate-house. On the side of the inner court, facing the entrance, the principal apartments were placed, amongst which may be enumerated the hall, the chapel. the great chamber and dining-room, and were connected with a gallery for amusements running the whole length of another of the sides of the quadrangle. Several examples of this description are to be found, of which Hannaker House, near Midhurst, Sussex, will give us a good idea; this mansion was built round a court, with the entrance under an embattled gate-house, flanked by small octagonal towers on the south; a square tower stood at the south-east angle; the chapel and other apartments on the east, and the hall and principal rooms on the north. In mansions of less pretensions, the gate-house stood in advance of the building, connected with it only by mantle walls, as at East Barsham, Norfolk.

The materials of which such buildings were constructed were either brick or stone, and sometimes both combined, the main building being of brick and the dressings of free-stone; this practice was very common. Bricks of two colours, usually black and red, and sometimes highly glazed, were employed to variegate the surface, the darker-coloured bricks being disposed in the form of lozenges and other figures; and in some instances the brick-work was rendered in ornamental plaster, as at Nonsuch. Moulded brick-work and terra-cotta were also employed for decorative purposes; medallions, or busts of terra-cotta were frequently inserted in small circular and other-shaped cavities in the walls, and heraldic devices, cognizances, &c. were dispersed in various parts of the building.

The details and style of ornament adopted in those houses are, for the most part, the same as those to be found in ecclesiastical buildings of the same period, the principal difference consisting in the different composition and arrangement of the various parts. Amongst the more striking peculiarities may be reckoned the gate-houses, the numerous turrets and chimneys, the beautiful bay and oriel windows, the roof, ceilings, and panelled wainscot round the internal walls.

The gate-houses were very prominent features in these buildings, of lofty elevation, containing several apartments; they seem to have received a great deal of attention as to design, &c., and were more beautifully ornamented than almost any other part of the building. They were mostly placed in the centre of one of the sides of the court, and were usually embattled, and flanked by more lofty turrets at the angles. Stair-case turrets, rising above the general elevation, served to relieve the general outline, and of these there were frequently several in the angles and other parts of the court as occasion demanded; the gables, also, were often flanked with turrets. Grouping well with these turrets, the heavy masses of chimneys stood out in bold relief, and gave great character to the elevation. Previous to this date, chimneys had been rarely used, and, when employed, had been made of secondary importance in the general design; but now they not only began to be extensively used, but formed very prominent objects in the elevation; and received, probably, as much attention in the design as any other part of the edifice. They were of lofty proportions, circular or octagonal in plan, and usually clustered together in groups of two, four, or more. The shafts were ornamented with various devices, as roses, fleur-de-lis, &c., moulded on the surface; at other times they were carved with spiral flutings, and ornamented in an infinite variety of ways; the tops, or caps, as they may be called, were richly moulded, and, indeed, the inventive powers seem to have been exhausted in the multitude of designs for the enrichment of this member of the edifice. The projecting windows form a very characteristic feature of the style: they are of two kinds, those which rise immediately from the level of the ground being termed *bays;* and those which project out in the upper part of the building, being corbelled out so as to overhang that below, are termed *oriels*. Both kinds of windows are erected on plans of various figures, but more especially upon those of a rectangular, semi-octagonal, or semi-circular plan. Sometimes they are restricted to a single floor, while at others they are carried up through several. The bay-window is very common in large halls, where it is found at the upper end forming a recess at the side of the dais; sometimes we find a bay on either side of the dais; such windows were usually loftier than the others, being carried from about three feet from the ground to the ceiling. Oriel windows are principally confined to the buildings of Henry VII.'s and the early part of Henry VIII.'s reign, but bays were common in the reign of Elizabeth.

Many of the great halls of this period had open timber-roofs, of bold construction and beautiful design: they are mostly what are termed hammer-beam roofs. *See* Roof. The most remarkable are those erected by Cardinal Wolsey, at Hampton Court Palace, and at Christ Church Oxford, both of which are 40 feet in width: many others are to be seen in the halls of colleges at Oxford and Cambridge, and in the inns of court in London. The ceilings were usually of timber, divided into compartments by the main timbers of the floor above, and sometimes into smaller compartments by the joists, the timbers being either moulded or chamfered on the edge. Sometimes the flooring-timbers are concealed by panels with ribs of oak, which divide the surface into compartments of various forms, the ground between the ribs being either of wood or plaster. At the intersections of the ribs, bosses of foliage and devices in wood or plaster were frequently introduced.

The walls of the principal chambers were often lined with carved wainscoting in panels, which were small, and mostly of what is termed the linen pattern; sometimes they were enriched with carved work in the shape of ciphers, cognizances, chimeras, mottoes, &c.

The windows of this style are usually square-headed, divided into lights by mullions and transoms, the latter being frequently enriched with a series of small battlements on the top, and the lights arched and cusped.

The following examples will serve to afford some idea of the general character of the buildings of this period :—

Hampton Court Palace, commenced in 1514, was erected by Cardinal Wolsey; it is a very magnificent building, comprising no less than five courts. In the centre of the entrance-front is a square tower, flanked by an octagonal turret at each angle, which rises above the general elevation of the tower; in the lower story is the grand gateway, with obtuse-pointed or Tudor arch, over which in front and rear is a rich oriel window. The walls are crowned by battlements of open work, and each turret is terminated by an octagonal roof, the contour being a curve of contrary flexure.

On the right and left of the tower the buildings are partly modernized, but at each extremity is one of the old gables, the raking cornices of which are ornamented with figures of griffins. From these extremities wings project towards the front at right angles to the body of the building. The first quadrangle, which is entered by the above gateway, consists of the dwelling-house, the walls of which are crowned with embattled parapets; the windows are square-headed, and the doors covered by plain arches. In the centre of the side of this quadrangle, which is opposite to the grand entrance, is another tower similar to, but smaller than the first, and flanked by rectangular battlemented turrets; through this tower is an arched passage leading into the second quadrangle, and over it an oriel window.

The second quadrangle is smaller than the first, the left side being occupied by the grand hall, which is covered by a lofty roof; the walls are strengthened by buttresses, and the windows, which are pointed, are divided by mullions carried perpendicularly to the head. The right-hand side of the court is occupied by a colonnade designed by Sir Christopher Wren. In the third side is a tower in a line with the two previously mentioned, containing a passage leading to the third quadrangle, the ceiling of which is enriched with delicate fan-tracery. The third quadrangle is surrounded by an arcade supporting the fronts of the buildings; the walls of which are of red and dark brick set in diamond patterns, and are crowned with plain and perforated battlements. This court was modernized in the reign of William III. The windows of the ancient building are distributed without respect to symmetry; the frames are rectangular, and in general of greater width than height; they are divided vertically by one or more mullions, and some by transoms running across at about mid-height; the lights are obtusely arched at the head.

The timber-roof of the hall is of very good construction, and of beautiful design. Each frame is formed by two inclined principals, separated by a straining-piece at top, and tied together at about mid-height by a collar-beam; a hammer-beam at the bottom of each principal projects for about a quarter the entire width of the hall, and is supported at the extremity by a curved brace resting on a wall-post, which again is supported on a corbel at some distance below the top of the wall. The extremity of the hammer-beam carries a pendant, and above it springs a curved rib which meets one from the opposite side of the roof, immediately under the centre of the collar-beam, and thus forms an obtuse-pointed arch. The contour of the roof, as seen from below, will therefore present the appearance of a trefoil; it is enriched with pierced panelling, and other carved work.

Thornbury Castle, Gloucestershire, was commenced about 1511; the parts at present existing, having been built in the reign of Henry VIII., by Edward Stafford, Duke of Buckingham, who was engaged on it for ten years, but was not suffered to live to complete it. "The towers at the entrance to the inner court are bold in design; the projecting machicolations, still preserved, are very good examples. The bay-windows of the great hall are beautifully composed; the plans of the upper and lower parts vary, the one being a combination of five semi-circles of four lights in each, whilst the latter is angular, and more solid in construction."

The great oriel window is very beautiful, as are also the enriched chimney-shafts, fire-places, &c., illustrations of which will be found in *Pugin's Examples.*

The following description of a mansion of this period, at Midhurst, in Sussex, is given by Warton :—"We enter a spacious and lofty quadrangle of stone, through a lofty Gothic tower with four angular turrets. The roof of the gateway is a fine piece of old fret-work. There is a venerable old hall, with a noble oak-raftered roof, and a large high range of Gothic windows. Opposite the screen is the arched portal of the buttery. Adjoining the hall is a dining-room, the walls painted all over (as was anciently the mode soon after the beginning of the reign of Edward VI.,) chiefly with histories (out of perspective) of Henry VIII.; the roof is in flat compartments. A gallery with window-recesses, or oriels, occupies one side of the quadrangular court. A gallery on the opposite, of equal dimensions, has given way to modern convenience, and is converted into bed-chambers. In the centre of the court is a magnificent old fountain, with much imagery in brass, and a variety of devices for shooting water. On the top of the hall is the original louvre or lantern, adorned with a profusion of vanes. The chapel, running at right angles with the hall, terminates in the garden with three large Gothic windows."

Hengrave Hall, Suffolk, was built, as we learn from an inscription on the outside of the curious oriel window, in 1538. It consists of an open court surrounded on three sides by a gallery, communicating with all the apartments, and lighted by windows looking into the court: on the other side is the hall, (34 feet by 25,) which is lighted by a bay and two other windows, also looking into the court. The principal part presents a very picturesque appearance, measuring about 160 feet in length. The building is of brick and stone, and the gateway, which is in good preservation, is of peculiar design.

The manor-house at East Barsham, Norfolk, is composed almost entirely of bricks: it was commenced in the reign of Henry VII., and finished in that of his successor. The following description is given by Mr. Bury :—"The walls of the principal front are nearly on one plane, being broken only by the porch in the centre; and octagonal turrets of different sizes are so disposed as to give a variety of outline to the combination. The hall is to the left of the porch by which it is entered; the great parlour and principal apartments are beyond, or at the back of it. The windows are large, and must have given the rooms a cheerful appearance. The building consists of only two stories, except in one part, where another is added as a tower. The upper string-courses are bold in moulding, and rich in cast ornaments and panels; these are surmounted by moulded battlements with beautiful traceried panels. The stack of ten chimneys at the west end of the hall, and the turret-terminations, are fine in design and execution. "The building, which measures 140 by 58 feet, has a gate-house tower, about 40 feet in front of the porch (a paved court intervening;) on this, if possible, a still greater degree of moulding and enrichment has been bestowed; comprising figures, armorial bearings, battlements, and panelling, which are all executed in brick in a surprising manner."

Elizabethan, or Late Tudor.—During the whole of the above period, the influence of Gothic art had been disappearing throughout the continent. As early as the middle of the fifteenth century, Brunelleschi had introduced that partial revival of the classical styles which has been denominated Italian, from the name of the country where it first made its appearance, and where it afterwards chiefly flourished. This revival had been practised throughout the continent, ere it reached this country, where the Gothic maintained its position for a very long time, and even after the introduction of the Italian, gave place but slowly, and not without a severe and lengthened struggle. Our constant intercourse with the continent during the reign of Henry VIII., must have had considerable influence on the arts in this country, the effects of which are evident in the later buildings of this reign; in the hall of Hampton Court Palace are introduced details of Italian design, and in many other buildings of the same or later date. The next reign brings us a step further in this direction. John of Padua, an Italian architect, was introduced into England under the patronage of the protector Somerset; and from his designs were erected the mansions of Sion House, and Longleat, Wilts. In the reign of Elizabeth, however, the Italian style of art began to make more rapid strides, and assume a position of equality with the Gothic. Early in her reign, the treatises of Lomazzo and Philibert de Lorme were translated into English, and a work upon architecture was published by John Shute, an artist and architect who had been sent out to Italy by Dudley, Duke of Northumberland. From this and other circumstances, it is not difficult to account for the change which came over architecture during this period. This change, however, was rather in matters of detail than in general construction, although a considerable improvement would seem to have been made in the internal arrangement of houses, which were altogether more commodious. Up to this time, the mansions of the nobility were usually only one story in height, and in plan greatly deficient in the requirements incidental to the improved social condition of the country; but now we have lofty buildings, and considerable skill exhibited in the disposition of the apartments; indeed, we have ample evidence that no building was now undertaken, without the previous arrangement of a well-considered plan.

The plans of buildings of this reign were of varied character, sometimes quadrangular, having three sides surrounded with buildings, with the portico in the centre, the quadrangles being usually surrounded with an open arcade or corridor. This, however, was but one plan out of many others, some of which were exceedingly curious; for instance:—Longford Castle, Wiltshire, was in plan similar to the ecclesiastical device on which the doctrine of the Trinity was illustrated; it was a triangular court surrounded with buildings, having a circular tower of the same height as the other parts of the building, at each angle, from each of which in the interior was carried a row of buildings meeting in the centre.

A mansion, designed by John Thorpe, the architect, for his own use, was elevated on a plan which represented his own initials in monogram; and that this was designedly so arranged, we learn from the epigraph appended to his design, which is as follows:

"Thes 2 Letters I and T
"Joyned together as you see
"Is meant for a dwelling-house for mee" "John Thorpe."

The principal deviations in matters of construction from the buildings of the preceding era, consist in the multiplication of bay-windows; the addition of large projecting porticoes richly ornamented; the importance given to the halls and staircases, which became very spacious and magnificent, often occupying a large proportion of the mansion; the increased length and spaciousness of the galleries, which frequently exceeded 100 feet in length; the increase of lighting area, the windows being greatly enlarged in size, having sometimes three or four tiers of openings; the magnificence of the fire-places, which frequently reached to the ceiling, and were enriched with carving and sculpture, in the shape of heraldic devices, &c.; the beautiful and richly-moulded plaster ceilings, with deep cornices, also of plaster: the walls were either panelled or whited, and ornamented with labels containing poetry, maxims, &c. Another peculiarity is observed in the large and imposing flights of steps, and in the noble terraces in front of the mansions: these were raised one above the other, approached from one to the other by broad flights of steps, and defended on the edge with richly-perforated parapets or balconies.

The general characteristic of the style is manifested in the admixture of Italian details with Gothic features and designs. Quasi-classic columns and pilasters are frequently introduced, but they are often ill-proportioned and very inaccurately and rudely profiled; they are frequently banded at intervals in their height with circular or square blocks, which when square, are mostly ornamented with diamond or jewel-shaped projections, a species of ornament which is of frequent general application: at other times the shafts were decorated with grotesque ornaments of various kinds, flutings, &c. Arcades, with circular arches, are also common, the space from pier to pier being often of an extravagant width, their height sometimes running up into the entablature, which member, again, is rarely or never found continuous or unbroken, and it is frequently frittered away with scroll and other ornaments. The bay-windows, parapets, and gables are usually terminated by perforated crestings of scroll or geometrical pattern; this perforated work and scroll ornament in general, as also the lozenge and other ornaments, standing in relief upon the surface to be enriched, are very profusely employed, and may be considered decidedly characteristic of the style. The shell-roofed niche and caryatid columns are also frequent. The plaster ceilings were usually of very elaborate design, and very richly moulded; they form a very praiseworthy feature in buildings of this date. Heraldic devices and grotesques were not unfrequently employed in general ornamentation.

It would be superfluous to enter into a more detailed description, for the style altogether is so abnormal and intricate, that a full description would necessitate illustrations of almost every example. Very contrary opinions have been held respecting the merit of this style; for our own part, while we must condemn it as being unscientific in construction, and impure, if not barbarous, in taste, at the same time we are inclined to allow it a great deal of credit for its picturesque appearance. It certainly will not stand the test of severe criticism.

Amongst the more noted architects of this time we may mention the following:—Robert Adams, Surveyor of Works to Elizabeth; John Shute, author of a book upon architecture

Bernard Adams; Lawrence Bradshaw; and John Thorpe, who has left us a book of his designs, which are very numerous: he was engaged upon a great many works, of which the principal are—Holland House, Middlesex; Longford Castle, Wilts; Wollaton Hall, Notts; and Audley End, Essex. Gerard Christmas was engaged upon Northumberland House, as was also Moses Glover and Bernard Jansen; of whom the second was further employed in the completion of Sion House, and the latter in the erection of Audley Inn. Robert and Huntingdon Smithson, father and son, were engaged upon Wollaton House, Notts, and Bolsover, Derbyshire. Thomas Holte was architect of the Public Schools, and of the quadrangles of Newton and Wadham Colleges, Oxford.

Several mansions of this style were erected or completed during the reign of James I., and even the early works of Inigo Jones were in this style, as, for instance, the quadrangle of St. John's College, Oxford. The pure Italian, however, was rapidly gaining the ascendancy, and was destined to be permanently introduced by this same man in the early part of the 17th century.

The following is a list of some of the principal mansions belonging to this period of architecture. As a description, apart from illustrations, would be of little use, we beg to refer the reader to a beautifully-illustrated work upon the subject by Mr. Nash, entitled 'Mansions of England in the Olden Time.'

Name.	Date.	County.	Present State.
Basinghouse	1560	Hants.	In ruins.
Gorhambury	1565	Herts.	Do.
Knowle	1570	Kent	Perfect.
Penshurst	"	Kent	Do.
Kenilworth	1575	Warwick	In ruins.
Hunsdon	"	Warwick	Rebuilt.
Burleigh	1577	Lincoln	Perfect.
Longleat	1579	Wilts.	Do.
Westwood	1590	Worcester	Do.
Hardwick Hall	1597	Derby	In ruins.
Holland House	1607	Middlesex	Perfect.
Bramshill	"	Hants.	Do.
Castle Ashby	"	Northampton	Do.
Summer Hilt	"	Kent	Do.
Charlton	"	Wilts.	Restored.
Hatfield	1611	Herts.	Perfect.
Longford Castle	1612	Wilts.	Do.
Temple Newsham	"	Yorkshire	Do.
Charlton	"	Kent	Do.
Bolsover	1613	Derby	Dilapidated.
Audley Inn	1616	Essex	Perfect.
Wollaton	"	Notts.	Do.

There is one class of houses which reached its zenith during the reign of Elizabeth, and which deserve some mention in this place: we allude to the half-timbered houses. They were composed of timber frame-work, and present the appearance of brick-nogging, the spaces within the frame being plastered: the timbers are arranged sometimes vertically, with horizontal beams at intervals, and this arrangement has a very pleasing appearance; at other times the secondary timbers were ranged diagonally, or disposed so as to form geometrical figures, such as squares, triangles, diamonds, &c., and, not unfrequently, curved timbers were introduced. Such houses are peculiar in having the upper stories of larger dimensions and projecting over the lower ones, and are remarkable for their barge-boards overhanging the gables. These are frequently of very beautiful design, and delicately carved; they have a singularly pleasing appearance. Wooden corbels, in the shape of grotesque figures, are also common. The plaster-work was frequently ornamented with devices of various kinds, either in relief or recession.

The counties of Cheshire and Shropshire were peculiarly noted for country mansions of this class; and many examples are to be found in the towns of Chester, Shrewsbury, Leicester, Warwick, and Ipswich. They invariably present a very picturesque appearance. The following is a list of some of the principal examples; and, for further information respecting them, we refer the reader to a work upon the subject by Mr. Habershon:—

The Oaks, West Bromwich:	... date ...	Henry VIII.
Elmley Lodge, near Droitwich	"	Charles I.
Old House, Market Place, Preston	"	Do.
Bramall Hall, near Stockport	"	Elizabeth.
Hop-pole Inn, Bromsgrove.		
Pitchford Hall, near Shrewsbury.		
Salwarp Court, near Droitwich.		
Samlesbury Hall, near Blackburn	"	Edward VI.
Hall-i'-the-wood, near Bolton	"	Charles I.
Ince Hall, near Wigan.		
Park Hall, near Oswestry.		
Moreton Hall, near Congleton.		
Mere Hall, near Droitwich.		

For further particulars on the subject of this article, *see* House.

TUDOR FLOWER, a flat flower or leaf of a diamond shape, placed upright on its stalk, much used in the crestings of Perpendicular work.

TUFA, a calcareous earth, composed of broken and concreted shells, or the deposit from water impregnated with lime.

TUMBLING-IN, or Trimming-in: when a piece of timber is to be fitted between two others, given in position, the fitting is called *tumbling-in;* a trimmer may be tumbled-in between two joists, and the purlins of a roof between two of the rafters, when they are not bridged over them.

TUN OF TIMBER, about 40 solid feet.

TUNNEL, a subterranean passage.

TURNING PIECE, a board with a circular edge, for turning a thin brick arch upon, as the breast of a chimney.

TURRET, a small tower; frequently found attached to a larger one at its angles, or at the angles of buildings; they are sometimes built out to contain stairs.

TUSCAN ORDER, an ordinance with a column and entablature the same as the Roman Doric, divested of its triglyphs, mutules, and guttæ, the members of the entablature being continued throughout the whole length, without interruption.

It has been customary to consider this method as a separate order; but there would seem to be little reason for so doing; for indeed it is little more than a variation of the Roman Doric, which, divested of its enrichments, is to all intents and purposes Tuscan.

We find no remains of a complete Tuscan order amongst the relics of antiquity; the present delineations of the order being determined by the interpretations which different architects have put upon the passage in Vitruvius, in which it is described. As this description is somewhat obscure, it is not unnatural that we should find that different conclusions have been arrived at upon the subject: thus we have different designs by Palladio, Vignola, and Scamozzi. Although we have no remains of a perfect order, we have examples of Tuscan columns, amongst the more noted of which stands the Trajan column at Rome. Vitruvius does not speak of this as a distinct order, although he alludes to the construction of Tuscan temples. He makes the column six diameters in height, with a diminution of one quarter of a diameter; the base and capital each one module in height. He decides no height for the architrave or cornice, omits the frieze, but places mutules over the architrave, which are to project one-fourth of the total height of the column, including base and capital. He does not provide a pedestal.

Palladio makes the total height of the order nine diameters and three-quarters, of which he gives six to the column; the height of base and capital each measuring half a diameter; he provides no pedestal, but places the base on a plinth whose height is equal to one diameter.

Serlio makes the height of the architrave half a diameter, and gives an equal height to the frieze and cornice. His pedestal consists of a plinth and base, a die and cymatium, the whole being a third of the height of the column.

Scamozzi assigns as the height of the entablature one-fourth of the total height of the column, less half a diameter; and makes his pedestal of the same height. He also places a sort of triglyph in the frieze.

Plate 1.—The entablature, capital, and base of the Tuscan order finished.

Plate 2.—Outline, with the measures of the various members.

TUSK, (from the Saxon *tysos*, a fang,) a bevel shoulder made above a tenon, and let into a girder to strengthen the tenon.

TYMPAN, (from *τυμπανον*, *a timbrel*,) the hollow recessed part of a pediment, being either a plane triangle, or filled with ornaments of sculpture raised from the plane of the triangle.

Though the pediments of the ancient Greeks were very low, they were long enough to admit of the most beautiful sculpture; as that of the Temple of Minerva at Athens, now deposited in the British Museum.

Tympan also signifies the die of a pedestal, or the panel of a door.

TYPE, the canopy over a pulpit.

U.

UMBER, a fossil brown substance, used by painters, which grinds freely, and bears a good body. When burnt, it furnishes the most natural imitation of gold: with a mixture of white, it resembles the colour of new open wainscot. It dries quickly, with a considerable gloss. It has its name from the ancient province of Umbria in Italy, whence it was originally obtained; but is also found in Germany, Spain, Egypt, Cyprus, and other parts of the Turkish dominions, from which last what is brought into England mostly comes. Dr. Hill and Mr. De Costa consider it as an earth of the ochre kind, which might be found in considerable quantities in England and Ireland, if properly looked after; several large masses of it having been thrown up in digging on the Mendip hills, Somersetshire, as well as in the county of Wexford, Ireland. It is also met with occasionally in the veins of lead-ore in Derbyshire and Flintshire.

UNDECAGON, (Greek *ενδεκα*, *eleven*, and *γωνια*, *an angle*,) a figure of eleven sides.

UNDERCROFT, a crypt, or subterranean apartment.

UNDER-PINNING, the act of bringing a wall up to the ground-sill, or sometimes that part of the wall itself. The temporary support of a wall whose foundations are defective, or the formation of new foundations.

UNGULA, of a cylinder, or cone, a part of the solid comprehended by part of the curved surface, the segment of a circle, which is part of the base, and another plane.

UNIVERSITY, (from the Latin *unus*, one, and *verto versus*, to turn,) a collection of colleges for teaching the various branches of knowledge. In an architectural point of view, the term is applicable to the houses, or edifices, in which the classes are held.

UPHERS, fir poles, from 4 to 7 inches in diameter, and from 20 to 40 feet in length; they are frequently hewn on the sides, so as not to reduce the wane entirely. They are of great use in scaffolding and ladders; and are also employed in slight roofs, where they are slit.

UPRIGHT, the elevation of a building. The term is rarely used, *elevation* being more commonly employed.

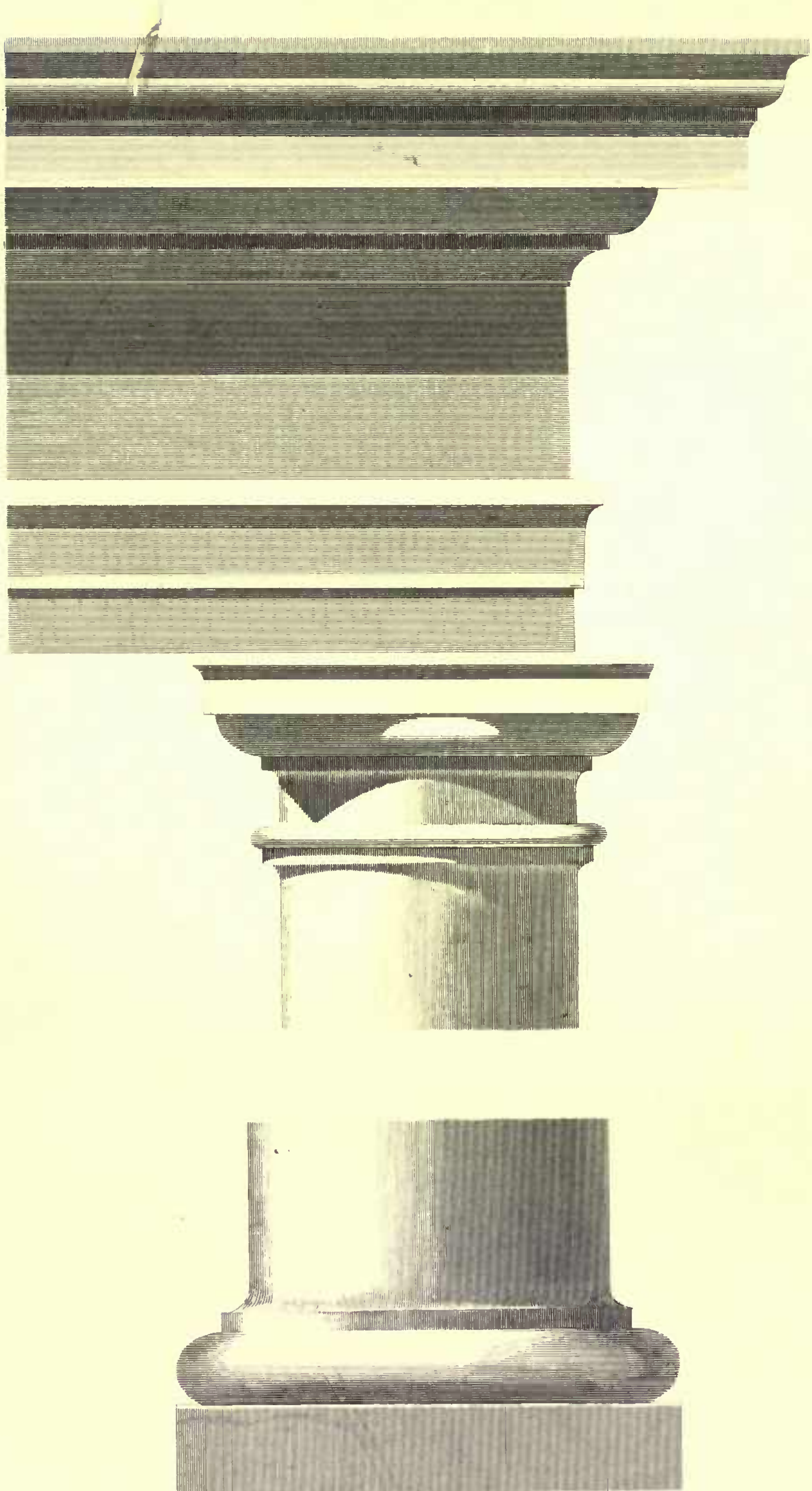
URBIN, or URBINO, a name frequently given to that most sublime and excellent painter, Raphael Sanzio, from the place of his birth. He was the son of an indifferent painter, named Sanzio, and was born on Good Friday, 1482. He was employed by the popes Julian II. and Leo X., who loaded him with wealth and honours; and the cardinal De St. Bibiana held him in such high estimation that he offered him his niece in marriage: but he declined this honour, from an expectation he entertained, founded upon the promise of Leo X., of being made a cardinal himself. His pictures are to be found principally in Italy and Paris. That of the *Transfiguration*, preserved at Rome, in the church of St. Peter Monterio, is reckoned his master-piece. His person was handsome, and his manners were polite, affable, and modest, though he lived in the utmost splendour. He was not only the best painter in the world, but perhaps the best architect too; on which account he was employed by Leo X. in building St. Peter's church at Rome. This engagement prevented his acceptance of an invitation into France from Francis I., for whom he had painted a *St. Michael and the Holy Family*, and had been remunerated by that monarch with sums so far beyond his expectation, that he resolved to show his gratitude by a performance, in which he even surpassed himself: this was the *Transfiguration* above alluded to intended as a present to Francis; but he died before the picture was quite finished, and it was detained at Rome. His death happened on his birth-day, 1520, when he had completed his 38th year; the consequence of his passion for the fair sex, and the injudicious treatment of his physicians. His celebrated *Cartoons*, for which Louis XV. offered a hundred thousand pounds, were purchased by Rubens for Charles I. and brought to England, and have successively graced the palaces of Hampton Court, Buckingham House, and Windsor Castle. A considerable jealousy existed between this artist and Michael Angelo, which sometimes manifested itself in a manner not very creditable to either. Raphael frequently exercised himself in sculpture, and excelled as much in it as in painting and architecture. A *Jonas*, of the size of life, which is deemed his *chef-d'œuvre* in this line, is shown in the chapel of Madonna del Popolo, at Rome, the cupola of which he also painted.

Urbin is also a name sometimes given to Bramante, from his having been born in the province of Urbino. *See* Bramante.

URN, (from the Latin *urna*,) a vase of a circular form, used as a terminating ornament upon an acroter, or the like. Urns were not much employed in the celebrated edifices of antiquity.

TUSCAN ORDER.

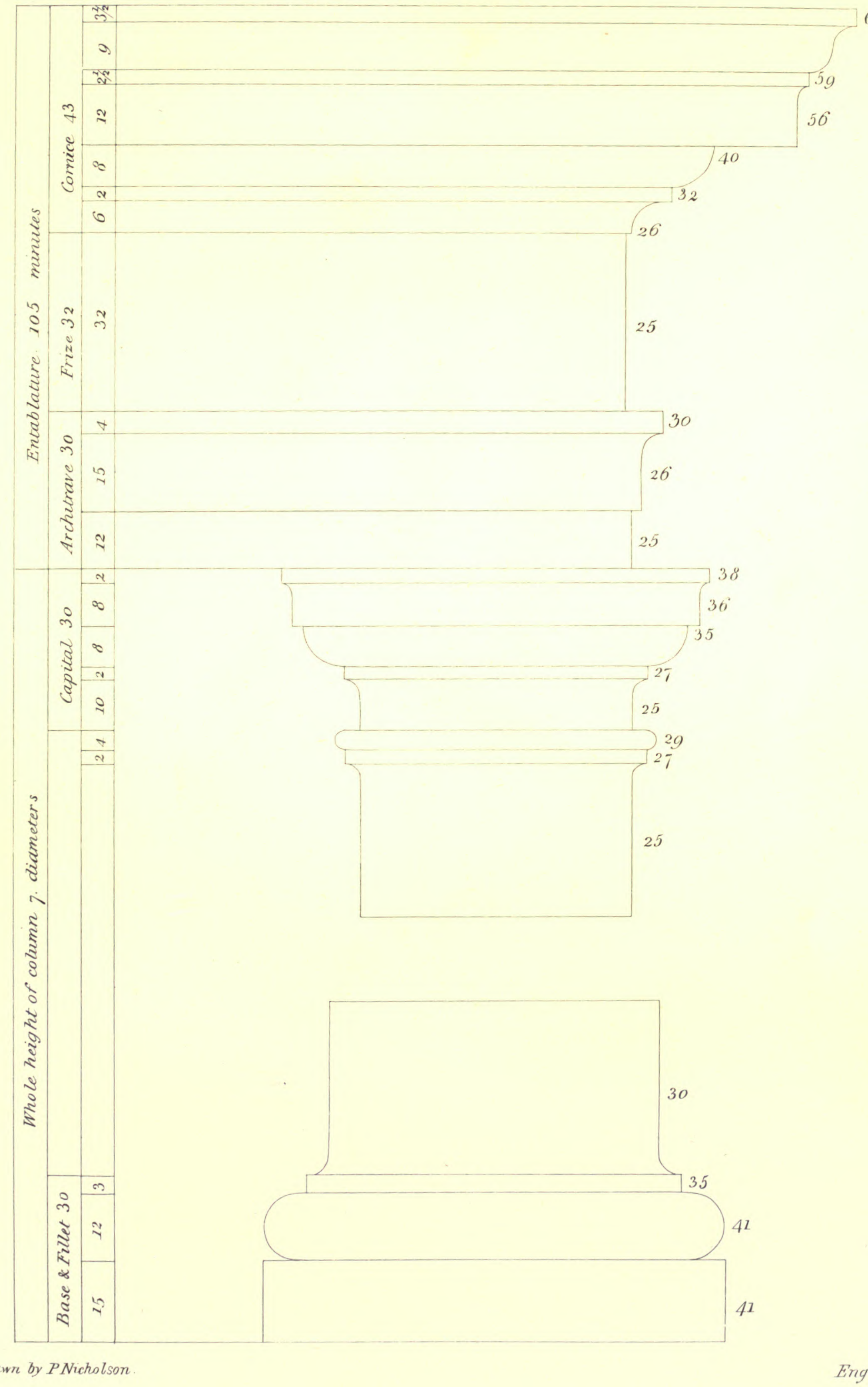
PLATE I.



Drawn by P. Nicholson. *Engd by R. Thew.*

TUSCAN ORDER.

PLATE, 2.



Drawn by P Nicholson.

Engd. by R. Thew.

V.

VAGINA, (Latin,) the lower part of a Terminus, resembling a sheath, in which the lower part of the statue is inserted.

VALLEY, (from the Latin, *vallis*, a hollow,) the internal angle of two inclined sides of a roof.

Valley-Board, a board fixed upon a valley-rafter for the leaden gutter to lie upon.

Valley-Rafter, the rafter under the valley, or that which supports the valley.

It is evident, that since the internal angle is above the roof, the external angle is under it; and, in hip-rafters, that since the external angle is outward, the internal angle is inward; therefore, the hipped angles will be stronger than the valleys, and consequently require timbers of less scantling to support them. This circumstance should be attended to in the description or particulars of a building, as the judgment of the architect will be shown in such discriminations.

Valley-Rafters, in old books, are called *sleepers;* but in this sense the term is antiquated. *See* Sleepers.

Valley-Pieces, the same as Valley-Rafters. The term is used in some parts of the country, particularly in Devonshire.

VALLUM, a rampart or raised wall or mound erected for the purpose of defence.

VALVED, anything that opens upon hinges.

VANE, a plate of metal turning on a vertical spindle, and fixed on the summit of a tower, spire, or other elevated building, to show the direction of the wind. The custom of placing vanes on church-steeples is very ancient; and as they were commonly made to represent the figure of a cock, they have been thence termed *weather-cocks.* In late Gothic buildings, they frequently present the appearance of little flags, perforated with heraldic devices, &c.

VANISHING LINE, in perspective, the intersection of the parallel of any original plane with the picture.

Vanishing Point, that point to which all parallel lines in the same plane tend in the representation.

VARIATION OF CURVATURE, the change made on a curve, so as to make it quicker or flatter in every succeeding part; as the curvature of the quarter of an ellipsis terminated by the two axes is continually quicker from the extremity of the greater axis to that of the lesser.

VARIETY, (from the Latin, *vario*, to change,) the agreeable disposition of the parts of an edifice.

VARNISH, a preparation used to preserve and put a glossy surface upon painted articles. It consists of different resins in a state of solution, of which the most common are mastic, sandarac, lac, copal, &c.; they are prepared with either expressed or essential oils or alcohol.

VASE, (from the Latin, *vas*, a vessel,) an ornamental termination to the wall or other parts of an edifice, or to a pillar, obelisk, or the like.

Vases are made in imitation of vessels, or urns, in the form of a solid of revolution, and are often ornamented with basso-relievos in infinite variety. Those who would form a good idea, may consult the article Oval, where they will find the mathematical outlines which give the most pleasing variety to the curvature, and to the general section of the solid through its axis; the ornaments, though essential decorations, are merely auxiliaries.

Vase of the Corinthian or Composite Capital, a solid of revolution, from the surface of which all the ornaments project: the section of the vase having its general outline of a form nearly similar to the surrounding contour of the leaves.

The situation of the vase is between the abacus and the astragal, at the top of the shaft, and the outline of the generating figure is concave, springing parallel to the axis, and receding gradually therefrom to the top, where it generally terminates in a fillet, also parallel to the axis.

Vases of a Theatre, were vessels under the seats used by the ancients, in order to produce greater harmony.

VAULT, (from the French *vaulte*, a cave,) an arched roof over an apartment, concave towards the void; the section may, therefore, be circular, elliptical, parabolical, hyperbolical, catenarian, cycloidal, &c., but, in general, the sections are either portions of a circle or of an ellipsis.

Vault, *Cylindric*, that of which the surface is any portion of a cylinder, never greater than the half when the axis is in the same plane with the springing of the arch. Also termed *barrel* or *wagon-headed* vault.

Vault in full Centre, that which is formed of the surface of a semicylinder.

Vault, *Surmounted*, or *Surhaussé*, that which is formed by the portion of any curve where the height is greater than half the span.

Vault, *Surbaisse*, that which is formed by the portion of any curve whose abscissa is less than the ordinate which forms half the base.

Vault, *Rampant*, that whose springing is not parallel to the horizon; such as those of the old staircases of the Louvre, and the descent into the cellars.

Vault, *Double*, a mode of construction, where one vault stands above another, in order to preserve the proportion between the exterior and interior of the building; as in St. Peter's at Rome.

Vault, *Conic*, that which forms the surface of a cone. Conic vaults may be of three kinds, according to the disposition of the axis, viz., parallel, perpendicular, or oblique to the horizon. They are seldom used in building houses; the only kind likely to come into use, is that with its axis parallel to the horizon.

Vault, *Spherical*, a vault forming the portion of the surface of a sphere; more usually called a Dome. *See* Dome.

Vault, *Annular*, that of which the plan is contained between two concentric circles: its generating section may either be that of a pointed arch, or of a semicircle, or indeed of any other curve.

Vault, *Simple*, that which is constructed of the surface of some regular solid, around one axis, or centre.

Vault, *Compound*, that which is compounded of more than one surface of the same solid, or of two different solids. Vaults of this kind are of the same solid as those whose surfaces have different axes, or different centres, as those formed of two cylinders, equal or unequal, or of two spheres, equal or unequal, penetrating each other.

Vault, *Cylindro-cylindric*, that which is formed of the surfaces of two unequal cylinders. When their axes cut each other, they are denominated *Welsh groins.*

Vault, *Groined*, a compound vault, which rises to the same height in its surfaces as that of two equal cylinders, or a cylinder with a cylindroid.

In the Temple of Peace, at Rome, the middle aisle is groined, all the arches are elliptic, their chord, or springing line, being that of the lesser axis : the small groins spring from mere points. The main vault of this edifice was supported by columns, which have long been removed; the entablatures, however, and the springing of the groins, still remain. The side vaulting is cylindrical, and coffered in octagons and squares. The elliptic passages of the Coliseum are groined. Groins are to be found in many Roman buildings still remaining. *See* Adams's *Ruins of Spolatro;* also the *Ruins of Balbec and Palmyra*, by Wood. The dome of the Pantheon is coffered; that of the Temple of Bacchus is plain.

The groins of Gothic edifices are numerous, and form a different class, which it would be difficult to define. The most beautiful specimens are to be found in England; and among the numerous variety, we might mention King's College, Cambridge, and King Henry the Seventh's Chapel, Westminster. *See* Gothic Architecture.

A vault is an extended arch, and therefore the theory is the same as that of the arch, which has been given under the article Stone Bridge. The four walls of a building are strong ties to every kind of vaulting; and more particularly that of groins, where the horizontal pressure is directed against the angles, and, consequently, the four walls in this case will become ties, which ought, therefore, to be firmly built or bound together with a cast-iron bar, which will be entirely concealed. Besides what has been shown under the article Stone Bridge, the reader should also consult the article Dome, and the following quotation from Hutton's *Mathematics*, vol. iii., which is necessary to be understood by every engineer.

"In the practice of engineering, with respect to the erection of powder-magazines, the exterior shape is usually made like the roof of a house, having two sloping sides, forming two inclined planes, to throw off the rain, and meeting in an angle, or ridge, at the top; while the interior represents a vault, more or less extended as the occasion may require; and the shape, or transverse section, in the form of some arch, both for strength and commodious room, for placing the powder-barrels. It has been usual to make this interior curve a semicircle. But, against this shape, for such a purpose, I must enter my decided protest; as it is an arch the farthest of any from being in equilibrium in itself, and the weakest of any, by being unavoidably much thinner in one part than in others. Besides, it is constantly found, that after the centering of semicircular arches is struck, and removed, they settle at the crown, and rise up at the flanks, even with a straight horizontal form at top, and still much more so in powder-magazines with a sloping roof; which effects are exactly what might be expected from a contemplation of the true theory of arches. Now, this shrinking of the arches must be attended with other additional bad effects, by breaking the texture of the cement, after it has been in some degree dried, and also by opening the joints of the voussoirs at one end. Instead of the circular arch, therefore, we shall in this place give an investigation, founded on the true principles of equilibrium, of the only just form of the interior which is properly adapted to the usual sloped roof.

"For this purpose, put $a =$ D K the thickness of the arch at the top, $x =$ any absciss, D P, of the required arch A D C M, $u =$ K R the corresponding absciss of the given exterior line K I, and $y =$ P C $=$ R I their equal ordinates. Then by the principles of arches, in my tracts on that subject, it is found that C I or $w = a + x - u = Q \times \frac{\dot y \ddot x - \dot x \ddot y}{\dot y^3}$, or $= Q \times \frac{\ddot x}{\dot y^2}$ suppossing $\dot y$ a constant quantity, and where Q is some certain quantity to be determined hereafter. But K R or u is $= ty$, if t be put to denote the tangent of the given angle of elevation K I R, to radius 1; and then the equation is $w = a + x - ty = \frac{Q\ddot x}{\dot y^2}$.

"Now, the fluxion of the equation $w = h + x - ty$, is $\dot w = \dot x - t\dot y$, and the second fluxion is $\ddot w = \ddot x$; therefore, the foregoing general equation becomes $w = \frac{Q\ddot w}{\dot y^2}$; and hence $w\dot w = \frac{Q\dot w\ddot w}{\dot y^2}$, the fluent of which gives $w^2 = \frac{Q\dot w^2}{\dot y^2}$: but at D the value of w is $= a$, and $\dot w = 0$, the curve at D being parallel to K I; therefore the correct fluent is $w^2 - a^2 = \frac{Q\dot w^2}{\dot y^2}$. Hence, then, $\dot y^2 = \frac{Q\dot w^2}{w^2 - a^2}$, or $\dot y = \frac{\dot w\sqrt{Q}}{\sqrt{(w^2 - a^2)}}$; the correct fluent of which gives $y = \sqrt{Q} \times$ hyp. log. of $\frac{w + \sqrt{(w^2 - a^2)}}{a}$.

"Now, to determine the value of Q, we are to consider that when the vertical line C I is in the position A L or M N, then $w =$ C I becomes $=$ A L or M N $=$ the given quantity, c suppose, and $y =$ A Q or Q M $= b$ suppose, in which position the last equation becomes $b = \sqrt{Q} \times$ hyp. log. $\frac{c + \sqrt{(c^2 - a^2)}}{a}$; and hence it is found that the value of the constant quantity $\sqrt{Q}$, is $\frac{b}{\text{h. l. } c + \sqrt{(c^2 - a^2)}}$; which being substituted for it, in the above general value of y, that value becomes

$$y = b \times \frac{\text{log. of } \frac{w + \sqrt{(w^2 - a^2)}}{a}}{\text{log. of } \frac{c + \sqrt{(c^2 - a^2)}}{a}}$$

$$= b \times \frac{\text{log. of } w + \sqrt{(w^2 - a^2)} - \text{log. } a}{\text{log. of } c + \sqrt{(c^2 - a^2)} - \text{log. } a};$$

from which equation the value of the ordinate P C may always be found, to every given value of the vertical C I.

"But if, on the other hand, P C be given, to find C I, which will be the more convenient way, it may be found in the following manner: Put A $=$ log. of a, and C $= \frac{1}{b} \times$ log. of $\frac{c + \sqrt{(c^2 - a^2}}{a}$; then the above equation gives C $y +$ A $=$ log. of $w + \sqrt{(w^2 - a^2)}$; again, put $n =$ the number whose log. is C $y +$ A; then $n = w + \sqrt{(w^2 - a^2)}$; and hence $w = \frac{a^2 + n^2}{2n} =$ C I.

"Now, for an example in numbers, in a real case of this nature, let the foregoing figure represent a transverse vertical section of a magazine arch balanced in all its parts, in which the span or width A M is 20 feet, the pitch or height D Q is 10 feet, thickness at the crown D K = 7 feet, and the angle of the ridge L K N 112° 37′, or the half of it L K D = 56° 18½′ the complement of which, or the elevation K I R, is 33° 41½′ the tangent of which is = $\frac{2}{3}$, which will therefore be the value of t in the foregoing investigation. The values of the other letters will be as follows, *viz.* D K = a = 7; A Q = b = 10; D Q = h = 10; A L = c = $10\frac{1}{3} = \frac{31}{3}$; A = log. of 7 = .8450980; c = $\frac{1}{b}$ log. × of $\frac{c + \surd (c^2 - a^2)}{a}$ = $\frac{1}{10}$ log. of $\frac{31 + \surd 520}{21}$ = $\frac{1}{10}$ log. of 2.56207 = .0408591; c y + A = .0408591 y + .8450980 = log. of n. From the general equation, then, *viz.* C I = $w = \frac{a^2 + n^2}{2n} = \frac{a^2}{2n} + \frac{1}{2}n$, by assuming y successively equal to 1, 2, 3, 4, &c., thence finding the corresponding values of c y + A or .0408591 y + .8450980, and to these, as common logs. taking out the corresponding natural numbers, which will be the values of n; then the above theorem will give the several values of w or C I, as they are here arranged in the annexed table, from which the figure of the curve is to be constructed, by thus finding so many points in it.

Value of y or C P.	Value of w or C I.
1	7.0309
2	7.1243
3	7.2806
4	7.5015
5	7.7888
6	8.1452
7	8.5737
8	9.0781
9	9.6628
10	10.3333

"Otherwise: Instead of making n the number of the log. C y + A, if we put m = the natural number of the log. C y only; them $m = \frac{w + \surd (w^2 - a^2)}{a}$, and $a m - w = \surd (w^2 - a^2)$, or by squaring, &c. $a^2 m^2 - 2 a m w + w^2 = w^2 - a^2$, and hence $w = \frac{m^2 + 1}{2m} \times a$; to which the numbers being applied, the very same conclusions result as in the foregoing calculation and table."

The following description of a method of stone-roofing in the Southern Concan, in the East Indies, was communicated to the Institution of Civil Engineers by lieutenant Outram, of the Bombay Engineers. Though hardly applicable to the climate of this country, it seems of considerable value as relating to an important part of the British Empire. The few houses which had been constructed on this plan were found to answer so well, at the time this paper was written, that government had given orders to construct, on this principle, all the public buildings, wherever suitable materials could be found.

The roofing with stone (iron-clay, or laterite) in the Southern Concan, is of a compound nature, consisting of two kinds of arches; the first being parallel to each other, from 2 to 3 feet apart, and very light, their average section being from 12 by 10 inches to 15 by 12; *i. e.* for roofs of from 25 to 35 feet span; so that when any two of these arches or ribs are complete, they are strong enough to bear slabs of stone 5 or 6 inches thick, extending a few inches over each, beginning from the wall and meeting at the top, thus forming a second complete arch, and making, with the ribs, a compound much stronger than vaulting of equal solidity over the same extent, made in the usual way.

The lateral thrust of the arches of one room are counteracted by those of the rooms on its sides, and so on for any extent; those of the end-rooms being counteracted on their outer sides by buttresses, or by the walls of baths, &c., so that the walls are required to be only sufficiently strong to support the mere weight of the masonry of the roofs, which has an average thickness of about 9 inches, excepting the plaster or tiles, and, therefore, in rooms of 400 square feet, would be about one-fifth the weight of the upper walls of a two-storied house. As the roof itself is of considerable altitude, the walls supporting it need not be of more than two-thirds the usual height.

One advantage of the lightness of these roofs is, that of whatever form the arches may be, very little *loading* will suffice; of course some arches would require no loading, but such are not the most convenient for roofs in general. The best appears to be a compound of two segments of a circle of 50° or 55°, their chords intersecting at an angle of about 100°, such compound arch requiring a little loading at the top and the haunches, which, when duly added, gives an outer surface of two inclined planes to each roof, which may be then either plastered or tiled. But instead of loading the haunches throughout with solid rubble, it is better to do so partly with hollow masonry, to the upper surface of which may be given any slopes which, by the connection of the opposite slopes of any two adjacent roofs, form a gutter of the securest kind. The average height of this gutter should be about one-third that of the roof, if to be plastered, but not so much if the roof is to be tiled.

The expense of these roofs, including the outer plaster, has been found by myself and successor, in the Concan, to be much less than that of tiled roofs over the same extent. The walls should cost no more than those of a substantial bungalow; for although the transverse walls have a greater weight to support, yet, as they need be only two-thirds the height, their total expense should not be greater than that of the walls of a substantial house. The only part of which the comparative expense remains to be considered, is the ceiling. The inner surface of the stone roofs, when finely plastered, forms an excellent ceiling; being light and cleanly, and most durable. The expense of this plastering, if not much ornamented, is below one-third that of the lath-and-plaster generally used. Hence it is plain, and has been practically found, that the total expense of stone-roofed houses in the Concan, if properly constructed, is less than that of tiled houses of the same size; but the sums saved in annual and special repairs are of far greater consideration. In the Decan, where timber is so expensive, the comparative cost of these buildings would be still less, in all those parts of it where proper stone is met with.

The principal cause of the cheapness of these stone roofs is the very little centering, &c., that is requisite. For as the ribs, or primary arches, are very light, centering of the simplest kind does for any one of them, and thus for all successively in either room. But as the centering cannot be removed from any rib till its counteracting ribs are complete, there is of course required one centering for each room, which, when one series of the primary arches is complete, may be removed with ease for the next, till a convenient number are ready for the superior arching, which of course is very quickly formed (as before described) without any centering.

The material fittest for this kind of building are the various kinds of sand-stone, including the calcareous sand-stone of Cutch. The laterite, or iron-clay, although a good material, and the only one hitherto used, is apparently not so proper as the substance generally called free-stone, which is worked with saws, &c., and would be found to answer better than the laterite, which can be shaped only with a pickaxe, and is very heavy.

This iron-clay is found to extend from Bancoate, E. N. E., to, I believe, Ceylon, lying over the trap-rock, even on the highest Ghauts, but is very unequal in thickness and quality; that of Purnalla and Pawnghur, for instance, being of the softest and most porous kind, and that near Mahabulesher of the best. This stone, when exposed to rain, &c. becomes very hard, if good; but if taken from any depth, is so soft as to be easily cut with a knife. It is hence called *soap-stone* at Belgaum and other Madras stations.

If adopted in Europe, buildings of this kind would he as remarkable for warmth as in this country for coolness. But the plastering outside would not be advisable on account of the frost; tiles, however, or slate, would protect the roof completely.

The principal advantages of these buildings in this country are, their coolness, and the little expense incurred in annual and special repairs; indeed, the latter will never be required, if the buildings be properly constructed at first. It is also very evident, that they can never take fire, nor can white ants affect them; of course they could be built of several stories, the form of the floor-ribs being merely a small segment of a circle (or ellipse) instead of a compound of two, as in the roof. The upper floor of the jailor's house at Rutnaghery is thus built, as also part of another house.

VAULT, *Reins of a*, the sides or walls which sustain the arch.

VAULTING SHAFT, the shaft which supports the ribs of a groined vault. These shafts either rise direct from the ground, or are supported upon corbels at a height above the ground; they are frequent in Romanesque and Gothic buildings.

VELLAR CUPOLA, a dome, or spherical surface, terminated by four or more walls. This kind of ceiling is frequently used over great staircases, as also over saloons, or other lofty apartments. The term is used by Alberti, vol. i. book iii., chap. 14, in the sense here defined.

VENEER, a very thin leaf of wood, of a superior quality, for covering doors, or articles of furniture, made of an inferior wood.

VENETIAN DOOR, a door lighted on each side.

VENETIAN WINDOW, a window in three separate apertures, divided by slender piers, and having the centre aperture larger than the side ones. *See* Adams's *Ruins of Spolatro*, p. 26; likewise Disgodily's *Roman Antiquities*, vol. ii. *Baths of Diocletian.*

VENT, (from the French, *fente*, a small aperture,) the tube of a chimney, for conveying the smoke from the fire. The term is mostly used in Scotland. In London it is called *flue*, and in many parts of England *funnel.*

VENTIDUCTS, (from the Latin, *ventus*, wind, and *ductus*, a passage,) subterraneous places where fresh or cool air is kept, being received by proper funnels and valves.

VENTILATION, the method of supplying buildings with fresh air. In buildings which are intended for habitation, or where large bodies of persons are at any time to be congregated, it is requisite that there should be some means of replenishing the apartment with a constant supply of pure air. This necessity arises from the fact, that air, when once passed through the human system, is unfit for re-inspiration, that portion which is emitted being not only useless, but deleterious to health. On this account it becomes necessary to remove this vitiated air, and to substitute fresh air, which should be at a temperature of about 60° to 65°. The vitiated air, on being emitted from the mouth, has a temperature between 80° and 90°, and being thereby rarified and rendered lighter, has a tendency to rise to the upper part of the apartment. The method hereby naturally suggested for its removal is the provision of some means of escape at the top of the apartment; the success of this method, however, would be nullified, if the heated air, on emerging from the top of the room into a shaft intended to conduct it away, were to meet with a current of cold air, and it is therefore found necessary to heat the air in the shaft, so as to assist the upward draft. It is further necessary to keep up a constant supply of fresh air to take the place of the foul air as it is removed; this is necessary, not only for the purposes of health, but also to preserve the upward draft. In some instances, means have been adopted of forcing fresh air in with fans or bellows; but this is scarcely necessary, for if the fresh air be only allowed admission into the apartment, it will naturally enter to fill up the vacuum caused by the dispersion of the foul air. These methods, however, are seldom adopted together; sometimes the shaft, and at others the fan, is employed. Some persons contend, that the method of heating the air in the shaft does not answer the intended object, but rather causes a downward current. In supplying fresh air, it is to be observed, that cold currents of air are to be avoided: it is sometimes customary to heat the air to a certain temperature before admitting it into the apartment, the temperature being regulated according to the season of the year.

VENTILATOR, (from the Latin, *ventilo*, to fan,) a machine made to turn with the wind, and placed in the wall or roof, in order to throw a due quantity of fresh air into a close apartment.

VERGE, a small ornamental shaft in Gothic architecture.

VERGE BOARD, same as BARGE BOARD.

VERMICULATED RUSTICS, stones worked to appear as if eaten by worms.

VERSED SINE, that part of the radius of a circle intercepted between the foot of the sine and the circumference, otherwise termed *sagitta*. *See* TRIGONOMETRY.

VERTEX, (Latin,) the top, generally applied to the termination of anything ending in a point; as the vertex of a pyramid, &c.

VERTEX OF A CONIC SECTION, the extremity of the abscissa.

VERTICAL ANGLES, the opposite angles made by two straight lines cutting each other.

VERTICAL PLANE, that position of a plane in which its surface is perpendicular to the horizon.

VESICA-PISCIS, a figure frequently used in the decorative part of Early English and Gothic architecture generally. It is formed by the intersection of two arcs of equal circles, and is somewhat similar in outline to that of a fish, whence its name. This form is commonly given to the auricola, or nimbus of glory, in which the representations of saints are enclosed.

VESTIBULE, a porch or entrance to any building.

VESTMENT, the hangings for an altar, or robes for the priests.

VESTRY, a building attached to a church, in which the sacred vestments and vessels were deposited; the same as SACRISTY.

VIADUCT, a term applied to a roadway supported on a succession of arches.

VIGNETTE, a running ornament in Gothic mouldings.

VIGNOLA, a name commonly given to JAMES BAROZZI, or BAROGGIO, from the place of his birth, a small town in the duchy of Modena. He was born in 1507, and was the son of a person of consequence, whom the political strife of the day obliged to expatriate himself. James discovered an early inclination for the arts, and was sent for education to Bologna, where, from painting, to which he was first attached, he directed his attention to architecture, and by various designs, upon the principles of Vitruvius, some of which he communicated to the historian Guicciardini, he acquired an early reputation. With a view to farther improvement, he went to Rome, and, being admitted into the Academy of Design, then newly founded, was there employed in measuring the most celebrated remains of antiquity; in the prosecution of which labour he evinced uncommon taste and precision; so that the abbé Francisco Primaticcio, an able painter and architect of Bologna, who was sent to Rome in 1537 by Francis I. of France, to procure designs of the ancient buildings and casts of statues, was induced to avail himself of the assistance of Vignola, and on his return took him with him to France, where he drew plans for several eminent structures. After two years' residence in that country, Vignola returned to Bologna, and was employed in forming a plan for the façade of the church of St. Petronius, but, through the envy of his competitors, it was not executed till some years afterwards. In and near this city he built some palaces, and constructed the canal of Naviglio, running thence to Ferrara. Unduly recompensed for this work, he went to Placentia, and planned a palace for the Duke of Parma. After his return to Rome, in 1550, he built several churches there; and, through the interest of Vasari, was appointed architect to Pope Julius III., for whom he built a villa, and near it a small church, dedicated to St. Andrew, in the form of an ancient temple; and by his command he also brought the Aqua Vergine to Rome. After the death of Julius, he was employed by Cardinal Alexander Farnese in the construction of the magnificent palace, or castle, of Caprarola; and he had likewise the charge of building the church of the Jesuits at Rome, an edifice of extraordinary beauty and grandeur; but it was raised only to the cornice before the death of Vignola, and was finished by his disciple, James della Porta. After the decease of Michael Angelo, Vignola was appointed to succeed him as architect of St. Peter's, in conjunction with Piero Ligorio, a Neapolitan; which engagement, added to his advanced age, obliged him to decline an invitation from Philip II. to the court of Spain. He was, however, consulted with regard to the different plans given in for the Escurial; and one furnished by himself was highly approved, though not adopted. His other professional labours were interrupted by a commission from Gregory XIII., to settle the limits between the territories of the Church and those of the Duke of Tuscany; which he executed to the pope's satisfaction. Upon his return from this service, he was seized with a fever, and died in 1573, aged 66. His remains were solemnly interred in the church of Santa Maria della Rotunda, the ancient Pantheon.

Vignola acquired reputation as an author no less than as a practical artist. His rules for the five orders were formed on the purest taste of antiquity, and have been always reckoned classical and original. His treatise on the subject, in three volumes quarto, has been often reprinted, and translated into almost all the European languages. The French translation, with the commentaries of Daviler, is most esteemed. Vignola also wrote a treatise on practical perspective, which has passed through many editions.

VILLA, (from the Latin.) a country-house; of which the situation ought to be agreeable, commodious, and healthy, with winter and summer apartments; and surrounded with trees, to yield a cool refreshing air and shade during the heat of summer, and break the stormy cold winds of the winter. The Roman villas were very magnificent. See the description of Pliny's villas, under the article HOUSE.

VISE, a spiral staircase winding round a central newel or perpendicular shaft.

VISUAL POINT, the point of vision from which an object is viewed. *See* POINT.

VISUAL RAY, the thread or beam of light reflected to the eye from a certain point of the object.

VITRUVIAN SCROLL a peculiar pattern of scroll-work used in classical architecture, consisting of entwined undulations.

VITRUVIUS, M. POLLIO, a very distinguished writer on architecture, is supposed to have flourished in the times of Julius Cæsar and Augustus. Of his parentage, and place of nativity, nothing certain is known: Verona and Plaisance both claim him; but the pretensions of Formiæ, now Mola de Gaëta, are more generally allowed. Of his liberal education, and his travels for information and improvement, there can be no doubt. By the exercise of his profession he had acquired some property, though perhaps not very considerable; for he says, he did not, like the generality of architects, solicit employment. Under Augustus, or perhaps one of the succeeding emperors, to whom he dedicated his works, he occupied the post of Inspector of Military Engines. But as Pliny the Elder mentions his name among other authors, in his *Natural History*, composed in the reign of Vespasian, his work must have been published before that period. Of edifices planned or constructed by him, one only is mentioned by himself, which was a basilica at Fano. His work was discovered in MS. by Poggio, in the fifteenth century, and it has ever since been held in high estimation. The ten books, into which it is distributed, not only treat on everything belonging to buildings public and private, their site, materials, forms, ornaments, conveniences, and the like; but include much of what would be termed engineering, civil and military; and even digress to geometrical problems and astronomical inventions. Besides the instruction that may be derived from it, it has afforded much important matter to the antiquary relative to the state of art and science, as well as the detail of private life, among the Romans.

Some of the most esteemed editions of Vitruvius are by Dan. Barbari, *Venet.* fol. 1567; J. de Laet, *Amst.* fol. 1649; Galiani, *Neap.* fol. 1758, with an Italian translation and notes. Claude Perrault has given a good French translation, *Paris*, fol. 1684; and we have an English one by Mr. Newton, *London*, 1791. A magnificent edition of the civil architecture of Vitruvius, in two parts, royal quarto, has been also published by W. Wilkins, Jun., A.M., F.R.S., &c. During the reign of Augustus, it does not appear that the Romans had one architect, sculptor, painter, or musician, except Vitruvius, who has given Aristoxenus's system in Latin; but he was obliged to retain the Greek *technica*, as he was the first Roman writer on the subject of music, and used Greek technical words as we do Italian. Vitruvius has described the theatrical vases used by the Greeks for the augmentation and continuation of sound, and has given a description of the organ of the ancients worked by the fall of water.

VIVO, the shaft of a column. *See* COLUMN.

VOLUTE, one of the principal ornaments in the Ionic capital composed of two or more spirals of the same species, having one common eye and centre, variously channelled, or hollowed out in the form of mouldings.

Among the remains of ancient architecture, the Ionic capitals of the temples of Erechtheus and Minerva Polias, at Athens, are the most beautiful. The spiral best adapted for this purpose, is known by the name of the *logarithmic spiral;* the method of describing which is as follows:

Draw a straight line for the cathetus; take any point in the straight line as a centre; through this point draw another straight line at right angles, and these two straight lines cutting each other, will form four right angles: bisect any two adjacent right angles, and let the bisecting lines be produced on the other side of the centre, and the whole will be divided into eight equal angles by as many lines, upon which the radii are to be placed.

In the calculation we are here about to make, that part of the cathetus above the centre is supposed to be 20 minutes at a medium, and the next radius 18.3; both these being given, the calculation is founded upon the following principle:

Let $a = 20$, and $b = 18.3$,

then $a : b :: b : \frac{b^2}{a}$, which gives the third radius.

$b : \frac{b^2}{a} :: \frac{b^2}{a} : \frac{b^3}{a^2}$, which gives the fourth radius.

$\frac{b^2}{a} : \frac{b^3}{a^2} :: \frac{b^3}{a^2} : \frac{b^4}{a^3}$, which gives the fifth radius.

Therefore, any radius may be found, independent of the rest: thus, $\frac{b^{x-1}}{a^{x-2}}$; x being a variable quantity, representing the numbers of the radius. Thus, suppose the eighth radius were required; make $x = 8$, then $\frac{b^{x-1}}{a^{x-2}} = \frac{b^7}{a^6}$.

The arithmetical operation will be best performed by logarithms: now, as $b = 18.3$, and $a = 20$, multiply the logarithm of 18.3 by 7, and the logarithm of 20 by 6, subtract the latter product from the former, and the remainder will be the logarithm of the answer.

Now the logarithm of 18.3 is 1.26245, which, multiplied by 7, gives 8.83715: and the logarithm of 20 is 1.30103; which, multiplied by 6, gives 7.80618: then 8.83715 — 7.80618 = 1.03097, which is the eighth radius.

The following method will serve to prove the result of the operations, which are all dependent on each other; and will save the trouble of frequent reference to the Logarithmic Tables.

Log. 20 = 1.301030
log. 18.3 = 1.262451
1.262451
2.524902
1.301030
1.223872, the corresponding number is 16.74, which is the third radius.

Log. 18.3 = 1.262451
log. 16.74 = 1.223872
2
2.447744
1.262451
1.185293 = log. 15.32, 4th radius.

Log. 16.74 = 1.223872
log. 15.32 = 1.185293
2
2.370586
1.223872
1.146714 = log. 14.01, 5th radius.

Log. 15.32 = 1.185293
log. 14.01 = 1.146714
2
2.293428
1.185293
1.108135 = log. 12.82, 6th radius.

Log. 14.01 = 1.146714
log. 12.82 = 1.108135
2
2.216270
1.146714
1.069556 = log. 11.73, 7th radius.

Log. 12.82 = 1.108135
log. 11.73 = 1.069556
2
2.139112
1.108135
1.030977 = log. 10.73, 8th radius.

Log. 11.73 = 1.069556
log. 10.73 = 1.030977
2
2.061954
1.069556
.992398 = log. 9.82, 9th radius.

And thus, having gone through one revolution, the radii of the remaining revolutions may be found in a similar manner.

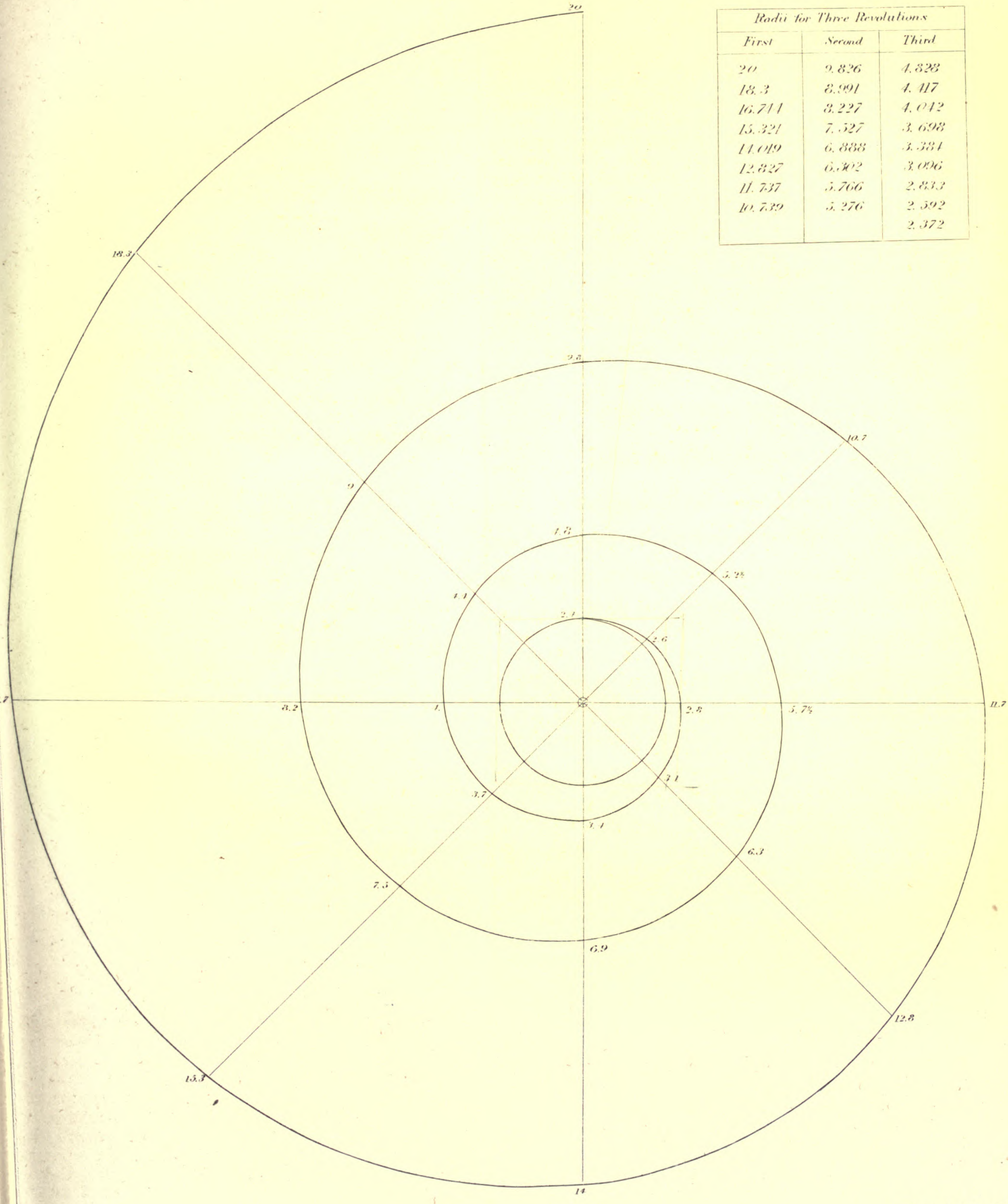
Now to apply the number thus found:

Plate I.—The centre is marked by the point ⊙; upon the cathetus set 20 from ⊙ upwards, which will give the extremity of the first radius; upon the second radius towards the left, set 18.3 from the centre, which will give another point in the curve; then, following round in the same progression, from the centre, set 16.74, 15.32, 14.01, 12.82, 11.73, 10.73, 9.82, &c. upon each succeeding radius respectively, to 2.37, and three points will be found in each quadrant.

In the Plate here referred to, we have only retained one

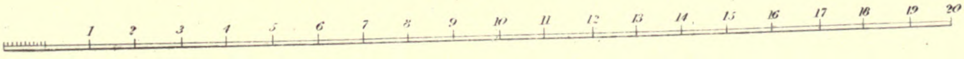
VOLUTE.

Radii for Three Revolutions		
First	Second	Third
20.	9.826	4.828
18.3	8.991	4.417
16.744	8.227	4.042
15.321	7.527	3.698
14.019	6.888	3.384
12.827	6.302	3.096
11.737	5.766	2.833
10.739	5.276	2.592
		2.372

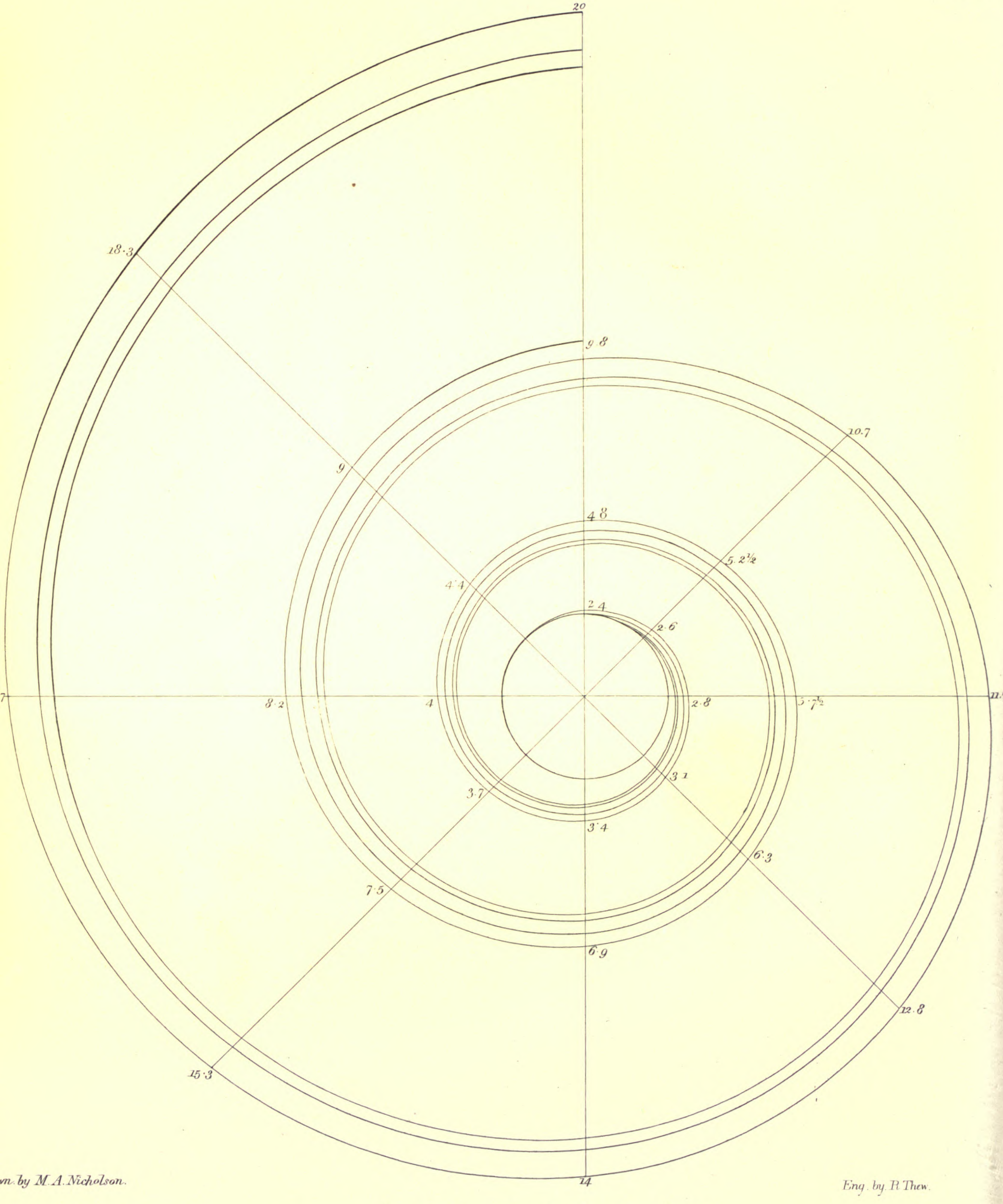


Engraved by J.C.B

…n by M.A. Nicholson



VOLUTE.



...wn. by M. A. Nicholson. Eng. by R. Thew.

1 2 3 4 5 6 7 8 9

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

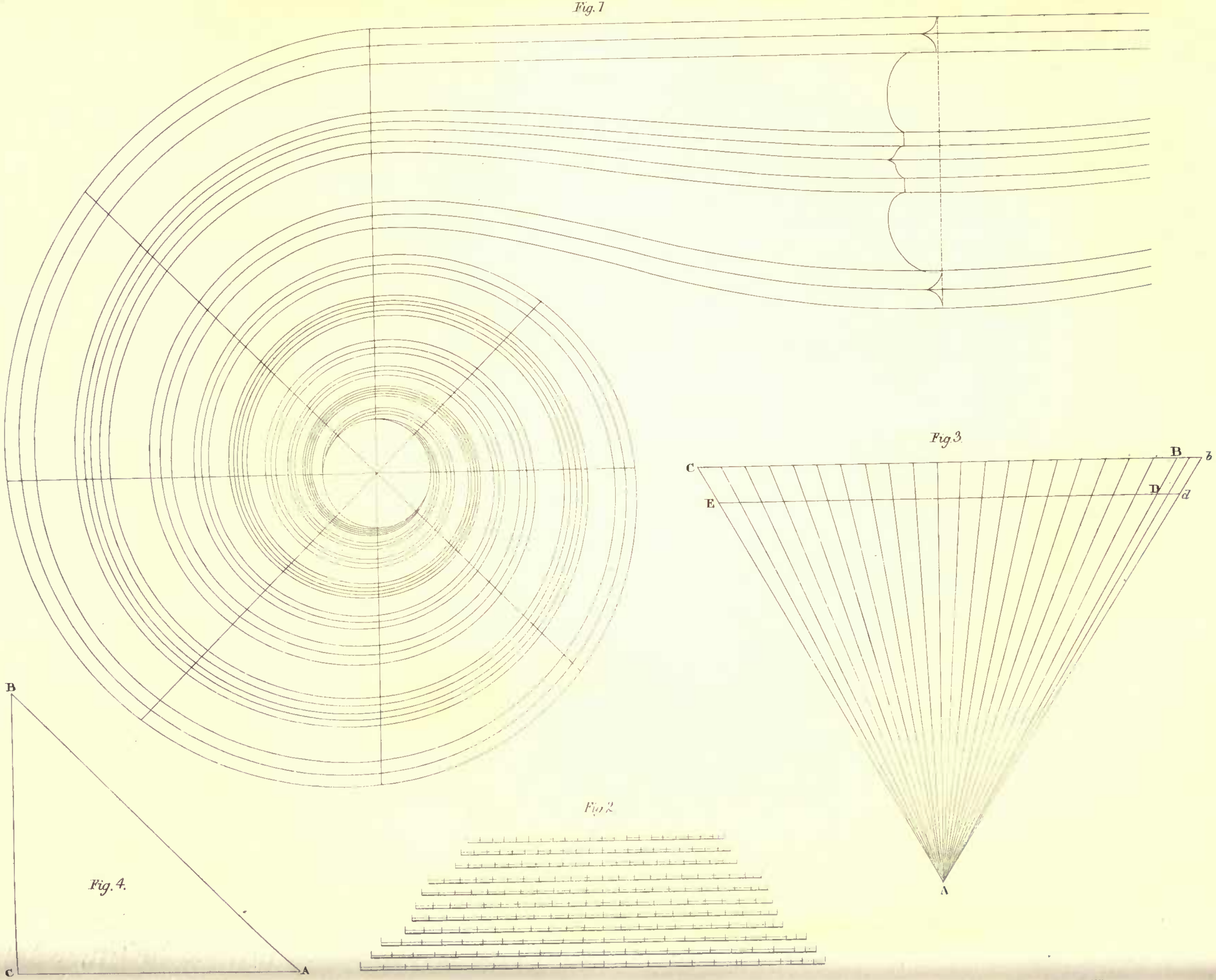
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Fig. 1

Fig. 3

Fig. 2

Fig. 4.



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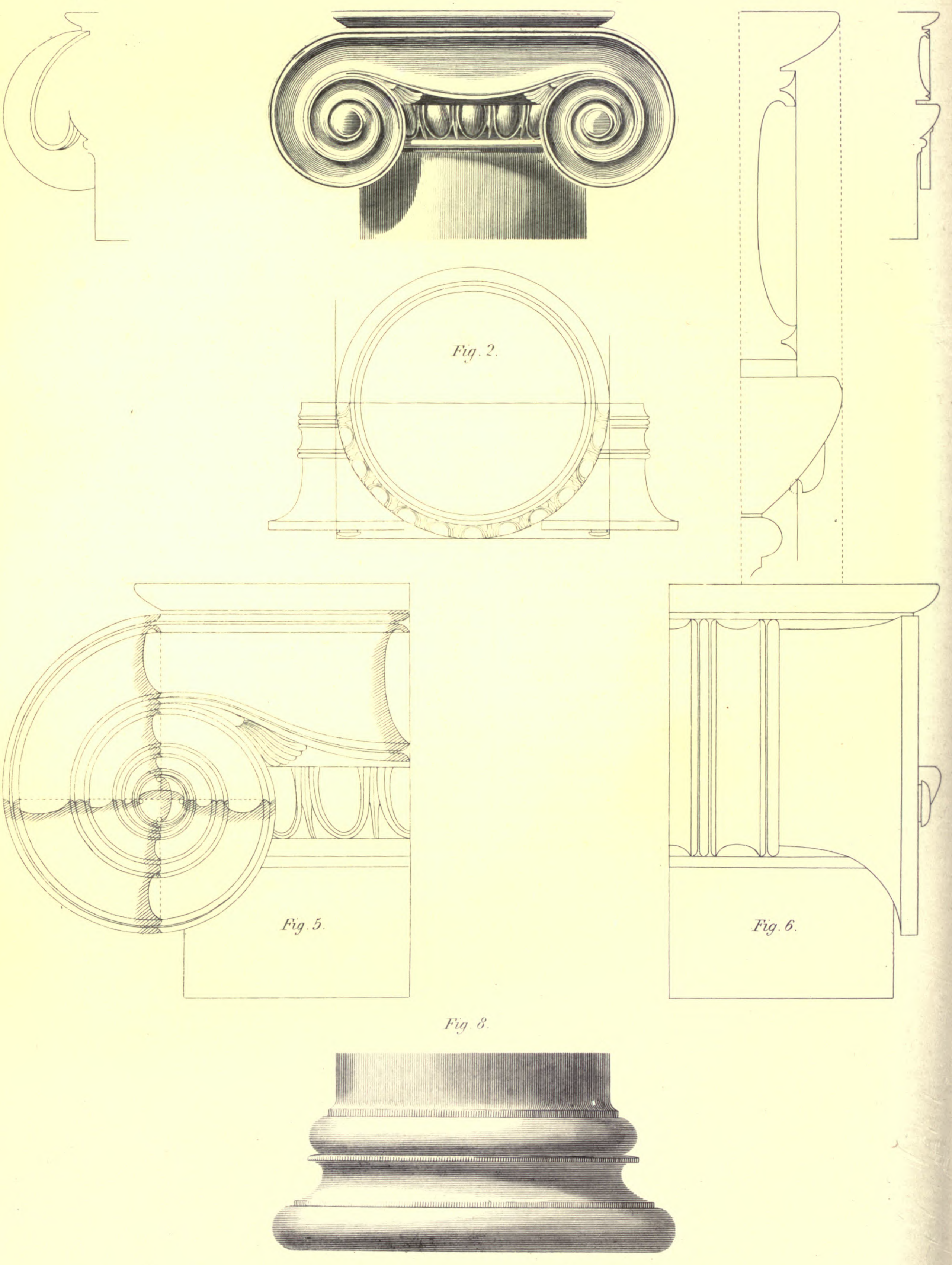
Fig. 4.
Fig. 1.
Fig. 7.
Fig. 3.
Fig. 2.
Fig. 5.
Fig. 6.
Fig. 8.

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In the first quadrant, take the length of the middle radius, *viz.* 18.3: set one foot of the compasses in 20, then describe an arc near to the centre; with the same radius set the foot of the compasses in 16.7, and describe an arc cutting the former; then, from the point of intersection, as a centre, describe an arc through all the three points 20, 18.3, 16.7. Proceed in the same manner with every quadrant, by taking the middle radius; and from the extremity of each outer radius, describe two arcs intersecting each other; and from the point of intersection, as a centre, with the same radius describe an arc through the two extremities, until you arrive at 2.4; then with radius 2.4 describe a circle for the eye, and the whole spiral will be completed.

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Plate II.—A volute drawn according to the preceding principles, consisting of three spirals; the numbers affixed round the outer spiral are supposed to be minutes, and consequently no other scale will be required than that of the order itself; but in drawing the two interior spirals, two new scales must be formed; or the scale of the order might be made to answer the purpose, by setting the proportional compasses in the ratio of the two radii, then taking the length of the radii from the scale with the long legs, and transferring the distances between the short legs to the spiral, and drawing the curve; so that the whole may be completed as before.

The volute in this Plate is similar to that of the Ionic temple at Athens, the temple of Bacchus at Teos, and that of Minerva Polias at Priene in Ionia.

Plate III. *Figure* 1.—A volute in imitation of that of the temple of Erechtheus, at Athens, drawn according to the preceding principles. It consists of eleven spirals, which may be all drawn from the scale of the order by the assistance of a pair of proportional compasses. But if this useful instrument is not in the hands of the delineator, the eleven scales are here exhibited at *Figure* 2, for drawing the same number of spirals.

An universal scale may be made, as in *Figure* 3, thus: describe an equilateral triangle, C A B, upon C B, equal to the greatest radius; divide C B into twenty equal parts, and draw straight lines from the points of division to A; produce C B to *b*, and make B *b* equal to one of the equal parts; divide B *b* into ten equal parts, and draw lines to A; then make A D and A E each equal to the first radius, and draw the line E D, which produce to meet A *b* at *d;* then E D *d* will give the scale for drawing the spiral required: E D being the scale of units, and D *d* that of tenths; and thus any other radius may be divided at once.

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Plate IV. shows a design for the capital and base of an Ionic column, with the details of capital and volute.

Figure 1.—Front view of the capital.

Figure 2.—Plan of the same.

Figure 3.—Profile or section through the front.

Figure 4.—Section through the flank.

Figures 5, 6, and 7.—Parts of the capital enlarged.

Figure 5.—Half of the front, showing the sections through the volute and through the front.

Figure 6.—Elevation of the flank.

Figure 7.—Section through the front.

Figure 8.—Elevation of the base of the column to the same scale as *Figure* 1.

VOUSSOIRS, the wedge-shaped stones forming the curvature or intrados of an arch.

W.

WAGGON-HEADED ceiling, a semi-cylindrical, or barrel-ceiling, not uncommon in churches of the Gothic style.

WAINSCOT, (from the Dutch *wayschot*,) in joinery, the lining of walls, constructed of wood, and most generally panelled.

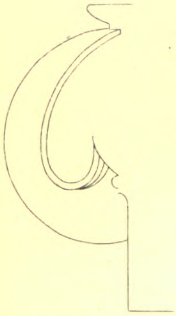
The term *wainscoting*, as applied to the lining of walls, originated in a species of foreign oak of the same name, used for that purpose; and although that has long been superseded by the introduction of fir-timber, the term has been continued notwithstanding the change of the material.

Wainscoting is generally used for the lining of walls to the height of about 5 or 6 feet; and when it does not reach the whole height, it is called *dwarf wainscoting*.

To prevent the joints of panels from opening in consequence of the glue being softened or consumed by damps from the walls, the back of the wainscot ought to be primed over at the joint with white lead, or Spanish brown, and linseed oil.

The method of measuring wainscot is, to multiply the length by the breadth, and find the number of square yards; the price is adjusted according to the difficulty of the work, or the time required to perform it. *See* CARPENTRY and JOINERY.

Fig. 4.



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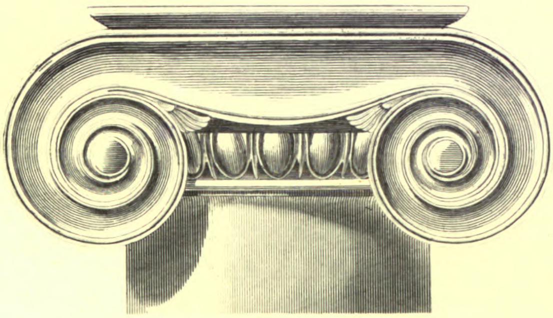

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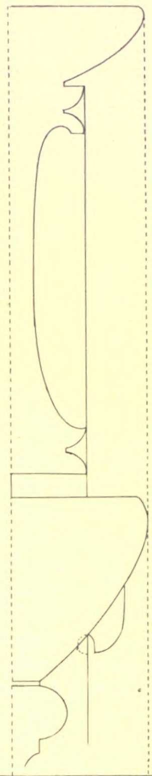

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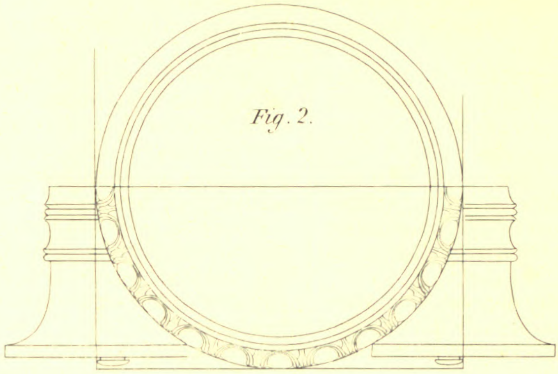

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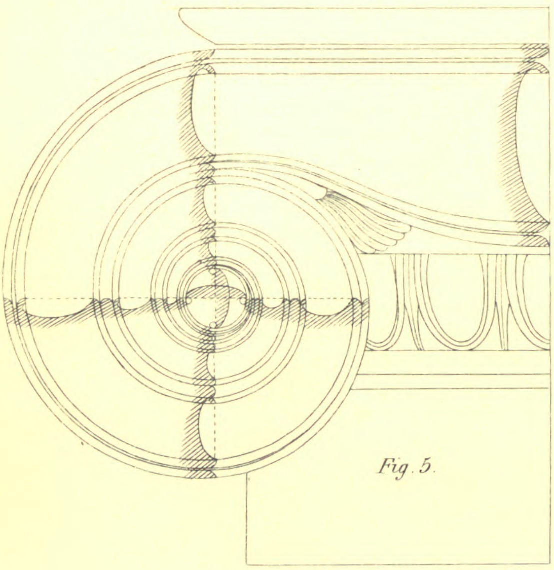

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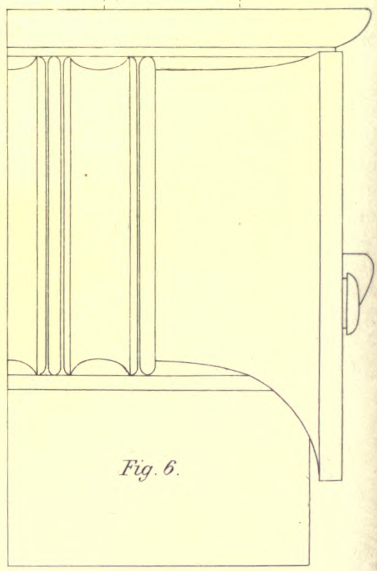

Fig. 6.

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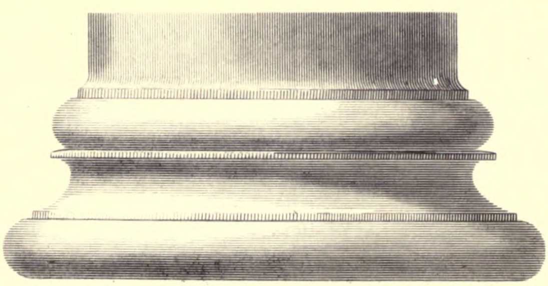

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Figures 5, 6, and 7.—Parts of the capital enlarged.

Figure 5.—Half of the front, showing the sections through the volute and through the front.

Figure 6.—Elevation of the flank.

Figure 7.—Section through the front.

Figure 8.—Elevation of the base of the column to the same scale as *Figure* 1.

VOUSSOIRS, the wedge-shaped stones forming the curvature or intrados of an arch.

W.

WAGGON-HEADED ceiling, a semi-cylindrical, or barrel-ceiling, not uncommon in churches of the Gothic style.

WAINSCOT, (from the Dutch *wayschot*,) in joinery, the lining of walls, constructed of wood, and most generally panelled.

The term *wainscoting*, as applied to the lining of walls, originated in a species of foreign oak of the same name, used for that purpose; and although that has long been superseded by the introduction of fir-timber, the term has been continued notwithstanding the change of the material.

Wainscoting is generally used for the lining of walls to the height of about 5 or 6 feet; and when it does not reach the whole height, it is called *dwarf wainscoting*.

To prevent the joints of panels from opening in consequence of the glue being softened or consumed by damps from the walls, the back of the wainscot ought to be primed over at the joint with white lead, or Spanish brown, and linseed oil.

The method of measuring wainscot is, to multiply the length by the breadth, and find the number of square yards; the price is adjusted according to the difficulty of the work, or the time required to perform it. *See* CARPENTRY and JOINERY.

WALL-PLATE, a piece of timber placed in or upon a wall to receive the ends of joists or rafters.

WALLS, (perhaps from the Latin *vallum*, a fence,) those masses of materials which generally have their faces in vertical or plumb-lines; or, at least are so disposed, that a plumb-line from any point in either surface will fall entirely within the surface, or within the thickness of the wall.

In walls constructed for shelter, if the materials cannot be joined without interstices, those interstices ought to be so closed as to render the work impervious to rain or drift.

The materials with which walls are generally constructed are brick or stone. Some walls may be built either of rough or squared stones. When the exterior walls of dwelling-houses are to be constructed of rough stone, the stones ought to be laid in mortar; but when they are squared and smoothed, this is not necessary. The ancients, in building their edifices with squared stones, seldom laid them in mortar; but their joints and beds were so exactly wrought, as to come nearly in contact with each other. *See* Stone Walls.

As bricks cannot be formed so regularly as stones, on account of the burning, they are usually laid in mortar. *See* Bricklaying and Brickwork.

From the definition given of a wall, founded upon the axiom, that every material which overhangs has a tendency to fall, or to break off, or to overturn the structure of which it is a part, it is evident, that as a wall rises it ought either to diminish in its thickness, or to follow the plumb-line.

Walls common to two apartments are called *partition walls*, or simply *partitions*. When a wall is divided or separated by ornaments, apertures, or projections, it is said to be *intermitted;* but if uninterrupted, it is called *a continued wall.* It is, however, generally understood, that when a wall has apertures without projections, as columns and pilasters, it is said to be *continued*, which is contradictory to the common acceptation of the term.

Walls, *Abutments in*, the beds that are prepared for the springing of an arch.

Walls, *Cased*, those that are faced up anew all round the building, in order to cover an inferior material, or old work gone to decay.

Walls, *Emplecton*, those which are built in regular courses, with the stones smoothed in the face of the work: they are of two kinds, Roman or Grecian. The difference is, that the core of the Roman emplecton is rubble; whereas in the Grecian it is built in the same manner as the face, and every alternate stone goes through the entire thickness of the wall.

Walls, *Isodomum*, those where the courses are of equal thickness, compact, and regularly built; but the stones are not smoothed on the face.

Walls, *Pseudo-isodomum*, those which have unequal courses.

For other particulars respecting walls, *see* the articles above referred to; also Building, Pise, and Mensuration.

WATER-CLOSET, an apartment so generally known as to render any definition of it unnecessary. There are no good houses without one or more of them. Their construction belongs entirely to the engineer: the chief thing which the architect has to attend to is, to place his water-closets in such a situation as to be isolated from the principal apartments, to conceal them from general observation, and to make them as accessible as possible. The number of water-closets in a house ought to be in proportion to the magnitude of the building; in large mansions, a certain number of water-closets must be appropriated to the servants, as well as to the family itself. One of the principal things which the architect must attend to is, to prevent all recoil or return of noxious effluvia.

Water Shoot, a wooden trough for discharging rain-water from a building.

Water Table, the upper surface of a coping, or projection, where the superior part of a wall recedes from the inferior or lower part.

Water tables are frequently used in edifices of the pointed style, particularly near the base of the building: as in buttresses consisting of several stages, where the sloping parts, which cover the solids below, are called *water-tables.*

WAY-WISER. *See* Perambulator.

WEATHER BOARDING, signifies the nailing up of boards lapped upon each other, so as to prevent rain or drift from passing through. For this purpose, the boards are generally made thinner on one edge than on the other; particularly when the work is intended to be permanent: the boards thus formed are called *feather-edged boards.* In using feather-edged boards, the thick edge of the upper board is laid upon the thin edge of the board below, about an inch over, or, in very secure work, an inch and a half, the nails being driven through the lap.

WEATHERING, a slight inclination given to copings or ledges of walls, for the purpose of throwing off the rain.

WEATHER MOULDING, a moulding carried over a door or window, for the purpose of diverting rain-water from the parts beneath; otherwise termed *drip-stone*, or *label.*

Weather Tiling, the covering of an upright or wall with tiles.

WEDGE, (from the Danish *wegge.*) Writers on mechanics, in treating of the wedge, have frequently drawn false conclusions respecting the proportion which exists between the impelling power applied to the head, and the resisting powers opposed to the sides; and those conclusions have resulted from false opinions concerning the directions of the resisting powers.

It is evident, that when wood or other substance is split by a wedge which does not fill the cleft, that is, when the angle of the cleft is more acute than that of the wedge, the power or action of each side of the wedge, equal and opposite to the resistance of the cleft, must be resolved into two; the one in the direction of the side of the cleft, which tends to thrust it forward; and the other perpendicular to that direction, which tends to tear it asunder. It is by not attending to the above solution, that writers on this subject have been led into mistakes; for, instead of considering the powers which act in those two directions, they have imagined a single power only as acting obliquely on each side. But if the sides of the wedge are perfectly polished, as we must here consider them, no single permanent power can be applied to impel any one of them, unless its direction be perpendicular to the plane of the side to which it is applied; therefore, two oblique powers, applied on opposite sides of the same point, are at least necessary to sustain each other and the action of the plane; and in the case of the wedge above mentioned, the directions of those two oblique powers will always be perpendicular to each other, as will appear obvious from the two following Propositions.

Proposition I. *Figure* 1.—Let A B C be a vertical section passing through the centre and at right angles to the head and sides of any isosceles wedge; also in the plane of this section, and at right angles to its sides, A B, B C, and C A, let three powers be applied, such, that their directions may all mutually intersect in the axis, and their efforts sustain the wedge in equilibrio; which three powers are as A B, B C, and C A, respectively.

Let L M, K I, E D be the directions of these three powers, which, produced, intersect each other and the axis in O. Since, by hypothesis, these three powers directed to the same point are in equilibrio, and the three sides of the triangle A B C are at right angles to their directions; therefore, by a well-known statical principle, the intensities of these two powers are as A B, B C, and C A respectively.

PROPOSITION II.—When an impelling power applied to the head of an isosceles wedge is in equilibrio with the resisting power of a cleft, the angle of which is more acute than that of the wedge inserted, then, universally,

The impelling power applied to the head,
The action of the wedge on either side of the cleft,
The part thereof which tends to thrust it forward,
And the remaining part, which tends to tear it asunder,
Are
As twice the sine of half the vertical angle of the wedge,
The radius,
The sine of the angle contained by the sides of the wedge and cleft,
And the cosine of that angle, respectively; the same radius being common.

Figure 2.—Let A B C represent a vertical section of the wedge and cleft, similar in position to that described in Proposition I.; also let the two sides of the cleft D H, D H, be equal, and in contact with the sides of the wedge A C, A C, at equal distances, D C, D C, from the vertex C, in which case the sides of the wedge make equal angles with those of the cleft. Through either point D, draw D F, at right angles, and equal to A C; also through D draw D E, at right angles to D H, and complete the parallelogram D E F G. Then, by Proposition I. the line A A represents in quantity the impelling power applied to the head, and the line D F represents in quantity and direction the whole action of the side of the wedge on that of the cleft, which, by hypothesis, is balanced by its resistance; but the power D F is resolved into two, represented in quantity and direction by D G, D E, respectively: the one, being in the direction of the cleft, tends to thrust it forward; and the other, being at right angles thereto, tends to tear it asunder,

Therefore the powers mentioned in the Proposition are as A A, D F, D G, and D E, respectively; but as A C=D F, being radius, these lines are respectively equal to
Twice the sine of half the vertical angle of the wedge,
The radius,
The sine of the angle contained by the sides of the wedge and cleft,
And the cosine of that angle. Hence the proposition is manifest.

WEIGHT, in mechanics, denotes anything to be raised, sustained, or moved, by a machine, as distinguished from the power, or that by which the machine is put in motion.

WEIGHT, in commerce, denotes a body of a known weight, appointed by law to be the standard of comparison between different quantities of merchandise of certain descriptions; the weight itself being usually of lead, iron, brass, or other metal.

The great diversity of weights and measures, in all nations, for different kinds of commodities, has always been a just subject of regret and complaint; being the cause of various disputes and deceptions, which it is almost impossible to avoid under present circumstances. And it is therefore much to be wished, though perhaps little to be expected, that one uniform system of weights should be adopted as applicable to all kinds of substances; an attempt at which was made in France during the revolution, but which was afterwards laid aside by an imperial decree, in consequence of the repeated remonstrances of people in trade; so difficult is it to overcome prejudices and customs long established, however advantageous the change may be when properly understood.

In the reign of king Richard I. it was ordained, that there should be only one weight and one measure throughout England; and in the *Phil. Trans.* No. 458, p. 457, we find an account of the analogy between English weights and measures drawn up by Mr. Barlow; in which he states, that anciently the cubic foot of water was assumed as a general standard for all liquids. This cubic foot, of 62½ lb. multiplied by 32, gives 2000 lb. the weight of a ton; and hence 8 cubic feet of water made a hogshead, and 4 hogsheads a tun, or ton, in capacity and denomination, as well as weight.

Dry measures were raised on the same model. A bushel of wheat, assumed as a general standard for all sorts of grain, also weighed 62½ lb. Eight of these bushels make a quarter; and 4 quarters, or 32 bushels, a ton. Coals were likewise sold by the chaldron, supposed to weigh a ton, or 2000 lb., though in reality it probably weighs upwards of 3000 lb.

This principle, though not sufficiently accurate in some cases, was extremely obvious, and might have been improved so as to answer all the purposes of commerce; but unfortunately, instead of rendering it more simple, it has been made infinitely more complicated by the different weights since introduced.

Modern European Weights.—1. English weights. By the twenty-seventh chapter of *Magna Charta*, the weights all over England are to be the same; but for different commodities there are two different sorts, viz.: Troy weight and Avoirdupois weight. The origin from which they are both raised is, a grain of wheat gathered in the middle of the ear.

In Troy weight, 24 of these grains make 1 pennyweight sterling; 20 pennyweights make 1 ounce; and 12 ounces 1 pound.

By this weight we weigh gold, silver, jewels, and liquors. The apothecaries also use the Troy pound, ounce, and grain: but they divide the ounce into 8 drachms, the drachm into 3 scruples, and the scruple into 20 grains.

In Avoirdupois weight, the pound contains 16 ounces, but the ounce is less by near one-twelfth than the Troy ounce; this latter containing 480 grains, and the former only 437½. The ounce contains 16 drachms; 80 ounces Avoirdupois are only equal to 73 ounces Troy; and 17 pounds Troy are equal to 14 pounds Avoirdupois.

By Avoirdupois weight are weighed meat, grocery wares, base metals, wool, tallow, hemp, drugs, bread, &c.

Comparison between Troy and Avoirdupois Weight.

175 Troy pounds are equal to 144 Avoirdupois pounds.
175 Troy ounces are equal to 192 Avoirdupois ounces.
1 Troy pound contains 5760 grains.
1 Avoirdupois pound contains 7000 grains.
1 Avoirdupois ounce contains 437½ grains.
1 Avoirdupois drachm contains 27.84375 grains.
1 Troy pound contains 13 ounces, 2.651428576 drachms Avoirdupois.
1 Avoirdupois pound contains 1 lb. 2 oz. 11 dwts. 16 gr. Troy.

Therefore the Avoirdupois lb. is to the lb. Troy as 175 to 144, and the Avoirdupois oz. is to the Troy oz. as 437½ to 480.

Goldsmiths, jewellers, &c., have a particular class of weights, viz.: for gold and precious stones, the carat and grain; and for silver, the pennyweight and grain. In the mint, they have also a peculiar subdivision of the Troy grain: thus dividing

the grain into 20 mites,
the mite into 24 droits,
the droit into 20 periots,
the periot into 54 blanks.

The dealers in wool have likewise a particular set of weights, viz.: the sack, weigh, tod, stone, and clove; the proportions of which are as follow:

the sack contains 2 weighs,
the weigh $6\frac{1}{2}$ tods,
the tod 2 stones,
the stone 2 cloves,
the clove 7 pounds.

Also 12 sacks make a last, or 4368 pounds.

Farther,

56 lb. of old hay, or 60 lb. new hay, make a truss.
40 lb. of straw make a truss.
36 trusses make a load of hay or straw.
14 lb. make a stone.
5 lb. of glass a stone.

Other nations have also certain weights peculiar to themselves: thus, Spain has its arrobas, containing 25 Spanish pounds, or one-fourth of the common quintal: its quintal macho, containing 150 pounds, or one-half of the common quintal, or 6 arrobas; its adarme, containing one-sixteenth of its ounce. And for gold, it has its castillan, or one-hundredth of a pound; and its tomin, containing 12 grains, or one-eighth of a castillan. The same are in use in the Spanish West Indies.

Portugal has its arroba, containing 32 Lisbon arratals, or pounds. Savary also mentions its faratelle, containing 2 Lisbon pounds; and its rottolis, containing about 12 pounds. And for gold, its chego, containing 4 carats. The same are used in the Portuguese East Indies.

Italy, and particularly Venice, have their migliaro, containing 4 mirres; the mirre containing 30 Venice pounds; the saggio, containing a sixth part of an ounce. Genoa has five kinds of weights, viz.: large weights, whereby all merchandizes are weighed at the custom-houses; cash weights for piasters, and other specie; the cantara, or quintal, for the coarsest commodities; the large balance for raw silks, and the small balance for the fine commodities. Sicily has its rottolo, equal to $32\frac{1}{2}$ pounds of Messina.

Germany, Flanders, Holland, the Hanse-towns, Sweden, Denmark, Poland, &c., have their schippondt, which, at Antwerp and Hamburgh, is 300 pounds; at Lubeck, 320; and at Konigsberg, 400 pounds. In Sweden the schippondt for copper is 320 pounds; and the schippondt for provisions 400 pounds. At Riga and Revel, the schippondt is 400 pounds; at Dantzic, 340 pounds; in Norway, 300 pounds; at Amsterdam, 300, containing 20 lysponts, each weighing 15 pounds. In Moscow they weigh their large commodities by the bercheroet, or berkewits, containing 400 of their pounds. They have also the poet, or poede, containing 40 pounds, or one-tenth of the bercheroet.

In order to show the proportion of the several weights used throughout Europe, we shall add a reduction of them to one standard, viz.: the London pound.

Proportion of the Weights of the principal Places in Europe.

The 100 lb. of England, Scotland, and Ireland, are equal to

lb.	oz.	
91	8	of Amsterdam, Paris, &c.
96	8	of Antwerp or Brabant.
88	0	of Rouen, the viscounty weight.
106	0	of Lyons, the city weight.
90	9	of Rochelle.
107	11	of Toulouse and Upper Languedoc.
113	0	of Marseilles or Provence.
81	7	of Geneva.
93	5	of Hamburgh.
89	7	of Frankfort, &c.
96	1	of Leipsic, &c.
137	4	of Genoa.
132	11	of Leghorn.
153	11	of Milan.
152	0	of Venice.
154	10	of Naples.
97	0	of Seville, Cadiz, &c.
104	13	of Portugal.
96	5	of Liege.
112	$0\frac{2}{3}$	of Russia.
107	$0\frac{1}{24}$	of Sweden.
89	$0\frac{1}{2}$	of Denmark.

Proportion of the Weights of several Places in Europe compared with those of Amsterdam.

The 100 lb. of Amsterdam, are equal to

lb.	
105	of Antwerp.
100	of Bayonne and Paris.
$95\frac{1}{4}$	of Bergen in Norway.
151	of Bologna.
103	of Bremen.
125	of Breslaw.
105	of Cadiz.
107	of Copenhagen.
97	of Dublin and Edinburgh.
109	of London.
114	of Madrid.
169	of Naples.
109	of Riga.
146	of Rome.
110	of Stettin.
182	of Venice.

Comparison of English and Foreign Weights.

English Weights.

Troy Weight.

lb.	oz.	scrup.	drs.	grains.	grammes
1 =	12 =	96 =	283 =	5760 =	372.96
	1 =	8 =	24 =	480 =	31.08
		1 =	3 =	60 =	3.885
			1 =	20 =	1.395
				1 =	0.06475

Avoirdupois Weight.

lb.	oz.	drs.	grains.	grammes.
1 =	16 =	256 =	7000 =	453.25
	1 =	16 =	437.5 =	28.32
		1 =	27.975 =	1.81

German.

71 lb. or grs. English Troy = 74 lb. or grs. German apothecaries' weight.
1 oz. Nuremburg, medic. weight = 7 dr. 2 scru. 9 grains English.
1 mark Cologne = 7 oz. 2 dwt. 4 gr. English Troy.

Dutch.

1 lb. Dutch = 1 lb. 3 oz. 16 dwt. 7 gr. English Troy.
$787\frac{1}{2}$ lb. Dutch = 1038 lb. English Troy.

Swedish Weights, used by Bergman and Scheele.

The Swedish pound, which is divided like the English apothecary's, or Troy pound, weighs 6556 grains Troy.

The kanne of pure water, according to Bergman, weighs 42250 Swedish grains, and occupies 100 Swedish cubic inches. Hence the kanne of pure water weighs 48088.719444 English Troy grains, or is equal to 189.9413 English cubic inches; and the Swedish longitudinal inch is equal to 1.238435 English longitudinal inch.

From these data the following rules are deduced :—

1. To reduce Swedish longitudinal inches to English, multiply by 1.2384, or divide by 0.80747.

2. To reduce Swedish to English cubic inches, multiply by 1.9, or divide by 0.5265.

3. To reduce the Swedish pound, ounce, drachm, scruple, or grain, to the corresponding English Troy denomination, multiply by 1.1382, or divide by 0.8786.

4. To reduce the Swedish kannes to English wine pints, multiply by 0.1520207, or divide by 6.57804.

5. The lod, a weight sometimes used by Bergman, is the 32d part of the Swedish pound: therefore, to reduce it to the English Troy pound, multiply by .03557, or divide by 28.1156.

Correspondence of English Weights with those used in France before the Revolution.

The Paris pound (poids de marc of Charlemagne) contains 9216 Paris grains: it is divided into 16 ounces, each ounce into 8 gros, and each gros into 72 grains. It is equal to 7561 English Troy grains.

The English Troy pound of 12 ounces contains 5760 English Troy grains, and is equal to 7021 Paris grains.

The English Avoirdupois pound, of 16 ounces, contains 7000 English Troy grains, and is equal to 8538 Paris grains.

To reduce Paris grains to English Troy grains, divide by..........	1.2189
To reduce English Troy grains to Paris grains, multiply by..........	
To reduce Paris ounces to English Troy, divide by..........	1.015734
To reduce English Troy ounces to Paris, multiply by..........	

Or the conversion may be made by means of the following tables

I. *To reduce French to English Troy Weight.*

The Paris pound	=	7561	English Troy grains.
The ounce	=	472.5625	
The gros	=	59.0703	
The grain	=	.8204	

II. *To reduce English Troy to Paris Weight.*

The English Troy lb. of 12 oz.	=	7021.	Paris grains.
The Troy ounce	=	585.0893	
The drachm of 60 grains	=	73.1354	
The dwt. or dernier of 24 grains	=	29.2541	
The scruple of 20 grains	=	24.3784	
The grain	=	1.2189	

III. *To reduce English Avoirdupois to Paris Weight.*

The Avoirdupois lb. of 16 oz. or 7000 Troy grains	=	8538	Paris grs.
The ounce	=	533.6250	

The following is a Table of Weights, according to the new French system :

Names.	French value.		English value.
Millier......	1000 kilogrammes = 1 French ton.......	=	19.7 cwts.
Quintal	100 kilogrammes..	=	1.97 cwts.
Kilogramme...	Weight of one cubic decimeter of water of the temperature of 39° 12′ Fahrenheit		2.6803 lbs. troy. 2.5055 lbs. avoir.
Hectogramme	$\frac{1}{10}$th of kilogramme...	=	3.2 ozs. troy. 3.52 ozs. avoir.
Decagramme	$\frac{1}{100}$th of kilogramme ..	=	6.43 dwts. troy.
Gramme....	$\frac{1}{1000}$th of kilogramme..	=	15.438 grs. troy. 0.643 dwt. 0.032 ounce troy
Decigramme	$\frac{1}{10000}$ of kilogramme ..	=	1.5438 grains troy.

See also the article MEASURE.

WEIGHTS OF A SASH, two weights by which the sash is suspended, and kept steady in any situation it is put into, by means of cords passing over pulleys. The two vertical sides of the sash-frame are generally made hollow, in order to receive the weights, which by this means are entirely concealed : and thus, to keep the sash in suspension, each weight must be exactly half the weight of the sash. The cords must be of the best quality, otherwise they will soon fret to pieces.

WEIR, a dam placed across a river or stream, for the purpose of ponding back a portion of the water.

WELCH-GROINS, those formed by the intersection of two semi-cylindrical vaults, one of which is of less height then the other.

WELDING, the method of joining two pieces of metal by means of heat, by which they are brought nearly to a state of fusion.

WELL-HOLE, in building, a term differently understood by workmen and writers: by some, the whole space enclosed by the walls of a staircase is called the *well-hole;* by others, it is used only for the space left in the middle at the ends of the steps in a geometrical staircase. In strict propriety, the whole apartment in which the stairs are placed ought to be called *the well ;* and the void formed by the ends of the steps *the well-hole.*

WHEEL, (from the Saxon, *wheol,*) in mechanics, an engine consisting of a circular body turning on an axis, for enabling a given power to overcome or move a given weight or resistance. This machine may be referred entirely to the LEVER, which see.

WHEEL-WINDOW, a circular window, common in Lombardic and Gothic buildings; otherwise termed a ROSE or CATHERINE-WHEEL window.

WHETSTONE, a stone of a very fine quality, by which tools for cutting wood are brought to a fine edge, after being ground upon a grit-stone, or grinding-stone, to a rough edge.

WICKET, (from the Dutch,) a small door made in a gate.

WIND BEAM, an obsolete name for a COLLAR BEAM: *see* that article.

WINDERS, those stairs by which, in a continuous flight, the direction of ascent is changed, the risers being disposed as radii of a circle, and the treads in consequence being narrower at one end than the other; the width of the treads at the centre should be the same as that of the *flyers. See* STAIRS.

WINDING-STAIRS, those which wind round a central newel, or a circular well-hole. *See* STAIRS.

WINDLASS, or WINDLACE, a machine for raising weights, in which a cope or chain is wound about a cylindrical body, moved by several levers.

Also a handle, by which anything is turned.

WINDOWS, (from the Danish, *vindue*, or the Welsh *wynt dor*, a passage for the wind,) those apertures in walls through which light is transmitted to the interior of buildings.

Windows are generally of a rectangular form, the sides, or jambs, being vertical, and the bottom and lintel horizontal. Semicircular windows have a very elegant effect, particularly in circular buildings, as was generally the practice of the Romans; but those that are finished with segments, or semi-ellipses, are not so beautiful; and much less so are such as are constructed of entire circles or ellipses, for which, few or no precedents are to be found in the buildings of the ancients.

Windows must be proportioned in height and width to the principal rooms. The dressings of windows are the sill, and the insisting architrave, surrounding the upper part, crowned by a cornice and frieze. The breadth of the architrave may be one-sixth of that of the aperture; the frieze the same; the height of the cornice will depend upon the number of mouldings.

Windows should be so placed with respect to the principal room, or dining and drawing-rooms, as to be equally distant from each end of the apartment, and equidistantly distributed in the principal front, of one size, with their edges or sides in the same vertical lines. This adjustment will frequently be attended with difficulties; and to accommodate the principle, an alteration of the proportions, in a small degree, will sometimes be necessary. In houses of the middle class, where economy is an equal consideration with elegance or beauty, the windows frequently reach as high as the cornice, or even so high as to cut the cornice, wholly, or in part; a mutilation that destroys the beauty of the finishing. In such cases, it would be better to have more lofty stories, or lower windows. In large edifices, where proportions are considered, the spaces above the windows are more ample, and allow a more elegant finish, with a greater repose for the eye. Further particulars respecting windows will be found under APARTMENT, BUILDING, CASEMENT, HOUSE, JOINERY, SASH-FRAME, and SKYLIGHT. *See* also TRACERY, and GOTHIC ARCHITECTURE, &c.

Plate 1. *Figure* 1.—A window finished in the usual manner. No. 1. The elevation. No. 2. The flank.

Figure 2. The elevation of a window, where, the thickness of the wall not being sufficient to allow of boxings, the shutters are hinged upon a hanging style.

Figure 3.—The section of the foregoing.

Figure 4.—Section and plan of the sash-frame and shutters of a window, showing the same finishing, whether the shutters be folded in their boxings to admit light, or extended to their breadth upon the sashes to exclude it.

Figure 5.—Plan and section of the lower sash shutters and boxings of a common window, showing the nature of the work.

WINDOW-SHUTTERS, the wooden doors by which windows are occasionally closed, or secured. *See* BOXINGS, JOINERY, and SASH-FRAME.

WING, the outlying and returning ends of a building.

WITHS, (from the Saxon,) the partitions of flues. *See* CHIMNEY.

WOOD, (from the Saxon *wude*,) a fibrous material, of the greatest use in building, formed into shape by edge-tools. For a description of the different kinds of wood as applicable to building, see the articles TIMBER and MATERIAL; and for the method of measuring it, *see* MENSURATION, towards the end. *See* also SEASONING OF TIMBER, and STRENGTH OF MATERIALS.

WOOD BRICKS, blocks of wood cut to the form and size of bricks, inserted in the interior walls of apartments, as holds for the joinery.

WOODEN BRIDGES, are platforms constructed of carpentry, for crossing streams, rivers, roads, &c. These bridges may be looked upon as the origin of all such constructions, whether of stone, wood, or iron. In early times it may fairly be supposed, that trees, or planks made from them, would be thrown from one bank of the stream to the other, so as to serve for a footway, by which a passage might be effected. This might have been suggested in the first instance by accident, either by a tree falling in that position, or else by its growing across a stream, as sometimes happens with willows, &c. A plank placed from one bank of a stream to another, is the simplest form of a timber bridge; it is at the same time the most perfect; and the principle on which it is suspended, or kept in its proper position, is worthy of consideration, for we may learn how to construct the best and most advantageous kind of bridge, suitable for immense spans, from this unpretending, and apparently unpremeditated contrivance.

When a strong plank is thus laid upon two supports, that part of it which lies midway between them, has to sustain its own weight, together with the transit load which it has to bear, such as that of anything crossing over it, by the cohesion between its particles, for as that part of the plank has nothing to rest upon, it is therefore clear, that it has a tendency to break somewhere between the points of support when the strain becomes very great upon it; but owing to this cohesion of the particles, which attracts them to one another, such a plank cannot snap asunder, because the fibres of the timber of which it is formed, are so interwoven, that one particle or atom of the material will not readily be separated from its fellow, as long as such material remains in a sound state. This being the case, the effect of the weight upon the beam will cause it to bend, or what is technically termed, to sag, but in order to this, it will be necessary that the fibres on the under side of the beam should first be drawn out, or lengthened, that is, subjected to a tensile strain, while on the contrary, those on the upper surface will be forced to contract, or become shorter, in other words, they will be pressed upon longitudinally, and thus be subjected to a compressive force. It is also evident, that there must be some intermediate plane between the upper and lower surfaces of the beam, where the two opposite contending forces will meet, in which, of course, neither will preponderate; this, which is denominated the neutral plane, is situated lower or higher, according to the depth of the beam, the homogeneity and cohesion of the material of which it is composed, and a variety of other considerations. As a general formula for finding the weight with which it would be advisable to load such a beam, we may give the following,

$w = \dfrac{2\,b\,d^2 s}{3\,l}$ where w is the weight in lbs. with which the beam may be loaded, including that of the beam itself, b its breadth in inches, d its depth in inches, l its length in inches and s some known constant, representing the calculated strength of the kind of timber, or other material, employed. That of larch has been estimated at 280, Riga fir at 376, English oak 400, Mar Forest fir 415, red pine 447, pitch pine 544, Canadian oak 588, ash 675, teak 820. When the inertia of such a bridge is small, the deflection, or sagging, of the beam is found to depend upon a

WINDOWS.

Fig 1 N° 1

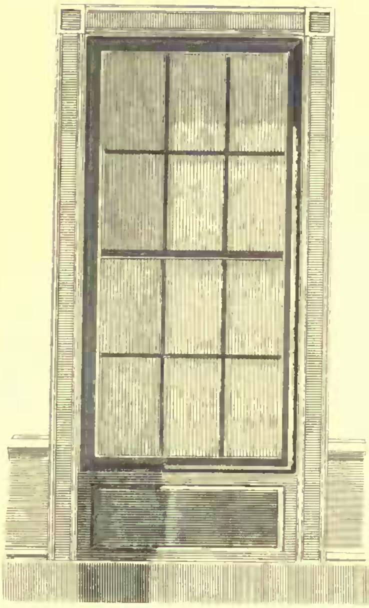


Fig 1 N° 2

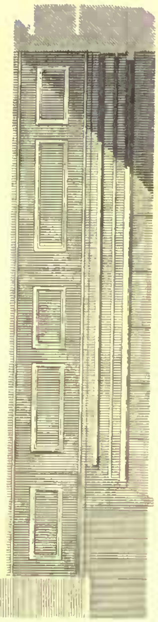


Fig 2

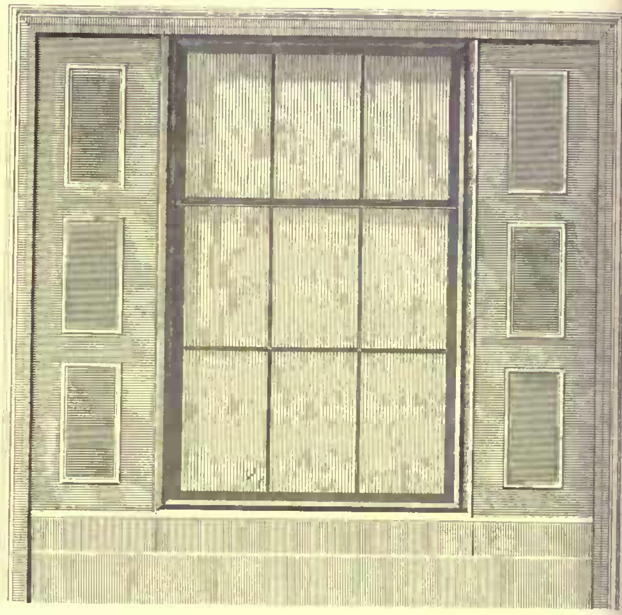


Fig. 3.

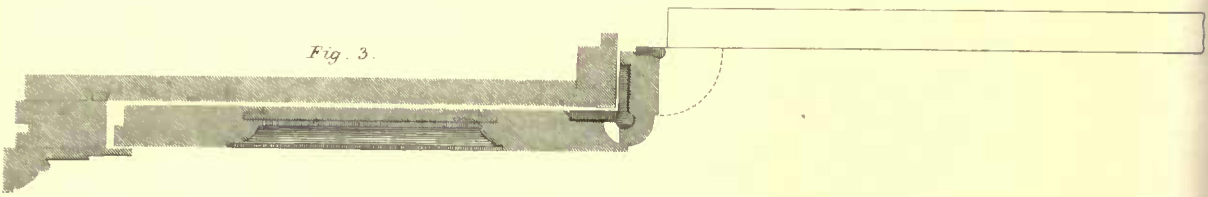


Fig. 4.

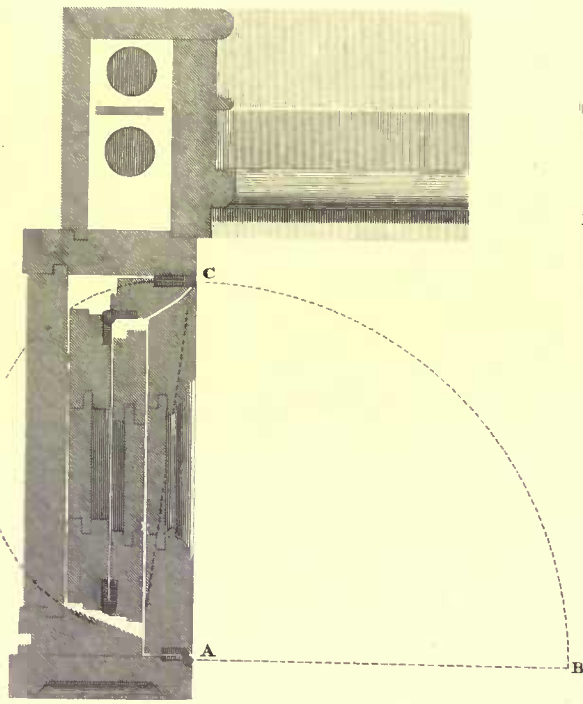
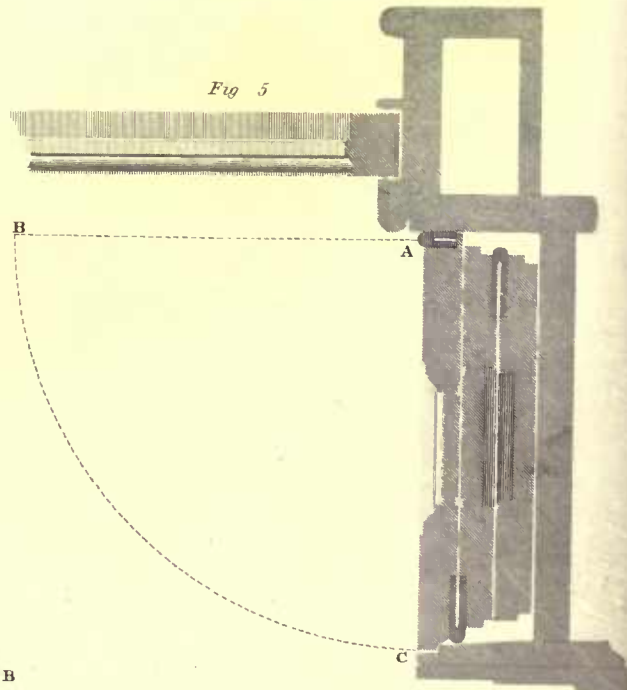


Fig 5



Drawn by P. Nicholson.

Eng^d by R. Thew

certain quantity, which varies directly as the square of its length, and inversely as the product of the central statical deflection, (that is, the amount of deflection which would take place if all the load were placed at the centre of the beam,) and with the square of the velocity with which the load passes over the bridge.

In a bridge, therefore, constructed with a single beam, there are two counteracting forces, which, by mutually neutralizing each other, prevent the beam of which it consists from yielding; this constitutes what is called the rigidity of the timber, which thus opposes an obstacle to its bending, and which is increased in the direct proportion of the square of the depth and inversely as its length within certain limits, provided it is not loaded to more than a third of its calculated capability, which is taken into consideration in the above formula. This form of bridge merely rests upon its abutments, or piers, pressing vertically upon them. It exerts no force tending to overturn or push against them in an oblique direction. In this consists its superiority over bridges which are constructed solely on the principle of compression, such as arched bridges in general, or bridges formed completely on the principles of tension, as in the case of suspended bridges, in both of which it is necessary to introduce some countervailing weight or pressure, so as to resist the tendency which both those descriptions of bridges have of oversetting their supports. This adds greatly to their complicated nature, and consequently to the difficulty of their construction, involving, as it does, nice calculation, founded upon careful observation and experiment.

It may be said, if such advantages are gained by forming bridges in this simple manner, why not have adhered to their principle all along, instead of adopting difficult and intricate plans of construction, which give rise to great additional expense, besides making the subject so much more involved and uncertain? but on the other hand, it must be remarked, that independently of the short duration of timber in comparison of stone, iron, &c., where large spans have to be crossed, it cannot always be obtained of sufficient dimensions, as respects length and depth, and besides, in some localities, a supply of such timbers is not always to be obtained; and even in those where a great quantity was at one period to be found, the very fact of a large consumption leads to a deficiency in the course of time, and trees of a later growth and smaller scantling would necessarily come to be used; and further, in connexion with the application of beams to large spans, it must be borne in mind, that where the distance between the supports becomes greater, the dimensions require to be augmented, and that when the size is increased in an arithmetical proportion the weight is added in a much greater ratio. Under these circumstances, it may easily be conceived, that beam or girder bridges could only be employed within certain circumscribed limits; now, however, that the Britannia Tube has originated the system of building up hollow beams, by which their strength may be made sufficient for the work required of them, without adding so enormously to their weight, we may expect to see wooden-bridges, formed of hollow beams, taking the place of rib and arched timber bridges, and indeed, in some instances superseding both stone and iron, as being calculated for much larger spans than have hitherto been attempted, and capable of being constructed at a comparatively small cost.

But to go back to the history of wooden bridges, we will find that where rivers were broad, and their channels deep, it would be impossible to cross them by single beams of timber. In such cases, a timber framing or scaffolding would be formed in the bed of the river, by driving piles, or a pier might be formed of stones, or other materials. On these, beams of timber would be placed, with one extremity resting on the pier, and the other on the bank of the river, or on an abutment raised at the water's edge, and upon several piers in the water, as the case might be. Where the distance between the supports were too great for the dimensions of the timber forming the roadway, the main beams were propped up by struts projecting from the sides of the piers or piles, which were sometimes made to meet in the centre, or if that was not practicable on account of the distance between the supports, they could each be made to sustain the beam, and a cross-piece on which their ends should abut be placed between them, and fastened to the underside of the beam, these struts, or stays, were then multiplied and disposed in various ways, until at length a rib or arch of timber was formed to support the roadway, while the spandrels were filled up with struts and ties to resist the compression.

The ribs of bridges constructed in this manner were composed of frames, the lower portion of which form segments of circles, frequently made up of several pieces of wood placed immediately one over the other, and joggled together, so arranged, however, that their ends should break joint. To these circular arcs, or polygonal frames, upright pieces were attached either by bolts, mortises, or iron straps, by which the weight of beams supporting the roadway was sustained at intervals, and so disposed as that each part might, as far as possible, conduce to the strength of the whole.

The spandrils, or spaces between the lower rib and the roadway, were differently arranged, according to circumstances; in some there were perpendicular braces, and in others pendant pieces were made to radiate towards the centre of the circle, or polygon, of which the ribs were composed. Again; instead of forming the lower bar of the polygon, &c., by layers of timber bound closely together, it was, in some cases, constructed of two rails placed at some distance from each other, and fastened to radiating pendants, the intermediate spaces being filled up by abutting pieces placed regularly across, so as to keep all the parts of the ribs in their proper places. Besides this, *lattice*-bridges may be mentioned, which consist of two or more frames composed of top and bottom rails, either horizontal or slightly cambered, and the spaces between them filled in with diagonal pieces, crossing one another at an angle of 45°, or some other suitable angle; these pieces are bolted to one another at every crossing, as also to longitudinal walings, and the top and bottom rail; bridges of this description are easily constructed, exceedingly cheap, and have been found to answer extremely well for large spans. In addition to those enumerated, there are a large class of timber-bridges formed on the tension principle, by framing king and queen-posts to the main beam on which the roadway is supported, and bolting to them an upper rail, at the same time filling in the intermediate spaces with ties and truss-bars.

The *Pons Sublicius* was the first bridge ever built across the Tiber. It was at first constructed of timber in the reign of Ancus Martius. It was put together without either bolts or ties, so that it could readily be taken asunder; and was built for the purpose of connecting together the Aventine and Janiculum hills.

The bridge built over the Danube by Trajan is almost one of the oldest timber-bridges of which we have a detailed account. It was supported on twenty stone piers, which were 150 feet high and 6 feet broad; on these were framed timber-arches, each 170 feet span, and formed of three concentric timber-rings bound together by radiating pendants; these, together with the arches, supported the longitudinal beams on which the flooring-joists were placed across the bridge.

It had a simple parapet, formed of a top and bottom rail, supported at intervals by upright posts, with diagonal braces filling in the intermediate spaces. This bridge was unfortunately destroyed by the succeeding emperor, to prevent the possible incursions of the barbarians, by its means, into the Roman territory.

The timber-bridge of Schauffhausen, built over the Rhine, by Ulrick Grubenmann, was remarkable for its ingenious construction; it consisted of two openings, one 172 feet span, and the other about 190. Its abutments and centre-pier were of stone; on these were laid a kind of compound beam, formed of three rails or walings, each of which consisted of two longitudinal beams bolted together, and toothed into each other, so as to be perfectly united; these were supported by an infinity of struts, kept in their places by vertical binding-pieces, all tending to transfer the thrust to the supports of the bridge. It was roofed in for the ostensible purpose of protecting the timber from the bad effects of the weather; but there can be little doubt but that the roof added greatly to its strength; and it is not improbable that its ingenious architect was aware of the important advantages to be derived from its introduction. This bridge, and others designed and executed by the brothers Grubenmann, were in fact *Timber Tubular Bridges.*

The beautiful bridge of Schauffhausen was unfortunately demolished by the French, about the year 1800.

John Grubenmann, assisted by his brother Ulrick, built a splendid bridge of a similar description over the Limmat, having the enormous span of 390 feet. It was formed of two immense circular ribs, one at each side of the roadway, formed of several beams bolted together, and made to fit one into the other, in a similar manner to the Schauffhausen Bridge.

This bridge had also angular struts, longitudinal beams, perpendicular binding-pieces, and abutments of masonry; it was likewise furnished with a roof, which added considerably to the stability of the structure. It was, however, burned down shortly after the destruction of the Schauffhausen Bridge. The bridge at Ceslingen, as also that of Zurich, the one upwards of 200 feet, and the other about 130 feet span, are splendid specimens of this kind of construction, as likewise the bridges of Mellingen and Berne, by Ritter, and those over the Saone by Gauthey.

The timber-bridge of St. Clair, built over the Rhone at Lyons, has seventeen openings, the centre one having a span of 45 feet, and the others diminishing towards each bank. This bridge has a roadway of about 36 feet, which is supported upon piers each formed of 13 piles, arranged in a single row, running parallel with the banks of the river; on the top of these piles a sill was framed, and longitudinal timbers were made to bear over the head of each pile; and upon these longitudinal timbers the flooring was laid.

The bridge of Grenelle, erected over the Seine, near Paris, by M. Mallet, consists of two equal and symmetrical bridges, separated by an intermediate piece of dry ground; each of these is formed of three timber-bays of 82 feet span, supported upon two abutments and two piers of masonry. The width of this bridge is nearly 33 feet. The piers are about 11 feet wide at their foundations, and are diminished to about 9 feet at the springing. The abutments have a half-pier attached to them, on which the timber-work rests. Those at the banks of the river have, besides, two wing-walls. The ground in the centre, measuring 85 feet, the whole bridge, reckoning the entire distance from the abutments on either bank of the Seine, is 632 feet long.

All the foundations were built on piles, upon which a planking was laid. These foundations were formed by means of coffer-dams, easily constructed on account of the shallowness of the river, which, at low water, was not more than 5 feet deep; each bay is composed of seven timber frames, placed about 5 feet apart from each other. The frames consist of segmental ribs, formed of three pieces of bent timber, bolted and bound together by means of iron, which support the roadway by radiating pendants; each of these compound segmental beams is 9 inches square, and of such a length as to take in two of the spaces formed by the pendants. In cutting and placing the frames in position, they were put 5 inches higher than they should have been, in order to allow for sinking, after the flagging was put upon the bridge; and even when opened to the public, the bridge had not settled into its place, so it would seem that 2, or at most, 3 inches, would have been amply sufficient to have allowed for.

Upon the roadway, a layer of bitumen was laid about half an inch thick, in order to prevent the water from injuring the timber of the bridge; however, it must be admitted, that after very heavy rain, the moisture has been found to have percolated through this pavement, either owing to its having been badly laid, or perhaps in consequence of cracks made in this coating by the contraction and expansion of the timber roadway. It might be better, therefore, in future, to place a layer of fine sand between the flooring-boards and the bitumen. Six drain-pipes in each bay convey the water off the surface.

The pavement of the roadway consists of a flagging, 6 inches thick, laid upon sand in the ordinary manner. Each bay is loaded to the extent of about 40 tons.

There is another bridge over the Seine, at Iory, which was put up in the year 1828, and which greatly resembles the bridge of Grenelle in construction.

Besides these, which are given by way of example, there are almost an endless number of wooden-bridges erected throughout the world; among which may be mentioned the bridge at Trenton, in America, of 180 feet span; a bridge over the Tees, 150 feet span; the bridge of Neucetringen, in Bavaria, 102 feet; the bridge across the Necker, 210 feet span; the bridge of Bamberg, with an opening of 206 feet, erected by M. Wiebeking, an engineer, who has constructed an immense number of timber-bridges; the bridge of Feldrich, with a span of 65 feet; the bridge at Zete, built by M. Coffinet, with a span of 125 feet, besides several put up by the celebrated Perronet; and a number of others remarkable for their ingenious construction and variety of form.

Timber bridges are either supported upon piers and abutments of masonry built on the solid foundation of the ground, or on a platform constructed upon piles driven into the earth, or they are supported upon piers formed of one or more rows of piles driven in a line with the road or river passing under the bridge. There are an almost infinite variety of ways in which such props or piers may be made. It is, however, usual to drive the piles about a yard apart from centre to centre, and to bolt capping-pieces or walings to the top of such piles, and either filling up the spaces between with large stones laid dry, or else grouted with mortar; on this, the masonry for the supports should be placed, or a timber-framing, if desired, or else the piles may be carried up to the height of the roadway, being kept in their places by walings and diagonal pieces, bolted on each side of them; these piles should be about a foot square, and when they are driven in salt water, or in tidal rivers, their surfaces, up to high-water mark, should be sheathed with copper, or protected by scupper-nails, from the ravages of the worm. At each end of the piers in the water, in cases where several rows of piles are driven, a sort of cutwater should be formed, in order to ward off heavy bodies, such as floating trees, ice, &c., and prevent them from injuring the superstructure. This is usually done by driving one pile by itself in advance of the rest, or by forming what is called a *dolphin* at each end of the pier. The piers and abutments should be made in all cases sufficiently strong to resist the thrust of the arch. In cases of small foot-bridges, where even the distance between the supports should be as much as 20 or 30 feet, longitudinal scarfed girders may be laid upon the caps of the piles. Under such circumstances, as we have seen, there is nothing but the weight, or perpendicular pressure, to be provided for; and the same may be said of timber-bridges of greater width, for roads, and even for railways, provided the distance between the piers does not greatly exceed 10 or 15 feet; beyond that opening, however, bridges are usually sustained by struts or tension rods, or the roadway-timbers are trussed so as to exert an oblique pressure upon the supports; indeed, in all instances of the kind, where the bays are formed upon the principle of compression, or tension, the piers must be so formed as to counteract the tendency constantly exerted to force them out of their perpendicular position; this must be done either by making them of sufficient weight and strength so as to overcome, by their inertia, any force that may be exerted against them, or else to counterbalance the efforts of one bay, or arch, acting in one direction, by a similar and similarly-acting arch, or timber-frame, exerting an equal and like force in a contrary direction. The former of these methods is used in the abutments of a bridge, while the latter is invariably adopted with respect to piers.

The roadway of timber-bridges is usually a flooring of boards laid upon the joists; for, in cases where sand and stones are employed, it is found that their weight, together with the humidity they engender, causes the timbers of such bridges speedily to decay. This, however, is far from being a general rule; and many splendid erections of this description are rapidly being destroyed, owing to a want of attention to this important particular. Some have proposed to cover the surface of the roadway with lead, iron, copper, &c., but the increased expense will be a great obstacle to their frequent introduction: we would recommend the wood pavement to be laid as a covering for the roadway of all timber-bridges. The parapet or handrail of these bridges is frequently of wood, or it may be of cast and wrought iron; now, however, that it has been shown how important an addition to the strength of a bridge the sides of a beam are, and that it acts usefully in the direction of its depth, if it has only sufficient breadth to prevent its yielding laterally, we would suggest that in future it should be made available to sustain the bridge, in addition to its present purposes of ornament and protection.

Draw Bridges of timber, made after the manner of a float, to draw up or let down, as occasions serve, before the gate of a town or castle, may be made in several different ways, but the most common are made with plyers twice the length of the gate, and a foot in diameter. The inner space is traversed with a cross, which serves for a counterpoise; and the chains which hang from the extremities of the plyers to lift up or let down the bridge, are of iron or brass. Such bridges are to be seen at Stirling and Edinburgh castles, at the Tower of London, at the castle of Vincennes, and many other regularly-fortified places. In navigable rivers, it is sometimes necessary to form the middle arch of bridges with two movable platforms, to be raised occasionally, in order to let the masts and rigging of ships pass the bridge. There are two piers which support the drawbridge, one of the platforms of which is raised, and the other let down, having a beam for its plyer. To this drawbridge are suspended two movable braces, which, resting on the supports, press against the bracket and thereby strengthen it.

It is one of the first principles of statics, that if two forces are represented, both in amount and direction, by the sides of a parallelogram, then their resultant will be represented by the diagonal of such parallelogram, likewise in direction and intensity. Now, if we reduce the polygonal framing, of which many wooden bridges are formed, to their simplest form, that of two beams abutting against one another, and resting upon two solid supports at their lower ends, we shall find that, inasmuch as the forces will act in the direction of the beams, their weight or gravity tending to keep the ends of the beams against each other by preventing them from rising, will be represented by a vertical line passing through their points of contact, which will be the diagonal of the parallelogram formed by the beams and lines drawn parallel to them at such a point in each as would limit the length of the line to what would fitly represent the force acting in the direction of the beam, and it is evident that the beams being in equilibrio, their horizontal thrusts must be equal and contrary, and consequently will be neutralized by their joint action.

The fact is, in a polygonal framing of any kind, there are three forces exerted at every joint; one in the direction of each beam, and one, a vertical force, acting by gravity, which being the diagonal of the parallelogram constructed upon the beams, is the resultant of the other two, and which, by acting as a counterpoise to the others, keeps the system in equilibrio.

To construct a polygon in any particular instance, we must know the direction and amount of each of the forces, and their points of application; when these are given, we may readily construct the successive sides of a polygonal bridge. It is a well-known fact that gravity always acts vertically; we may, therefore, take a line perpendicular to the horizon, and mark upon it a number of divisions, each one representing the effect of gravity at every successive joint; having, then, found a point at such a distance from it as will represent the horizontal strains which, for a system of forces in equilibrio, are always equal, and connecting that point with the several divisions marked on the vertical line, we shall have a number of right lines which, both in direction and intensity, will respectively represent the force acting at each joint or angle of the framework. Then, by drawing lines parallel to these, placing them one after the other, we shall construct a polygonal frame which will be in equilibrio, bearing in mind that the compressions of any two sides of the polygon are reciprocally as the sines of the angles which they form with the vertical lines, or directly as the secants of their inclination to the horizon.

In order to find the resultant of two forces acting in a given angle, we must add to the sum of the squares of the forces twice their products multiplied into the co-sine of the angle, and extract the square root of the sum, and this will give the required resultant. Again; to ascertain the angle between the resultant and one of the composants, we must divide the product of the sine of the given angle and the lesser force by the product of the co-sine of that angle, and the same force to which the greater force must be added.

It has been maintained, and apparently with a great deal of truth, and several eminent men who have studied the subject deeply have coincided in the opinion, that where an arch is constructed of several key-stones or voussoirs, and remains in equilibrio, its various parts being so adjusted as to cause it to remain without change of position, that a catenary or funicular curve will be found to be wholly included somewhere between its intrados and its extrados. Now, as a wooden bridge, formed on the principle of compression, either by a polygonal frame or with a timber arch, should be made to conform as much to the principle of the arch as possible, so as to make it as strong as can be, with a uniform pressure at every point by which it may be equally sustained, without throwing an undue strain upon any of the joints or beams, it is well to make the distance between the intrados and extrados as great as can be; hence the advantage of a double arch of timbers, with the intermediate space filled in with judiciously-arranged braces and diagonal pieces, by which the ribs are kept in their proper position without materially increasing the weight.

In the construction of wooden bridges it must be constantly borne in mind that every piece of timber introduced should be placed, as far as can be, so as to bear the strain which will be thrown upon it in the direction of its length; for the more it inclines from the direction of the thrust to which it is opposed, the less resistance it will be capable of exerting, and its useful effect will decline in the ratio of the radius to the sine of the angle of its inclination. In addition to this, the tendency to fracture is much greater by a transverse strain than by a force acting longitudinally by compression through the entire length of the beam.

When it is required to join two or more pieces of timber end to end, so as to make them, together, sufficiently long for any required purpose, the joint made use of in that case is called a scarf. This is made by cutting away a portion of the thickness of the wood in both pieces, so that they may fit into each other: the scarf is then made complete by bolting them well together with iron bolts, or with trenails, and putting iron straps round the joint where necessary. A scarf may be made by cutting away half the wood at the end of each piece, that so they may partially overlie or lap upon each other, or else, in a more advantageous way, by cutting away the wood in a slanting direction, at the same time making indentations or notches in one piece which exactly coincide with similar projections cut near the end of the piece to be joined to it; such scarfs are usually from 18 inches to 3 feet long.

Tenon-and-mortise joints are used for uniting timbers at right angles to one another. The thickness is diminished on both sides at the end of a piece of wood, so as to leave an oblong projection, called a tenon, which is fitted into a space termed a mortise, hollowed out of the piece to which it is to be united, and placed at about a third of the height from the under side; a wooden pin is frequently put through the mortise and tenon so as to prevent them from getting out of their places. A combination of a tenon-and-mortise joint with a scarf is sometimes made for joining timbers longitudinally; and it is found to add greatly to its strength. Scarfs in beams likely to undergo a transverse strain must always be carefully made; they should be very long and well notched, and this tenon-and-mortise joint added, the whole strongly bolted; and it is often a good precaution to put a plate of iron on the under and upper sides of the scarf.

A dove-tail joint is made by forming a tenon increasing in width towards the extremity of the wood, and having a narrow neck near the shoulder; this is fitted to a mortise made in the same shape, on another piece of wood, into which it is admitted laterally; when the wood is hard, this is a good kind of joint, but the ends of the inverted wedges are liable to be broken off if their sides diverge too much, and if they are made in too straight a direction, they are apt to shrink and thus become useless. This joint is, however, very suitable for ties when well made, and it is used in cases where it is thought desirable to secure two horizontal pieces of wood more firmly together, which are joined to one another at an angle. In that case, a piece of wood is made to act as a tie, by being dove-tailed into both the timbers at some distance from the joint.

The ends of struts and braces are usually let into the timbers with which they are connected at the ends by mortise-and-tenon joints; these joints are generally cut at the ends perpendicularly to their direction, and in this way resist the strains which they have to bear more effectually.

A king-post is a principal vertical timber, to which the centres of bays or girders are attached, and by which means, properly speaking, they should be sustained.

Queen-posts are similar to king-posts, but do not occupy so important a position in a piece of carpentry. A number of these may be introduced with great advantage; they should be well framed into the top and bottom timbers, either by halving or by mortise-and-tenon joints; and iron straps should, in most cases, be made use of to make them secure.

The timber, &c., used in the construction of wooden bridges is, according to the position it is made to occupy, obliged to undergo four kinds of forces, which tend to overcome the cohesion exerted between the particles of which it is formed. These are, first, and principally, *transverse pressure*, or a force acting transversely upon a beam, tending thereby to destroy the cohesion and continuity of its fibre, such is the force that the platform of a bridge must be made to resist; such, also, the roof, the joists, the flooring, and many of the levers, of which it is composed. This, however, is a compound force made up of the two succeeding forces. 2nd. A *compressive or crushing* force, which acts longitudinally; this is called generally into play in the framing of the bridge, posts, struts, piles, &c. 3rd. A *tensile* force, in which there is a tendency to pull the particles of the wood from one another, and thus cause a total destruction of its parts by stretching and drawing it to pieces; this force is exerted on king-posts, tie-beams, the under parts of the roadway, and of the joists, walings, &c.; and, lastly, there is a *twisting* force, by which the particles of bolts, rivets, trenails, gudgeons, &c., are strained or wrenched from each other, or are constantly subjected to a force tending so to disunite and destroy them.

In order to prevent these forces from having the effect of injuring the bridge, great care must be taken in the selection of the proper materials; in the manner of disposing them in the bridge, by adopting such an arrangement as will make one force act as a set-off to another by neutralizing its injurious effects, and, above all, by distributing the pressures judiciously, so as never to let any portion of the structure be loaded with more than one-third of the weight which it is calculated to bear without breaking.

In the case of a beam supported at its extremities, it has been found that if it be cut on the upper side, near the middle, to about one-third of its depth, and a piece of hard wood be inserted, in the form of a wedge, so as to give the entire beam a slight camber, that its strength will be increased about a sixth of what it was previously. This plan may be practised with great advantage when the distance between the supports is small, because the rigidity of the material is so much greater in proportion to the weigth to be supported, that the deflexion is not injurious; but when the spans are great, and the props or piers far removed from each other, it becomes necessary to truss the beams to prevent their falling below the horizontal line. This deflexion is as the product of the weight and cube of the length directly, and inversely as the product of the breadth and the cube of the depth. A deflexion of about tho fiftieth part of an inch is not very injurious, but, where possible, it should be provided against. It may be well to state here, that the deflexion from a weight uniformly distributed over a bridge is to the deflexion caused by the same weight placed in the centre, as 5 is to 8.

In the event of a beam being loaded up to the point of breaking, it will bend before giving way, and the transverse strain which would produce this result is in the ratio of the breadth multiplied into the square of the depth, and inversely as the length; and the square of the secant of the angle of deflexion, immediately before giving way altogether, must also form an element of the calculation. When this is ascertained, one-third of this breaking weight must be taken for the maximum load with which it must be weighted.

The inherent qualities of timber and other materials which enable them to resist the force of compression acting in the direction of their length, is directly as the fourth power of their sides in cubic blocks, and as the square of their height inversely. The cohesion of wood, &c., by which it is able to resist the force of tension, or a drawing force, exerted in the direction of its length, varies in the proportion of its cross section. The power of resisting a tensile strain, in different kinds of wood, varies in the ratio of their different specific gravities.

All materials withstand the twisting force of tension when in the form of cylinders, in the ratio of the angle of tension, and the fourth power of the diameter directly, and in the inverse proportion of their length.

The resistance of different woods to pressure, as derived from actual experiment made with blocks of an inch cube, is found to be—for elm, 1,284 lbs.; white deal, 1,928 lbs.; oak, (English) 3,860 lbs.; and pine, (American) 1,606 lbs.

The resistance to tension for bars of an inch square of transverse section, is ascertained to be—for ash, about 11,970 lbs.; beech, 17,371 lbs.; elm, 12,231 lbs.; fir (pitch pine), about 12,917 lbs.; fir (red), 10,829 lbs.; fir (Memel), 10,662 lbs.; fir (Russian), about 9,992 lbs.; fir (American), 870 lbs.; fir (yellow deal), 8,316 lbs.; fir (white deal), 4,204 lbs.; fir (Scotch), 6,569 lbs.; larch, 10,875 lbs.; oak (English), 13,943 lbs.; oak (French), about 14,405 lbs.; oak (Baltic), 11,189 lbs.; oak (American), 10,154 lbs.; oak (Dantzic), 7,558 lbs.; and for willow, about 12,538 lbs.

Oak and fir are principally used in bridge-building, on account of their great durability and hardness, which is a point of very great importance; for the principal objection to wooden bridges in general is, that they are extremely liable to decay; still, their great cheapness, in comparison with bridges constructed of other materials, makes them very suitable in many instances.

WOODEN COLUMN, a column consisting of a trunk, base, and capital, each constructed of wood. The column is glued up in staves, the base in regular sectors, and the capital in blocks used externally. The whole ought to be painted and sanded, in order to produce the effect of a stone column; but if used internally, the painting ought to correspond with that of the apartment in which it is placed.

WORKING DRAWINGS, consist of plans, elevations, and sections of the whole, and all the parts, of an edifice, to as large a scale as may be found convenient; generally in outline, excepting the sectional parts, which are frequently shadowed, or scratched, in order to make them more obvious to the workman, for whose use the drawings are made.

The general plans, elevations, and sections, as they cannot be made to the full size of the object to be executed, should all be figured with numbers of measurement, to show the dimensions of all the parts of the edifice, without obliging the workman to refer to the scale, which is not only very troublesome, but liable to lead to many mistakes detrimental to the work.

The plans, elevations, and sections, of the parts of an edifice, ought to be made to the full size; in which case the figuring of the dimensions becomes unnecessary.

Working drawings may be divided into three classes: distinguished severally as Block Plans, General Drawings, and Detailed Drawings.

Block Plans show no more than the outline of the proposed works or buildings, and their position with reference to surrounding objects; in fact, they point out the site of the buildings, and determine the space to be occupied by them. They are drawn to a small scale, so as to embrace the entire site of the works, and so much of the neighbourhood as may be necessary. They contain every information respecting the present state of the building-ground and its vicinity, and the manner in which it will be affected by the new work; thus, in most instances, it is necessary to show the proposed method of drainage, lighting, water-supply, &c.; and as this will necessarily depend upon the existing state of things, we must mark out the old drains, gas, and water-mains, and the method of connecting them with the new works. It is well also, on such drawings, to give some idea of the comparative levels of the district.

The *General Drawings* show the whole extent of the new works, and the arrangement and distribution of the several parts. They consist of *plans* of the various stories, including those of the foundations, and roofs, and indeed of any part of the building where some peculiar treatment renders explanation necessary; *elevations* of every side of the building, or of so many sides as present a different appearance; and *sections* showing the internal structure and arrangement of the works. On each of these drawings, the dimensions of the whole, and of the various parts, should be carefully figured; the directions in which the measurement are taken, being figured in dotted lines, and the points from and to which they are measured, being clearly defined by an arrowhead, or some such contrivance. So much of the details are shown on these drawings as the scale will allow. Perspective drawings or sketches may be added, to give a more general idea of the undertaking.

The *Detailed Drawings* show such parts of the work as cannot be shown on the general drawings with sufficient clearness and accuracy; and are drawn either of full size, or to such a scale as shall make them clearly intelligible to the workman. Such drawings are required both for the decorative and constructive parts of the building; thus are included the capitals and bases of columns, entablatures, cornices, tracery, or any other enrichment; as also the sections of mouldings, string-courses, &c.; and besides these, the method of framing floors, roofs, &c., the patterns of cast-iron or trussed girders, story-posts, and such like, of everything, in short, of which a particular description is necessary. It saves much trouble, if the detailed drawings are made out on separate sheets for the different trades. These drawings, like the others, should have their dimensions clearly figured upon them, and every drawing should be provided with a scale, from which any further dimensions may be taken by the compasses.

It is usual in drawings, to tint only such parts as are in section; but it will frequently be found desirable to colour also the parts which stand back, and are in elevation; and sometimes also to project the shadows, or shade up such parts, so as to give a general idea of their distance from, and relation to each other, as also of their forms, as whether flat, concave, or convex, &c.

WREATHED COLUMNS, such columns as are twisted in the form of a screw. They are very appropriately called *contorted columns*, as being the offspring of a false taste; for as the primitive use of columns is for supporting a superincumbent weight, whatever diminishes the idea of the stability they ought to afford, is a real blemish; and the very appearance of a twisted column is indicative of weakness.

They were the production of an age when novelty was mistaken for genius, and when meretricious ornament was suffered to usurp the place of real beauty; but since science has resumed her place in the public opinion, they have been laid aside, and are justly considered as blemishes to those buildings in which they appear.

WREN, SIR CHRISTOPHER, the only son of Dr. Christopher Wren, Dean of Windsor, was born at East Knoyle, in Wiltshire, on the 20th of October, 1632. His mother was Mary, daughter and heiress of Mr. Robert Cox, of Fonthill, in the same county. His first education in classic learning was (by reason of his tender health) committed to the care of a domestic tutor, the Rev. William Shepheard, M. A., excepting that for some short time before his admission to the university, he was placed under Dr. Busby, at Westminster School. In the principles of mathematics, upon the early appearance of an uncommon genius, he was initiated by Dr. W. Holder; and he made such rapid progress, that at the age of sixteen he distinguished himself by some important discoveries in astronomy, dialing, statics, and mechanics. While at Oxford, he became acquainted with, and obtained the friendship of, Dr. Scarborough, (afterwards Sir Charles Scarborough,) an eminent physician and mathematician, under whom he performed the part of an assistant, and first introduced geometrical and mechanical sciences to the aid of anatomy. At the age of nineteen, he composed a short algebraic tract relating to the Julian Period, of great use in chronology. In 1650, he was entered Bachelor of Arts at Wadham College, Oxford; where, in 1653, he took the degree of Master of Arts; and in the same year was elected into a fellowship of All-Souls. In 1657 he was chosen Professor of Astronomy in Gresham College, upon the resignation of Dr. Seth Ward; where, in the same year, he read admirable lectures on astronomy; and in 1653 not only solved the problem proposed by the great Pascal to all the English mathematicians, but returned another to those of France, of which they could never furnish any solution. His appointment at Gresham College he resigned in 1660, on being chosen Savilian Professor of Astronomy at Oxford, where, in 1658, he had been created LL.D. as he was shortly afterwards at Cambridge. He had now attained such eminence in architecture, that he was called from Oxford by Charles II. to assist Sir John Denham as surveyor-general of his majesty's works; and in 1663 he was one of the first Fellows of the Royal Society, after the grant of their charter. In 1665 he travelled to France; and it is evident from his letters, that he surveyed every structure with the studious eye of a critic.

After that most dreadful conflagration of London, in the fatal year 1666, had laid the metropolis of England in the dust, Dr. Christopher Wren drew a noble plan for rebuilding it, which he presented to the parliament; and had his scheme been followed, London would have become the most superb metropolis in Europe, or indeed in all the world. It interfered, however, with so many interests in the landed property, that its execution was deemed impracticable. In 1668, on the decease of Sir John Denham, he was appointed surveyor-general and principal architect for rebuilding the whole city, with the cathedral church of St. Paul, and all the parochial churches, in number fifty-one. In the year 1674, the honour of knighthood was conferred upon him; in 1677, he finished the Monument, which has been compared with the celebrated columns of antiquity; in 1680, he was elected president of the Royal Society; and in 1681, he completed his most beautiful structure, the church of St. Stephen, Walbrook; in 1698, he was appointed surveyor-general and commissioner of the works and repairs of the ancient abbey church of St. Peter, Westminster; and in 1710, he finished the magnificent cathedral church of St. Paul.

During the time of his employment in the service of the public and of the crown, by virtue of letters patent, consistent with the pleasure of six crowned heads, under the great seals of King Charles II., King James II., King William and Queen Mary, Queen Anne, and King George I., (besides the ordinary duties of his office in the survey and care of the repairs and new buildings of all the royal palaces,) he began and completed the cathedral church of St. Paul; fifty-one parochial churches; the great column, called The Monument, and other public edifices, in London; the two royal palaces at Hampton Court and Winchester; the royal hospitals of Chelsea and Greenwich; the north front and repairs of Westminster Abbey; the theatre of Oxford; the theatre royal in Drury Lane; the Duke's theatre in Salisbury Court, some time since taken down; the magnificent library of Trinity College, and the elegant chapel of Emmanuel College, Cambridge; with many other fabrics of less note, as well as private seats. All these works form such a body of civil architecture, as will appear rather the production of a whole century than the life and industry of one man, of which no parallel instance can be given.

In an act of parliament of the ninth year of the reign of King William, for completing and adorning the cathedral church of St. Paul, London, a clause was inserted " to suspend a moiety of the surveyor's salary until the said church should be finished; thereby the better to encourage him to finish the same with the utmost diligence and expedition." It was at the time a common notion and misreport, that the surveyor received a large annual salary for that building, and consequently it was his interest to prolong the finishing of the fabric for the continuance of this supposed emolument, which, it would seem, occasioned that clause.

The surveyor's salary for building St. Paul's, from its foundation to its completion, (as appears from public accounts) was not more than two hundred pounds per annum. This, in truth, was his own choice; but what the rest of the commissioners on the commencement of the works judged unreasonably small, considering the extensive charge; the pains and skill in the contrivance, in preparing draughts, models, and instructions for the artificers in their several stations and allotments; in almost daily overseeing and directing in person; in making estimates and contracts; in examining and adjusting all bills and accounts, &c. : nevertheless, he was contented with this small allowance, nor coveted any additional profit, always preferring the public service to any private profit.

Upon the completing of this great fabric, a clause passed in the act of parliament of the ninth year of the reign of Queen Anne, declaring the church finished, to empower the commisioners to pay the surveyor the arrears of the moiety of his salary. His allowance for building all the parochial churches of the city of London was about one hundred pounds per annum, and the same for the repairs of Westminster Abbey.

In the act for building fifty new churches in London and its vicinity, Sir Christopher, though then at a very advanced age, was named one of the commissioners for carrying it into effect. On this occasion he wrote the following letter, for the consideration of his colleagues in office; which, as it contains many points worthy the notice of the architect, is here inserted.

" Since Providence, in great mercy, has protracted my age to the finishing the cathedral church of St. Paul, and the parochial churches of London, in lieu of those demolished by the fire; and being now constituted one of the commissioners for building, pursuant to the late act, fifty more churches in London and Westminster, I shall presume to communicate briefly my sentiments, after long experience; and without farther ceremony, exhibit to better judgment what at present occurs to me in a transient view of this whole affair; not doubting but that the debates of the worthy commissioners may hereafter give me occasion to change or add to these speculations.

"First, I conceive that the churches should be built not where vacant ground may be cheapest purchased in the extremities of the suburbs, but among the thicker inhabitants, for convenience of the better sort, although the site of them should cost more; the better inhabitants contributing most to the future repairs, and the ministers and officers of the churches, and charges of the parish.

"2. I could wish that all burials in churches might be disallowed, which is not only unwholesome, but the pavements can never be kept even, nor pews upright; and if the church-yard be close about the church, this also is inconvenient, because the ground being continually raised by the graves, occasions in time a descent by steps into the church, which renders it damp and the walls green, as appears evidently in all the old churches.

"3. It will be inquired, where then shall be the burials? I answer, in cemeteries, seated in the outskirts of the town; and since it is become the fashion of the age to solemnize funerals by a train of coaches, though the cemeteries should be half a mile or more distant from the church, the charge need be little or no more than usual; the service may be first performed in the church. But for the poor, and such as must be interred at the parish charge, a public hearse of two wheels and one horse may be kept at small expense; the usual bearers to lead the horse, and take out the corpse at the grave. A piece of ground of two acres in the fields will be purchased for much less than two roods among the buildings. This being enclosed with a strong brick wall, and having a walk round, and two cross walks, decently planted with yew trees, the four quarters may serve four parishes, where the dead need not be disturbed at the pleasure of the sexton, or piled four or five upon one another, or the bones thrown out to gain room. In these places beautiful monuments may be erected; but yet the dimensions should be regulated by an architect, and not left to the fancy of every mason, for thus the rich, with large marble tombs, would shoulder out the poor, when a pyramid, a good bust or statue on a proper pedestal, will take up little room in the quarters, and be more proper than figures lying on marble beds. The walls will contain escutcheons and memorials for the dead, and the area good air and walks for the living. It may be considered, farther, that if the cemeteries be thus thrown into the fields, they will bound the excessive growth of the city with a graceful border, which is now encircled with scavengers' dungstalls.

"4. As to the situation of the churches, I should propose, they be brought as forward as possible into the larger and more open streets, not in obscure lanes, nor where coaches will be much obstructed in the passage. Nor are we, I think, too nicely to observe east or west in the position, unless it falls out properly. Such fronts as shall happen to lie most open in view should be adorned with porticoes, both for beauty and convenience; which, together with handsome spires, or lanterns, rising in good proportions above the neighbouring houses, (of which I have given several examples in the city, of different forms,) may be of sufficient ornament to the town, without a great expense for enriching the outward walls of the churches, in which plainness and duration ought principally, if not wholly, to be studied. When a parish is divided, I suppose it may be thought sufficient if the mother-church has a tower large enough for a good ring of bells, and the other churches smaller towers, for two and three bells; because great towers and lofty steeples are sometimes more than half the charge of the church.

"5. I shall mention something of the materials for public fabrics. The earth about London, rightly managed, will yield as good bricks as were the Roman bricks, and will endure in our air beyond any stone our island affords; which, unless the quarries be near the sea, are too dear for general use; the best is Portland or Roch Abbey stone; but these are not without their faults. The next material is the lime. Chalk lime is the constant practice; which, well mixed with good sand, is not amiss, though much worse than hard stone lime. The vaulting of St. Paul's is becoming as hard as stone; it is composed of cockle-shell lime, well beaten with sand: the more labour in the beating, the better and stronger the mortar. I shall say nothing of marble, for this will prove too costly for our purpose, unless for altar-pieces. In windows and doors, Portland-stone may be used, and with good bricks and stone quoins. As to roofs, good oak is certainly the best, because it will bear some negligence. The churchwardens' care may be defective in speedily mending drips; they usually whitewash the church, and set up their names, but neglect to preserve the roof over their heads. It must be allowed, that the roof being more out of sight, is still more unminded. Next to oak is yellow deal, which is a timber of length, and light, and makes excellent work at first, but if neglected, will speedily perish; especially if gutters (which is a general fault in builders) be made to run upon the principal rafters, the ruin may be sudden. Our tiles are ill made, and our slate not good; lead is certainly the best and lightest covering; and being of our own growth and manufacture, and lasting, if properly laid, for many hundred years, is, without question, the most preferable.

"6. The capacity and dimensions of the new churches may be determined by a calculation. They must be large, but must be fitted for auditories. I can hardly think it practicable to make a single room so capacious, with pews and galleries, as to hold above 2000 persons, and all to hear the service, and both to hear distinctly and see the preacher. I endeavoured to effect this in building the parish church of St. James, Westminster, which, I presume, is the most capacious, with these qualifications, that hath yet been built; and yet, at a solemn sime, when the church was much crowded, I could not discern from a gallery that 2,000 were present. In this church I mention, though very broad, and the middle nave arched up, yet there are no walls of a second order, nor lanterns, nor buttresses, but the whole roof rests upon the pillars, as do also the galleries. I think it may be found beautiful and convenient, and as such, the cheapest of any form I could invent.

"7. Concerning the placing of the pulpit, I shall observe, a moderate voice may be heard 50 feet distant before the preacher, and 20 behind the pulpit; and not this, unless the pronunciation be distinct and equal, without losing the voice at the last word of the sentence, which is commonly emphatical, and if obscured spoils the whole sense. A Frenchman is heard farther than an English preacher, because he raises his voice instead of sinking it at his last words. I mention this as an insufferable fault in the pronunciation of some of our otherwise excellent preachers, which schoolmasters might correct in the young, as a vicious pronunciation; and not as the Roman orators spoke, for the principal verb is, in Latin, usually the last word; if that be lost, what becomes of the sentence?

"8. By what I have said, it may be thought reasonable, that the new church should be at least 60 feet broad, and 90 feet long, besides a chancel at one end, and the belfry and portico at the other. The proportions may be varied; but to build more room than that every person may conveniently hear and see, is to create noise and confusion. A church should not be so filled with pews, but that the poor may have room enough to stand and sit in the alleys, for to them equally is the gospel preached.

"9 I cannot pass over mentioning the difficulties that may be found in obtaining the ground proper for the sites of the churches among the buildings, and the cemeteries in the borders without the town; and therefore I shall recite the method that was taken for purchasing in ground at the north side of St. Paul's cathedral, where, in some places, the houses were but 11 feet distant from the fabric, exposing it to the continual danger of fires. The houses were 17, and contiguous, all in leasehold of the dean, or bishop, or the petty canons, with divers under-tenants. First, we treated with the superior landlords, who, being perpetual bodies, were to be recompensed in kind, with rents of the like value for them and their successors; but the tenants in possession, for a valuable consideration, which, to find what it amounted to, we learned, by diligent inquiry, what the inheritance of houses in that quarter were usually held at. This we found was fifteen years' purchase at the most, and proportionally to this the value of each lease was easily determined in a scheme referring to a map. These rates, which we resolved not to stir from, were offered to each; and to cut off much debate, they were assured that we went by one uniform method, which could not be receded from. The whole at last was cleared, and all concerned were satisfied, and their writings given up. The greatest debate was about their charges for fitting up their new houses to their particular trades; for this we allowed one year's purchase, and gave leave to remove all their wainscot, reserving the materials of the fabric only. This was happily finished without a judicatory, or jury.

"Christopher Wren."

In the year 1685, Sir Christopher Wren was elected and returned a burgess for the borough of Plympton, in the county of Devon, and served in that parliament which began at Westminster on the 29th of May, 1685 in the first year of James II. In the parliament which met at Westminster on the 22nd of June, 1689, he was returned a burgess for the borough of New Windsor, in the county of Berks. In the year 1700, he was returned a burgess for the borough of Weymouth and Melcomb Regis, in the county of Dorset, and served in that parliament which began at Westminster on the 10th of February, in the 12th year of William III.

In 1718, Sir Christopher Wren's patent for the office of surveyor of the royal works was superseded, in the four-score-and-sixth year of his age, and after more than fifty years spent in a continued, active, and laborious service to the crown and public, at which time his merit and labours were not remembered by some. He then betook himself to a country retirement at Hampton Court; where, free from worldly affairs, he passed the greatest part of the five following and last years of his life in contemplation and study, principally of the Holy Scriptures; though he partially turned his thoughts to the discovery of the longitude at sea, and a review of his former tracts on astronomy and mathematics. Time had now greatly enfeebled his limbs, but it had little impaired the vigour of his mind, which continued, with a vivacity rarely found at his age, till within a few days of his dissolution, which happened on the 25th of February, 1723, in the ninety-first year of his age. He was buried in the vault under St. Paul's cathedral, a privilege accorded to him and his family exclusively. A plain stone covers his grave, bearing the appropriate inscription, *Si Monumentum quæris, circumspice:* "If thou seekest my monument, look around thee."

As an architect, his learning was great, and his invention fertile: his discoveries in mathematics and natural philosophy were numerous, and are only eclipsed by his performances in his master-science. He contrived an instrument for measuring the quantity of rain that falls on any space of land for a year: he invented many ways of making astronomical observations more accurately and easily; and was the author of the anatomical experiment of injecting liquors into the veins of animals. He translated into Latin Mr. Oughtred's *Horologiographia Geometrica;* and wrote a *Survey of the Cathedral Church of Salisbury*, and other places. He never printed any of his works, though some have been published by his friends. This excellent artist does not, therefore, derive his glory from his publications, but from the numerous edifices which adorn the British metropolis, and which hourly attract the regard even of the most inattentive.

His private character was extremely amiable, continuing to the last an example of benevolence, free from all moroseness in behaviour or aspect. He left a son, named after himself, who published in 1708, an elaborate treatise on ancient medals, intitled *Numismatum Antiquorum Sylloge*, and died in 1747, aged seventy-two.

X.

XENODOCHIUM, a room in a monastery of religious houses, for the reception and entertainment of strangers.

XYSTOS, or Xystus, (from ξυω, *to make smooth,*) among the ancient Greeks, a portico of unusual length, open or covered, where the athletæ practised wrestling and running, The word is derived from the custom of the athletæ of anointing their bodies with oil before the encounter, to render them smooth, so as to prevent their antagonists from taking hold of them: hence they were called *xystici*, and the place of their exercise *xystos.*

The Romans also had their xystos, which, was a long aisle, or portico, sometimes roofed over, and sometimes open, with trees on each side, forming an agreeable shade to walk under.

Y.

YARD, (from the Saxon, *gerd*), a well-known measure, 3 feet in length; the square yard will, therefore, contain 9 square feet, and the cubic yard 27 solid or cubic feet.

The square yard is used by artificers in measuring their work, and the cubic yard in finding the capacities of cavities dug in the earth. The solid yard is also used in measuring great masses of brick or stone work; of which a few examples, for practice, are here given.

Example 1.—Suppose a room 28 feet 6 inches long, and 14 feet 9 inches wide; how many square yards are contained in the ceiling, or floor?

```
     28   6
     14   9
    ---------
    119   0
    28
     21   4   6
    -----------
 9) 420   4   6
    -----------
     46   6
```

Therefore, the superficial contents are 46 square yards, 6 feet superficial, 4-twelfths of a foot superficial, and 6-twelfths of the twelfth part of a foot superficial, which is the contents of the floor, or ceiling, of the room.

Example 2.—Suppose a pit dug in the earth 58 feet long, 39 feet broad, and 19 feet deep; how many solid yards have been excavated?

```
          58
          39
         ----
         522
        174
        ----
        2262
          19
       -----
       20358
       2262
      ------
  27) 42978 (1591
      27
      ---
      159
      135
      ---
       247
       243
       ---
        48
        27
        --
        21
```

So that the contents is 1591 solid yards, and 21 solid feet.

Example 3.—Suppose a mound of earth, whose section is everywhere a given segment of a circle, the breadth of the mound 27 feet, the height 9 feet, and the length 3837 feet; what will be the expense of raising it, at 15d. per yard?

The easiest method of finding the area of the segment is the following, taken from the article MENSURATION, viz., Multiply the chord and versed sine together, to two-thirds of the product add the cube of the altitude, divided by twice the chord, and the sum will be the area of the section, which, being multiplied by the length of the mound, will give the solidity in feet: see the operation.

```
           27
            9
          ---
       3) 243
          ---
           81
            2
          ---
          162
Again,
            9
            9
          ---
           81
            9
          ---
     54) 729 (13
         54
         ---
         189
         162
         ---
          27
```

So that 162 + 13 = 175 feet, the area of the segment.

```
Then,      3837
            175
          -----
          19185
         26859
         3837
        ------
   27) 671475 (24869
       54
       ---
       131
       108
       ---
        234
        216
        ---
         187
         162
         ---
          255
          243
          ---
           12
```

Now 24869 at first is 24869 shillings
at $\frac{1}{4}$ is . . . 6217 3

2,0) 3108.6 3

1554 6 3
and $\frac{12}{27}$ or $\frac{4}{9}$ of a yard is 0 $6\frac{1}{2}$

1554 6 $9\frac{1}{2}$

Therefore the whole expense will be £1554 6s. $9\frac{1}{2}$d. *See* Brickwork and Mensuration, where yard-measure is employed.

Yard, an enclosed court or area.

YELLOW, (from the Saxon, *yealewe*,) a colour like that of gold. Yellows are of considerable variety, as yellow ochre, orpiment, gamboge, and many others, too well known to require description.

Z.

ZACCO, or Zaccho, (Italian,) the lowest part of a column, or pedestal.

ZAX, an instrument used for cutting slates.

ZETA, or Zeticula, (from the Greek,) a small withdrawing chamber, with pipes conveyed along in the walls to receive from below either the cool air or the heat of warm water; also a stove-room. The term is sometimes extended to signify a parlour, or even a dining-room.

ZIGZAG MOULDING, a moulding common in Norman buildings. *See* Norman Architecture.

ZINC, a bluish-white metal, which tarnishes but slowly when exposed to the air; and on this account is much used in external works, such as roofs, fences, &c.

ZOCCO, or Zocle, a low square member, serving to support a column instead of a pedestal.

A *continued zocle* is that on which an edifice is raised.

ZOPHORUS, (from ζωος, *living*, or ζωον, *an animal*, and φερω, *to bring*,) the frieze, or broad member which separates the cornice and architrave. It was so called by the Greeks, because they adorned it with representations of animals.

The ancients had no fixed proportion of the order for the height of the zophorus. However, in the same order, though the friezes are to be found of different heights in different examples, the variation is not very great.

When the zophorus was required to be ornamented, its height was generally enlarged in order to make room for the ornaments. This, however, was not the case with the Grecian Doric, as this extension would have necessarily destroyed the proportion of the triglyphs, and consequently that of the metopes, or spaces between them. The Tuscan order did not admit of any ornaments, and therefore the zophorus, or frieze, was always plain. The Doric, though grand, was extremely elegant, and the metopes were generally ornamented with sculpture, as in the Parthenon and temple of Theseus at Athens. The zophorus of the Ionic and Corinthian orders was not interrupted by any member of the order, as in the Doric, but the ornaments were frequently continued throughout the whole extent, in one or more processions. In the Doric order also, within the pronaos, the triglyphs were always omitted, and in this case the frieze, or zophorus, was adorned, equally with the Ionic and Corinthian, as may be seen within the pronaos of the Parthenon, and that of the temple of Theseus, already referred to. *See* Frieze.

ZOPHORIC COLUMN, any pillar supporting the figure of an animal.

ZOTHECA, a small room or alcove, which might be added to, or separated from, the room to which it adjoined.

ANALYSIS OF CONTENTS.

The CAPITAL letters denote the titles of each article.
The *Italics* " " words referred to under each article.
The Roman " " contents of each article.
The Numeral Letters " " volume.
The Figures " " page.

133

THE END.

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